Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

19-SGD-0022

MAY 01 2019

Mr. David Einan, Manager
Office of Environmental Cleanup
Site Cleanup Unit 4
U.S. Environmental Protection Agency
825 Jadwin Avenue, Suite 210
Richland, Washington 99352

Dear Mr. Einan:

REMEDIAL INVESTIGATION FOR THE 100-KR-1, 100-KR-2, 100-KR-4 OPERABLE UNITS, DOE/RL-2010-97, DRAFT B

This letter transmits the Remedial Investigation (chapters 1-8, and appendices A-J) for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units, DOE/RL-2010-97, Draft B. The Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units is currently in final development and will be transmitted separately.

The Remedial Investigation supports the remedy selection process for these 100-K Operable Units. Transmittal of this document partially satisfies and supports the requirement of Tri-Party Agreement Interim Milestone M-015-00 to complete the Remedial Investigation/Feasibility Study (or RCRA Facility Investigation/Corrective Measures Study) Process for All Non-Tank Farm Operable Units by June 30, 2026.

In accordance with section 9.2 of the Tri-Party Agreement Action Plan, please provide written comments within 45 days of receipt of this letter.

If there are any questions please contact me, or you may contact Mike Cline, of my staff on (509) 376-6070.

Sincerely,

William F. Hamel, Assistant Manager
for the River and Plateau

SGD:ETG

Attachment

cc: See page 2

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DOE/RL-2010-97
Draft B

Remedial Investigation for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
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DOE/RL-2010-97
Draft B

Remedial Investigation for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units

Date Published
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Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
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By Julia Raymer at 10:09 am, Apr 08, 2019

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Executive Summary

This document presents the results of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] remedial investigation (RI) for 100-K, a portion of the Hanford Site that was added to the CERCLA National Priorities List (NPL[2]) in 1989. 100-K has two source operable units (OUs) (100-KR-1 and 100-KR-2) and a groundwater OU (100-KR-4). The RI and risk assessment determined that contaminants in the vadose zone (the soil between ground surface and the top of the groundwater) and groundwater pose a threat to human health and the environment and a CERCLA remedial action is warranted. The associated feasibility study (FS) (DOE/RL-2018-22, *Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*) presents and evaluates remedial alternatives. The U.S. Department of Energy, Richland Operations Office (DOE-RL), in collaboration with the U.S. Environmental Protection Agency (EPA), will issue a proposed plan based on the RI and FS. The proposed plan describes the proposed final remedies to solicit comment from the Tribal Nations and the public. EPA, working in cooperation with DOE-RL, will consider input submitted during the comment period, as well as any new information that becomes available, and issue a record of decision (ROD) that identifies the final remedial alternative selected for 100-K and provides responses to Tribal Nations and public comments in a responsiveness summary.

100-K includes waste sites where waste was disposed during past operations. Beginning in 2002, many of these waste sites were remediated under interim action RODs [3,4,5] that

[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: https://www.csu.edu/cerc/researchreports/documents/CERCLASummary1980.pdf.

[2] 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol27/xml/CFR-2010-title40-vol27-part300-appB.xml.

[3] EPA/AMD/R10-97/044, *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D197225332

[4] EPA/ROD/R10-99/039, 1999, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites),* U.S. Department of Energy, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, Olympia, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r1099039.pdf.

[5] EPA/ROD/R10-00/121, 2000, *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton*

addressed several environmental threats. DOE reviewed the relevant operational histories and results of interim actions and conducted field investigations, as necessary, to determine the status of each site. Contaminated groundwater remediation began under the 1996 interim action ROD[6], which selected treatment for hexavalent chromium (Cr(VI)) through extraction, treatment, and injection back into the aquifer using a pump and treat (P&T) system. Groundwater P&T remediation is ongoing using systems installed or expanded under the interim action ROD and 2009 explanation of significant differences[7].

There are two reactors in 100-K: 105-KE Reactor and 105-KW Reactor (hereinafter called KE Reactor and KW Reactor). Both will be addressed in a future CERCLA decision.

There are 197 waste sites at 100-K, 43 of which have been closed out, consolidated, rejected, or not accepted as waste sites, and have a sufficient existing basis to determine a final remedy decision is not required. The remaining 154 waste sites are evaluated in this RI and associated FS and will be included in the ROD.

Of the 154 waste sites evaluated in this RI and the FS:

- 56 waste sites passed screening for groundwater/surface water protection, human health risk assessment, and ecological risk assessment based on evaluation of quantitative site-specific data and are identified for no action.
- 22 waste sites are identified for no action based on other site-specific evaluations.
- 76 waste sites are identified for further action and are evaluated in the FS.

The 76 waste sites identified for further action and FS evaluations include:

- 60 waste sites identified for remediation under an interim action ROD, but remediation was not completed by April 2017.

County, Washington, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.epa.gov/superfund/sites/rods/fulltext/r1000121.pdf.

[6] EPA/ROD/R10-96/134, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, and U.S. Department of Energy, Seattle, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196097243

7 EPA et al., 2009, Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site, Benton County, Washington, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0096029.

- 8 waste sites only have radiological contamination at concentrations greater than direct contact preliminary remediation goals (PRGs) in deep vadose zone soil (>4.6 m [15 ft] below ground surface [bgs]).
- 4 waste sites have contaminant concentrations greater than groundwater and/or surface water protection soil screening levels (SSLs).
- 2 waste sites have shallow vadose zone (< 4.6 m [15 ft] bgs) contaminant concentrations that exceed human health risk-based screening levels (RBSL) for direct contact (1 of the 2 also has deep vadose zone [>4.6 m [15 ft] bgs] radionuclide contamination at concentrations above the human health RBSL)
- 2 waste sites have contaminant concentrations that exceed groundwater or surface water PRGs and deep vadose zone (>4.6 m [15 ft] bgs) radionuclide contamination at concentrations above the human health RBSL

This RI, which supports the FS and proposed plan, has the following objectives:

- Provide information concerning the 100-K physical environmental setting.
- Draw conclusions concerning the nature and extent of contamination in 100-K soil and groundwater and contaminant migration potential.
- Evaluate the potential for adverse effects to human health and the environment if no action is taken and exposure occurs.

The associated FS develops and evaluates an appropriate range of remedial action alternatives for 100-K waste sites and groundwater based on unacceptable risk to human health and the environment. This RI was prepared using information gathered from reactor operations, process knowledge, waste management activities, historical studies and investigations, data collected during interim action RODs implementation, and the RI field investigation.

Soil and groundwater monitoring and remediation have been performed since the early 1990s, and remedial actions since the mid-1990s. Data have shown that the interim remedial actions are effective in achieving PRGs. RI work was done to provide supplemental information to what was already known. The RI field investigation from 2010 to 2011 included installing 15 groundwater monitoring wells and 3 aquifer tubes. A select network of 18 wells was sampled to determine spatial and temporal variations in

groundwater contaminant distribution. DOE and EPA identified in 2012 that additional characterization activities near the KE Reactor and select waste sites were needed to inform decisions on remediation. Two soil characterization boreholes were drilled and wells were installed in 2015 to characterize contaminants near the KE Reactor within the vadose zone and groundwater as part of the RI.

Additional interim remedial actions completed between 2012 and 2017 at 100-K included:

- 15 wells were installed and additional annual well realignments were completed for groundwater interim action P&T system optimization
- A rebound study was completed at the 183.1KW Headhouse area for secondary source characterization
- Interim action RTD and waste site characterization was completed and the nature and extent of contamination was assessed at 38 waste sites
- Groundwater monitoring data were collected and evaluated to refine groundwater contaminant distributions

100-K Background

100-K is located within the 100 Area (commonly referred to as the River Corridor) and comprises the 100-KR-1 and 100-KR-2 Source OUs and the 100-KR-4 Groundwater OU. 100-K is located in the northern portion of the Hanford Site, adjacent to the Columbia River, and is the site of the KE and KW Reactors. 100-K is downstream of the 100-BC Area and upstream of the other reactor areas, and encompasses approximately 9 km^2 (3.5 mi^2). The KE and KW Reactors were constructed beginning in 1952 using a similar design, which was about 60 percent larger than the older Hanford Site production reactors. Construction was completed and the reactors began operating in 1955. The primary mission of the reactors was plutonium production. The KE and KW Reactors used an increased amount of materials in comparison to the older reactors, including cooling water, inert gas recirculated over the graphite moderator blocks, and fuel elements in the reactor piles. Production continued until 1970 at the KW Reactor and until 1971 at the KE Reactor. Operation of each reactor was supported by multiple facilities that included infrastructure for water treatment, air filtration, nuclear fuel handling, cooling water effluent disposal, laboratories, and administration.

The water-cooled nuclear reactors, associated structures, and processes that generated solid and liquid wastes were the primary 100-K contaminant sources. Solid waste was placed in unlined burial grounds. Liquid contaminants were released to the environment by discharging effluent directly to the soil column via retention basins, trenches, cribs, and ditches and through outfall piping to the Columbia River.

The KE and KW Reactors' fuel storage basins (FSBs) were repurposed beginning in 1973 to temporarily store spent fuel from the N Reactor. This storage activity included plans for spent fuel removal and reprocessing in the 200 Area. Spent fuel was reprocessed from 1983 until 1992, after which the approximately 2,100 metric tons (2,300 tons) of spent fuel remaining in the FSBs was consolidated in the KW FSB where it was stored until 2004. Fuel rods and debris were removed from both FSBs by 2008, and the KE FSB and associated structures were removed in 2009. The spent fuel storage operation resulted in additional long-lived fission product contamination of the vadose zone and groundwater beneath the FSBs from spent fuel contamination of the FSB water and leaks from the FSBs.

Physical/Environmental Setting

The CSM includes consideration of the physical and chemical characteristics of vadose materials, geologic features of the area, local groundwater characteristics, and interaction of these elements with the Columbia River. Study area physical characteristics influence contaminant movement in the environment.

The topography at 100-K is relatively flat inland from the Columbia River, with elevations[8] decreasing from 162 m (530 ft) in the south to 120 m (390 ft) in the north along the riverbank. The area has been disturbed and graded extensively since reactor construction through waste site remediation activities. The semiarid climate has occasional high winds, and the land surface is mostly an undeveloped shrub-steppe community.

The Hanford formation is the dominant material in the vadose zone and consists of a sand and gravel unit that decreases in thickness away from the river. The unconfined aquifer is predominantly within the Ringold Formation unit E. The changing river height directly influences groundwater elevations in a zone that can stretch as far as several hundred meters inland. Water level data and contaminant migration indicate that groundwater

[8] Elevations based on NAVD88.

flow in the Ringold unit E is an average of 1.2×10^{-4} to 3.5×10^{-4} cm/s (0.024 to 0.072 ft/day) to the north. Groundwater extraction and injection for P&T system operations result in localized flow changes.

Natural recharge to the aquifer is low because of the hot, arid climate. Natural recharge rates may be as low as 1.5 mm/yr (0.059 in./yr) where mature vegetation is present, and as high as 52 mm/yr (2.0 in./yr) on disturbed soil. There is little recharge in areas with natural vegetation due to evapotranspiration.

Pore water in the riverbed along the 100-K shoreline is a mix of groundwater and surface water. Groundwater upwelling through the riverbed occurs during most of the year, except when the river stage is high for prolonged periods.

Nature and Extent of Contamination

This RI describes the current contaminant distribution in the environment, predicts contaminant attenuation and migration rates in the subsurface environment (fate and transport), and evaluates the potential for contaminant migration in groundwater and subsequent discharge to the Columbia River.

Waste site cleanup in 100-K began in 2002 under an interim action ROD amendment, and is ongoing during the development of a final action decision. Interim action waste site cleanup consists primarily of removing and disposing of contaminated material, then backfilling and revegetating.

Vadose zone contamination remains at the waste sites that have not been addressed by interim action. The most significant of these is the UPR-100-K-1 waste site, associated with cooling water effluent leakage at the KW FSB. High mixed fission product radionuclide activities are present in deep soil immediately underlying the FSB, and elevated strontium-90 contamination has been driven to the groundwater table. Residual deep zone radionuclide contamination, including higher mobility contaminants such as carbon-14, strontium-90, and tritium, is also present at other incompletely remediated waste sites around both reactors.

Groundwater contaminants of concern (COCs) at 100-K include carbon-14, Cr(VI), total chromium, nitrate, strontium-90, trichloroethene, and tritium. Groundwater monitoring indicates continuing contaminant source locations in the vadose zone for carbon-14, Cr(VI), nitrate, strontium-90, and tritium. Cr(VI) is the most widely distributed COC in 100-K groundwater, where five plumes are identified with concentrations that exceed the

10 µg/L state surface water quality standard, two of which also exceed the 48 µg/L drinking water standard (DWS). Carbon-14 at concentrations greater than the 2,000 pCi/L DWS is at two localized plumes, one each near the KE and KW Reactors, and a plume of nitrate with concentrations greater than the 45 mg/L DWS is near the KW Reactor.

Three strontium-90 plumes are in 100-K with concentrations above the 8 pCi/L DWS. The highest concentration plume is near the KE Reactor, where leaks from the KE FSB resulted in residual strontium-90 vadose zone contamination and groundwater concentrations over 15,000 pCi/L in 2017. Smaller plumes near the KW Reactor and 116-K-2 Trench west end report lower strontium-90 groundwater concentrations. Groundwater strontium-90 concentrations are generally decreasing due to radioactive decay, but the time required for concentrations to achieve the DWS is more than 300 years for the plume near the KE Reactor.

In 2016, tritium concentrations greater than the 20,000 pCi/L DWS at 100-K were in a small plume near the KE Reactor and a larger plume with higher concentrations near the former 118-K-1 Burial Ground. Trichloroethene at concentrations between 5 and 10 µg/L are in a plume near the KW Reactor, with additional nearby individual wells reporting concentrations greater than the 5 µg/L DWS.

Exposure Assessment

Exposure scenarios were developed to assess potential human health risk and ecological effects. The principal soil contaminants identified for direct contact exposure associated with one or more waste sites include cesium-137, carbon-14, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90. The groundwater risk assessment identified carbon-14, Cr(VI), total chromium, strontium-90, trichloroethene, and tritium as COCs in 100-K. These soil and groundwater contaminants are evaluated for potential remedial technologies in the FS.

The waste site human health and ecological risk evaluations used a comprehensive review of field data, radiological surveys, process history, analogous site information, personal interviews, engineering drawings and as-builts, and other information identified during RI development. For waste sites proposed for remediation, the data review indicated a need for action. This waste site data and characteristics review is sufficiently

defined for alternative development and comparison in the FS, and identification of a preferred alternative in the proposed plan.

Many of the 100-K waste sites evaluated in the RI/FS have cleanup verification data from interim action implementation. These waste sites were either remediated to meet interim action cleanup levels or determined to meet interim action cleanup levels without remediation. New SSLs and PRGs are established in this RI for each environmental medium of interest (soil and groundwater), each type of contaminant (hazardous substances and radionuclides), and human and ecological receptors. The SSLs and PRGs are based on EPA guidance and scenarios that include assumptions of vadose zone contamination and infiltration/recharge rates based on irrigated agriculture land use for SSLs and native vegetation for PRGs.

Quantitative evaluations identified 16 remediated waste sites for further action. Eight waste sites only have radiological contamination that exceeds direct contact soil preliminary remediation goals at depths greater than 4.6 m (15 ft) below ground surface, and two waste sites have radionuclide contamination that exceeds human health risk based screening levels in soil at a depth less than 4.6 m (15 ft) below ground surface. Four of the 16 sites for further action have selenium concentrations that are greater than soil screening levels for groundwater or surface water protection, and two remediated waste sites have residual contaminant concentration that exceed the surface water or groundwater PRGs. Sixty waste sites that are identified for remediation under an interim action ROD remained for completion as of April 2017.

The 16 waste sites identified for further action and 60 remaining for completion are evaluated for remedial action in the FS. The FS also develops and evaluates remedial action for the groundwater COCs.

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Terms

1D	one-dimensional
2D	two-dimensional
AEA	Atomic Energy Act of 1954
AEC	Atomic Energy Commission
ARAMS	U.S. Army Adaptive Risk Assessment Modeling Systems
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AWLN	Automated Water Level Network
AWQC	Ambient Water Quality Criterion
AWQS	Ambient Water Quality Standard
AUF	area use factor
BERA	baseline ecological risk assessment
B.P.	before present (time)
BAF	bioaccumulation factor
BCG	biota concentration guide
bgs	below ground surface
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CHRP	Cultural and Historic Resources Program
COC	contaminant of concern
COEC	contaminant of ecological concern
COPC	contaminant of potential concern
COPEC	contaminant of potential ecological concern
CRBG	Columbia River Basalt Group
CRC	Columbia River Component
CSL	cleanup screening level
CSM	conceptual site model
CSS	Colorado silica sand

CTE	central tendency estimate
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTS	contaminant treatment system
CVD	cold vacuum drying
CVP	cleanup verification package
CY	calendar year
D&D	decommissioning and demolition
D4	deactivation, decontamination, decommissioning, and demolition
DDT	dichlorodiphenyltrichloroethane
DO	Dissolved oxygen
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
DR	diesel range
DQA	data quality assessment
DQO	data quality objective
DTPA	diethylene triamine pentaacetic acid
DUA	data usability assessment
DWS	drinking water standard
EC	equivalent carbon number
Ecology	Washington State Department of Ecology
EcoSSL	ecological soil screening level
EIS	environmental impact statement
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EQL	estimated quantitation limit
ERA	ecological risk assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
ERDF	environmental restoration disposal facility
ETF	Effluent Treatment Facility

FEP	features, events, and processes
FS	feasibility study
FSB	fuel storage basin
FY	fiscal year
GHB	general-head boundary
GWFTM	groundwater fate and transport model
HCP EIS	Hanford Comprehensive Land-Use Plan Environmental Impact Statement
HCR	horizontal control rod
HCRC	Hanford Cultural Resource Case
HEAST	health effects assessment summary tables
HEIS	Hanford Environmental Information System
HHBP	Human Health Benchmarks for Pesticides
HHE	human health and the environment
HHRA	human health risk assessment
HHT	human health toxicity
HI	hazard index
HMS	Hanford Meteorological Station
HQ	hazard quotient
HRNM	Hanford Reach National Monument
HSP	health and safety plan
HSP	hyporheic sampling point
IAMP	Interim Action Monitoring Plan
IC	institutional control
IRIS	integrated risk information system
IRM	interim remedial measures
ISS	interim safe storage
IWTS	integrated water treatment system
IX	ion exchange
K_d	distribution coefficient
KN	K North

K_s	saturated hydraulic conductivity
LFI	limited field investigation
LIDAR	light detection and ranging
LOAEC	lowest observed adverse-effect concentration
LOAEL	lowest observed adverse-effect level
LOEC	lowest observed effect concentration
LOEL	lowest observed effects level
MATC	maximum allowable toxicant concentration
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDA	minimum detectable activity
MDL	method detection limit
MIS	MULTI INCREMENT® sampling
MTCA	Model Toxic Control Act
MW	molecular weight
NCP	*National Oil and hazardous Substances Pollution Contingency Plan*
NEPA	National Environmental Policy Act of 1969
NJDEP	New Jersey Department of Environmental Protection
NOAEC	no observed adverse-effect concentration
NOEC	no observed effect concentrations
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRHP	National Register of Historic Places
ORNL	Oak Ridge National Laboratory
OSE	orphan site evaluation
OU	operable units
P&T	pump and treat
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEF	particulate emission factor

PNEC	predicted no effect concentration
PNNL	Pacific Northwest National Laboratory
PPE	personal protective equipment
PPRTV	Provisional Peer Reviewed Toxicity Value
PQL	practical quantitation limit
PRG	preliminary remediation goal
PRZ	periodically rewetted zone
PUREX	plutonium uranium extraction
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
QRA	qualitative risk assessment
RA	remedial action
RAG	remedial action goal
RAO	remedial action objective
RBSL	risk based screening level
RCBRA	River Corridor Baseline Risk Assessment
RCRA	Resource Conservation and Recovery Act of 1976
RDL	required detection limit
RD/RAWP	remedial design/remedial action work plan
RDR/RAWP	remedial design report/remedial action work plan
REDOX	reduction and oxidation
RESRAD	RESidual RADiation
RfD	reference dose
RI	remedial investigation
RLM	Ringold Formation lower mud
RME	reasonable maximum exposure
ROD	record of decision
RPO	remedial process optimization
RSVP	remaining site verification package

RTD	removal, treatment, and disposal
RUM	Ringold Formation upper mud
SAP	sampling and analysis plan
SCV	secondary chronic value
SESP	Surface Environmental Surveillance Program
SGLS	Spectral Gamma Logging System
SLERA	screening-level ERA
SMDP	scientific management decision point
SNF	spent nuclear fuel
SOF	sum of fractions
SQS	sediment quality standards
SR-RAD	total beta radiostrontium
SSL	soil screening level
STOMP	Subsurface Transport over Multiple Phases
SVOC	semivolatile organic compound
TCE	trichloroethylene
TCP	traditional cultural property
TEF	toxic equivalence factors
TOC	total organic carbon
TPA	Tri-Party Agreement
TPA-CN	Tri-Party Agreement Change Notice
TPH	total petroleum hydrocarbons
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TRU	transuranic
TRV	toxicity reference value
TSCA	Toxic Substances Control Act of 1976
TSD	temporary storage and disposal
UCL	upper confidence limit
UPL	upper prediction limit
UPR	unplanned release

USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VCR	vertical control rod
VOC	volatile organic compound
WIDS	Waste Information Data System

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1 Introduction

The 100-K Area at the Hanford Site included two plutonium production reactors and support facilities that operated from 1955 to 1971. There are two reactors in 100-K: 105-KE Reactor and 105-KW Reactor (hereinafter called KE Reactor and KW Reactor). The similarly designed KE and KW reactors were constructed beginning in 1952 with each having a plutonium production capacity approximately 60% greater than the Hanford B, C, D, DR, F, and H Reactors.

Remediation of soil contamination from reactor operations began in 2002 under an amendment to an interim action record of decision (ROD) (EPA/AMD/R10-97/044, *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*). The soil remediation scope was subsequently expanded to include additional waste sites under EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)*, hereinafter called 100 Area Remaining Sites ROD, and EPA/ROD/R10-00/121, *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington*, hereinafter called 100 Area Burial Grounds ROD.

Groundwater remediation began under the 1996 interim action ROD (EPA/ROD/R10-96/134, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington)* with startup of the KR4 pump and treat (P&T) system in 1997. The groundwater remedial action expanded in 2007 when the KW P&T system began operating, and again in 2009 with the startup of the KX P&T system.

Waste site and groundwater interim remedial actions are ongoing. This chapter summarizes the assessment and remediation work, treatability tests, and other relevant studies for the 100-K Area. Historical information is presented to provide a comprehensive picture of current 100-K site conditions and establish a foundation for the remainder of this remedial investigation (RI) and the associated feasibility study (FS).

The following summary includes investigations and remedial actions that have occurred at 100-K:

- Liquid waste from reactor operations and support facilities was released to the vadose zone while solid wastes were disposed in burial grounds during reactor operations from 1955 to 1971. Soil contaminant characterization began in the mid-1970s.
- Limited field investigations (LFIs) of soil and groundwater were performed at 100-K in the early 1990s. Characterization work under this 100-K RI was performed from 2009 to 2017.
- Interim remedial action at 100-K waste sites began in 2002 and is ongoing. There were 197 waste sites at 100-K as of April 2017. Action that met interim cleanup standards was completed at 68 of these waste sites, and 6 waste sites were determined not to require action. Forty-one waste sites were either not accepted or rejected as waste sites. Eighty-two waste sites were identified for remedial action under the interim action RODs as of April 2017.
- Groundwater monitoring at 100-K began in 1952 following installation of wells to detect radionuclides from operations. The groundwater LFI results in 1994 indicated groundwater remedial action was needed to address hexavalent chromium (Cr(VI)), and a pump and treat system treatment became operational in 1997.

In 1989, the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) (known as the Tri-Parties) signed the *Hanford Federal Facility Agreement and Consent Order* (hereinafter called Tri-Party Agreement [TPA] [Ecology et al., 1989a]) to provide a framework for the cleanup of the Hanford Site. The scope of the agreement addressed the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remediation of inactive hazardous waste sites, active waste management operations, *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action for solid waste management units, and closure of RCRA treatment, storage, and/or disposal units across the Hanford Site.

For the purpose of CERCLA cleanup, the following four sections of the Hanford Site were placed on the 40 CFR 300 "National Oil and Hazardous Substances Pollution Contingency Plan" hereinafter called National Contingency Plan (NCP), Appendix B, "National Priorities List" (hereinafter called NPL):

- 100 Area (Reactor Operations)
- 200 Area (Irradiated Fuel Reprocessing and Waste Management)
- 300 Area (Nuclear Fuel Production and Research and Development)
- 1100 Area (Equipment and Maintenance)

Because of the large number of waste sites, unplanned releases (UPRs), and extensive groundwater contamination, the 100 Area was further divided into source and groundwater operable units (OUs) for investigation and remediation management.

This document presents the 100-K Area (Figure 1-1) CERCLA RI. The RI, together with the FS supports a Proposed Plan, which will go through a public review and provide the basis for a ROD. The 100-K ROD will apply to the 100-KR-1 and 100-KR-2 Source OUs and to the 100-KR-4 Groundwater OU (Figure 1-2). These three OUs are referred to as the 100-K Area or simply 100-K. The boundary for the 100-KR-4 OU is not based on a geographic area, rather it is identified on groundwater contamination originating from the 100-KR-1 and 100-KR-2 OUs.

The Tri-Parties determined in 1991 that there was a need to prioritize CERCLA investigations and identify early actions to address waste sites and groundwater contamination. The basis for prioritizing investigations and cleanup actions across the Hanford Site is provided in DOE/RL-91-40, *Hanford Past-Practice Strategy*, hereinafter called Past-Practice Strategy. This strategy emphasized the need to address waste sites and groundwater contamination that may pose a near-term risk to human health and the environment. In addition, the strategy proposed a bias for action to clean up waste sites and existing contamination where the remedy was evident.

For 100-K, the Past-Practice Strategy translated into LFIs being completed. LFIs (DOE/RL-93-78, *Limited Field Investigation Report for the 100-KR-1 Operable Unit*; DOE/RL-93-79, *Limited Field Investigation Report for the 100-KR-4 Operable Unit*, hereinafter called 100-KR-4 LFI) were initiated for the 100-KR-1 and 100-KR-4 OUs. The LFI for the 100-KR-1 OU characterized the nature and extent of contamination in the vadose zone, structures, and debris that received radioactive liquid effluent discharges. Radionuclides, metals, and organics were analyzed in the LFI samples. The qualitative risk assessment (QRA) in the LFI for the 100-KR-4 OU groundwater identified low to medium carcinogenic risk for arsenic, tritium, and carbon-14 under occasional-use and frequent-use scenarios, and a hazard quotient (HQ) >1 for arsenic, chromium, and nitrate/nitrite under the frequent-use scenario.

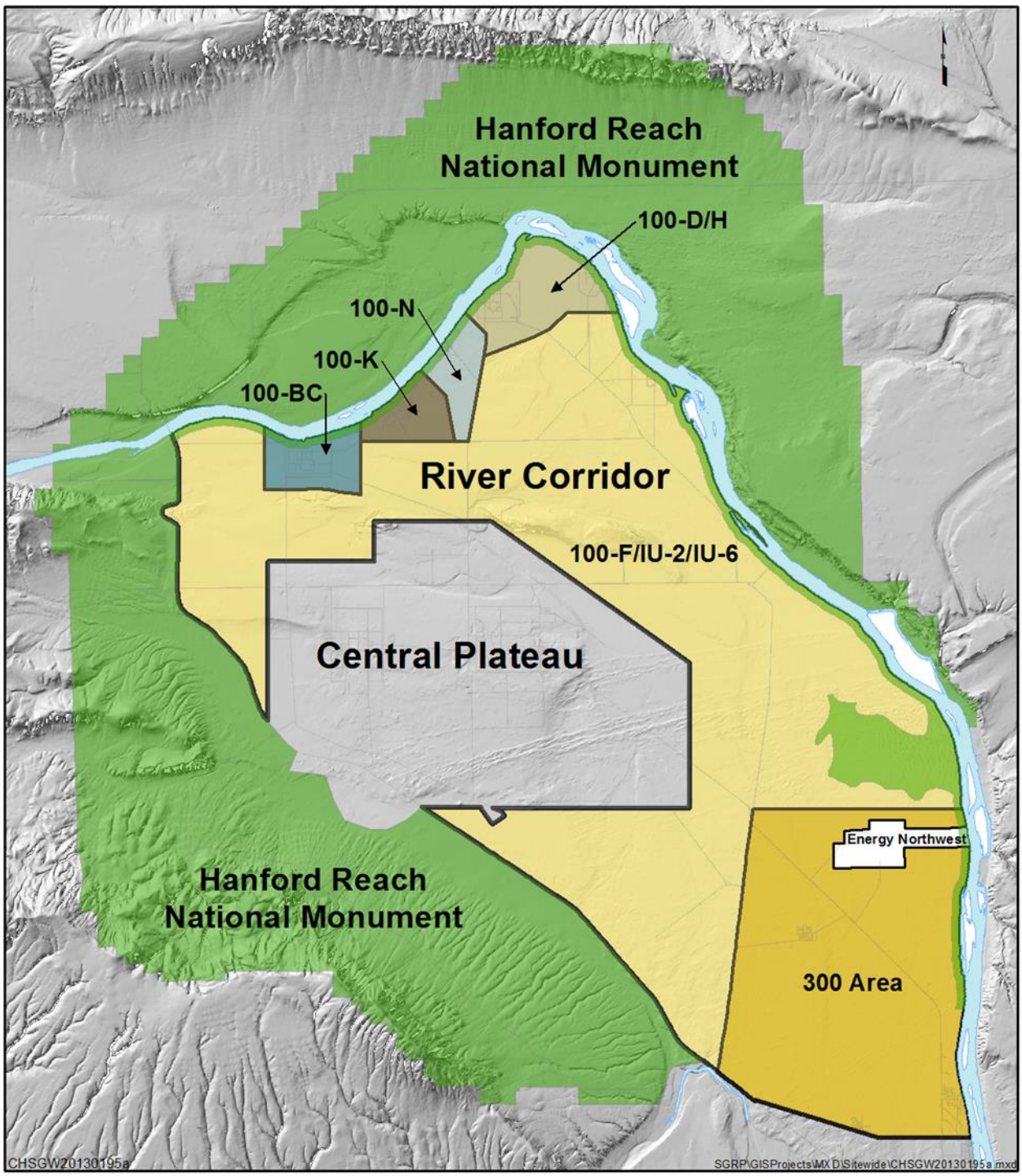
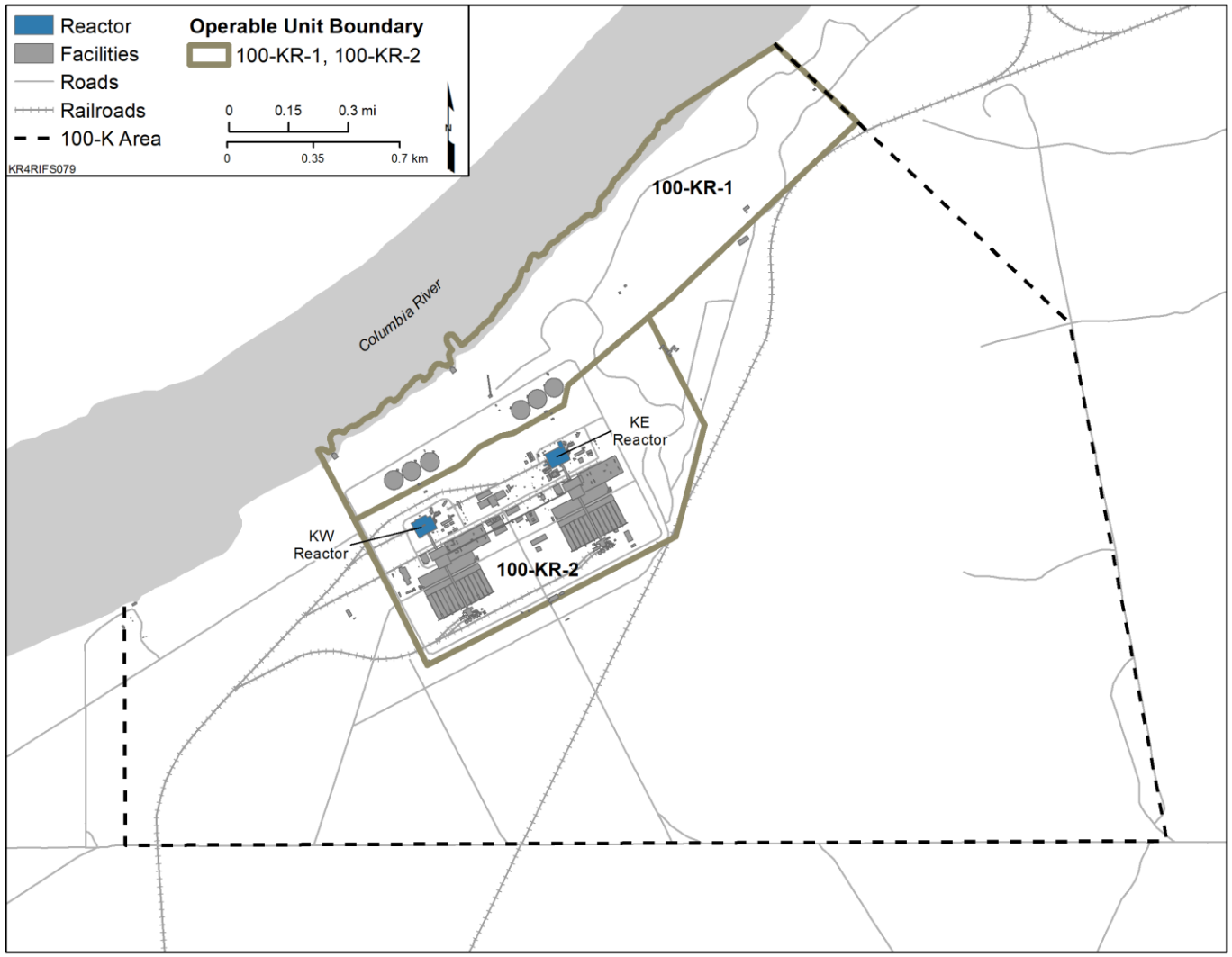


Figure 1-1. Hanford Site Map



Note: The 100-KR-4 OU comprises the groundwater contaminant plumes that are above drinking water standards, risk-based concentrations, and the state surface water quality standard. Chapter 4 presents plume maps.

Figure 1-2. 100-K Area OUs and Reactors

The LFIs indicated that liquid waste disposal sites in 100-K were primarily responsible for Cr(VI) releases to groundwater. For the 100-KR-4 OU, it was established that Cr(VI) in groundwater was entering the Columbia River at concentrations considered toxic to aquatic organisms. This led to the selection of interim actions to remediate source and groundwater contamination in the 100-KR-1, 100-KR-2, and 100-KR-4 OUs under the following interim action decisions: EPA/ROD/R10-96/134 (March 1996) and EPA/AMD/R10-97/044 (April 1997).

River Corridor cleanup work is progressing based on interim action and final RODs. Waste site cleanup objectives include contaminant source removal and disposal in the Environmental Restoration Disposal Facility (ERDF) on the Central Plateau. Reducing contaminant concentrations entering the Columbia River and restoring the groundwater to beneficial use remain the key objectives of groundwater remediation. Interim remedial action objectives (RAOs) for the waste site cleanups in the 100-KR-1 and 100-KR-2 OUs are focused on protecting human health from soil contaminants, controlling groundwater contaminant sources, and protecting the Columbia River. The 100-KR-4 OU interim action RAOs include protection of aquatic receptors in the Columbia River from Cr(VI) groundwater discharges to surface water, protection of human health by preventing exposure, and providing information for a final remedy.

Remedial actions for sites in the River Corridor are expected to restore groundwater to drinking water standards (DWSs) and protect aquatic life in the Columbia River by achieving ambient water quality criteria (AWQC) at groundwater discharge points to the river. Cleanup actions will support reasonably anticipated future land uses consistent with the Hanford Reach National Monument (HRNM) and 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)."

The River Corridor was divided into six geographic decision areas (100-BC, 100-K, 100-N, 100-D/H, 100-F/IU-2/IU-6, and 300 Area) to achieve source and groundwater remedy decisions (Figure 1-1). These decisions will provide comprehensive coverage for all areas within the River Corridor and will incorporate interim action cleanup activities. Cleanup levels will be established that will protect human health and the environment. These levels will also comply with applicable or relevant and appropriate requirements (ARARs) and consider the cleanup levels previously used in implementation of interim action RODs for River Corridor OUs.

This RI and associated FS build on a body of previous work, including the River Corridor Baseline Risk Assessment (RCBRA) (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*, hereinafter called RCBRA Volume I, and the Columbia River Component (CRC) (DOE/RL-2010-117, *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment*, and *Volume II: Baseline Human Health Risk Assessment*), discussed in Chapters 6 and 7. These discussions help provide an understanding of current site conditions that have been affected by remediation efforts to date.

For the purpose of this RI, the vadose zone is defined as follows:

- **Shallow vadose zone—**from ground surface to a depth of 4.6 m (15 ft). This depth interval is evaluated for protection of human health and ecological receptors as well as protection of groundwater and surface water.

- **Deep vadose zone—**from below a depth of 4.6 m (15 ft). This depth interval is evaluated for protection of groundwater and surface water. Residual contaminant concentrations in this zone are evaluated for human health protection to provide risk management information.

Per the CERCLA process, this RI for 100-K was undertaken in accordance with the following documents:

- DOE/RL-2008-46, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (hereinafter called the Integrated Work Plan), which contains the planning elements that are common to all the Hanford Site 100 Area source and groundwater OUs
- DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (hereinafter called the 100-K Work Plan), which is specific to 100-K
- DOE/RL-2009-41, 2009, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study* (hereinafter called the 100-K Sampling and Analysis Plan [SAP])

This RI includes the following chapters, and a list of the references used in preparing this report (Chapter 8):

- Chapter 2—Study Area Investigation
- Chapter 3—Physical Characteristics of the Study Area
- Chapter 4—Nature and Extent of Contamination
- Chapter 5—Contaminant Fate and Transport
- Chapter 6—Human Health Risk Assessment
- Chapter 7—Ecological Risk Assessment
- Chapter 8—References

This RI includes extensive data used to perform calculations and assessments. Due to the volume of this information (such as laboratory analytical data and risk calculations), data summaries are provided in this document and appendices, and electronic links are provided with the references in Chapter 8 to direct the reader to more detailed information contained in particular studies, databases, or reports found in the Administrative Record. Appendices are as follows:

- Appendix A—Site Map
- Appendix B—Annotated Bibliography
- Appendix C—Supporting Information for Wells and Boreholes
- Appendix D—Analytical Data
- Appendix E—Waste Site Summary
- Appendix F—Fate and Transport Modeling Documentation
- Appendix G—Human Health Risk Assessment Supporting Documentation
- Appendix H—Ecological Risk Assessment Supporting Documentation
- Appendix I—Nonoperational Area Evaluation
- Appendix J—Riparian/Nearshore Evaluation

1.1 Purpose and Scope of Report

The RI/FS process is outlined in EPA and DOE RI/FS guidance (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* [hereinafter called the CERCLA RI/FS Guidance], and DOE/EH-94007658, *Remedial Investigation/Feasibility Study (RI/FS) Process, Elements and Techniques*). The RI/FS process represents the methodology established by the

Superfund Amendments and Reauthorization Act of 1986 program for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and evaluating potential remedial options.

This RI was prepared in accordance with the previously referenced guidance as well as EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*, and EPA/540/G-89/009, *CERCLA Compliance with Other Laws Manual: Part II*. The guidance documents provide information on the regulations and standards that govern the RI/FS process, as well as an overview of the requirements for each section of the RI.

This RI has the following objectives:

- Provide information concerning the physical and environmental setting and site characterization.
- Draw conclusions concerning the nature and extent of contamination at the site, potential for migration of contamination from the site, and potential for adverse human health and the environment effects if no action is taken at the site and exposure occurs. This is achieved by evaluating site historical and operational information, identifying contaminants of potential concern (COPCs), evaluating potential migration pathways, and understanding potential impacts to receptors by estimating exposure effects in consideration of contaminant toxicity.

DOE has completed the RI and FS for 100-K OUs and is issuing this report as a component of its responsibilities under the NCP (40 CFR 300), acting in its role as lead agency for the cleanup. EPA is the lead regulatory agency for 100-K and, as such, has the primary responsibility for overseeing all remedial action activities to ensure that they meet applicable requirements. DOE is responsible for performing all 100-K remedial actions.

The conceptual site model (CSM) serves as a framework for evaluating the data from 100-K. The American Society for Testing and Materials, ASTM E1689-95, *Standard Guide for Developing Conceptual Site Models for Contaminated Sites*, defines the CSM as "a written or pictorial of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system." For the 100-K Work Plan (DOE/RL-2008-46, ADD2), the CSM was used to integrate relevant site information, determine whether information or data were missing (data gaps), and identify additional information to be collected. The CSM is refined in Chapters 2 through 7 by the additional information and then used to identify and evaluate potential risks to human health and the environment.

Figure 1-3 presents the basic elements associated with a CSM (as defined in the following bullets).

Figure 1-3. Conceptual Site Model

- Source is the location where a contaminant enters the physical setting. The primary sources of contaminants at 100-K were liquid and solid wastes generated during reactor and support facility operations, and are described in Section 1.2.2. Secondary sources are contaminants remaining in the vadose zone and within the aquifer matrix. Contaminants in secondary sources were typically released as primary source material. Reactor operations at 100-K have ceased; therefore, this document focuses on secondary contaminant sources in the vadose zone and groundwater and potential risk to human health and the environment. Chapter 4 describes the secondary sources.

- Release mechanisms are the actions necessary to release contaminants to the environment, such as resuspension of contaminated particulate matter, surface runoff, contaminant leaching, plant intrusion, animal burrowing, erosion, or groundwater migration. Release mechanisms and relevant 100-K physical features are introduced in Chapter 3 and discussed in Chapter 5.

- Transport is movement of a radiological, chemical, or physical agent in the environment from a source to environmental media where human or ecological exposure could occur. Contaminants introduced into the environment can be transported between environmental media such as air, vadose zone, groundwater, and surface water due to interconnecting release mechanisms. Transport is discussed in Chapter 5.

- Exposure is the process by which a contaminant comes into direct contact with the body, tissues, or exchange boundaries of an organism, human, plant, or animal (for example, ingestion, inhalation, dermal absorption, or root uptake). Potential exposure scenarios are discussed in Chapters 6 and 7.

- Receptors include humans and other organisms (e.g., plants, animals, and other species) that may come into contact with the contaminants. Chapters 6 and 7 evaluate receptor exposures.

In the FS, the refined CSM supports relevant remedial technology identification, remedial alternatives development, and the evaluation of remedial alternatives effectiveness in interrupting the contaminant exposure pathways to human and environmental receptors.

1.2 Site Background

The Hanford Site encompasses approximately 1,502 km^2 (580 mi^2) in Benton, Franklin, and Grant counties in south-central Washington State within the semiarid Pasco Basin of the Columbia Plateau. The site is approximately 50 km (30 mi) north to south and 40 km (24 mi) east to west, immediately north-northwest of the confluence of the Yakima and Columbia Rivers; the cities of Kennewick, Pasco, and Richland (the Tri-Cities); and the city of West Richland. The Columbia River flows 80 km (50 mi) through the northern part of the Hanford Site and, turning south, forms part of the eastern boundary of the site. Two small east-west trending ridges (Gable Butte and Gable Mountain) are located in the central portion of the site. Lands adjoining the site to the west, north, and east are principally range and agricultural. State Routes 240 and 24 skirt the southwestern and northern portions of the site, respectively.

The Hanford Site area is culturally rich, experiencing a history of land use by both Native and non-Native Americans. For thousands of years, Native American peoples have inhabited the lands both within and around the Hanford Site (Spier, 1936, *Tribal Distribution in Washington*; Walker and Sturtevant, 1998, *Handbook of North American Indians: Volume 12, Plateau*). Non-Native American presence in the mid-Columbia began in 1805 with the arrival of the Lewis and Clark Expedition along the Columbia and Snake Rivers. In the late 19th and early 20th centuries, non-Native people began intensive settlement on the Hanford Site, establishing an early settler and farming landscape. Farmstead communities existed from 1880 to 1943, located primarily in the upland environment adjacent to the Columbia River. The area

became one of the premier orchard regions in the state following formation of the Hanford Irrigation and Development Company in 1905.

The River Corridor includes approximately 3,360 ha (8,300 ac) of historical farmsteads of which 2,020 ha (5,000 ac) are historical orchard lands. There were two orchard and farm parcels totaling 0.31 km^2 (0.12 mi^2) in the 100-K Area. The established farming life at Hanford came to an abrupt halt in 1943 when the United States government took possession of the land to produce weapons-grade plutonium as a part of the Manhattan Project.

1.2.1 Site Description

The Hanford Site is divided into numerically designated areas. These areas served as the location for reactor, chemical separation, and related activities for the production and purification of special nuclear materials and other nuclear activities. The reactors and their ancillary/support facilities were located along the south shore of the Columbia River in the 100 Area, due to the need for large quantities of water to dissipate the heat generated during reactor operations. The 200 Area, located about 11 km (7 mi) from the Columbia River, contained all the facilities used to separate, isolate, store, and ship the plutonium from reactor operations. The 300 Area, located adjacent to and north of the city of Richland, contained the reactor fuel manufacturing plants and the research and development laboratories, while the 400 Area, located 8 km (5 mi) northwest of the 300 Area, contained the Fast Flux Test Facility designed for testing liquid metal reactor systems. The 600 Area consisted of facilities that served more than one specific area or, in some cases, the entire project.

100-K is adjacent to the Columbia River in the northern portion of the Hanford Site between 100-BC and 100-N, as shown in Figure 1-1. The 100-K Area encompasses the operating regions for the KE Reactor and KW Reactor, and includes the 100-KR-1 and 100-KR-2 Source OUs and the 100-KR-4 Groundwater OU. It includes 9 km^2 (3.5 mi^2) of land along the southern shore of the Columbia River. The 100-K boundary at the Columbia River is the ordinary low water mark, which is characterized by the presence of the "green line" of algae delineating the permanently inundated portion of the river channel. The HRNM extends inland a quarter mile from the Columbia River, along the entire length of the 100-K Area adjacent to the river. The HRNM is an important ecological, cultural, historical, and recreational feature.

Active facilities in 100-K include office buildings, storage buildings, an electrical substation, the KW FSB, KW Annex, 189K Water Treatment Facility, and groundwater P&T facilities. Inactive facilities remaining within 100-K include the KE and KW Reactor buildings, a water treatment plant, outfall structures, a mobile office, and numerous storage buildings. Figure 1-2 displays the location of 100-K OUs.

1.2.2 Hanford Site and Operational History

This section provides an overview of the Hanford Site history and operational and process histories at 100-K. It describes the KE and KW Reactors and support facilities, cooling water systems, radioactive and nonradioactive waste streams, and waste disposal facilities used during operations. It describes contaminant release locations and indicates the types of contaminants likely found in various locations at 100-K.

With the exception of the waste sites in orchard and farm areas, historical land parcels planted with fruit trees are not within the scope of this RI and FS. Figure 1-4 shows two former orchard and farm parcels totaling 0.31 km^2 (0.12 mi^2) in the 100-K Area.

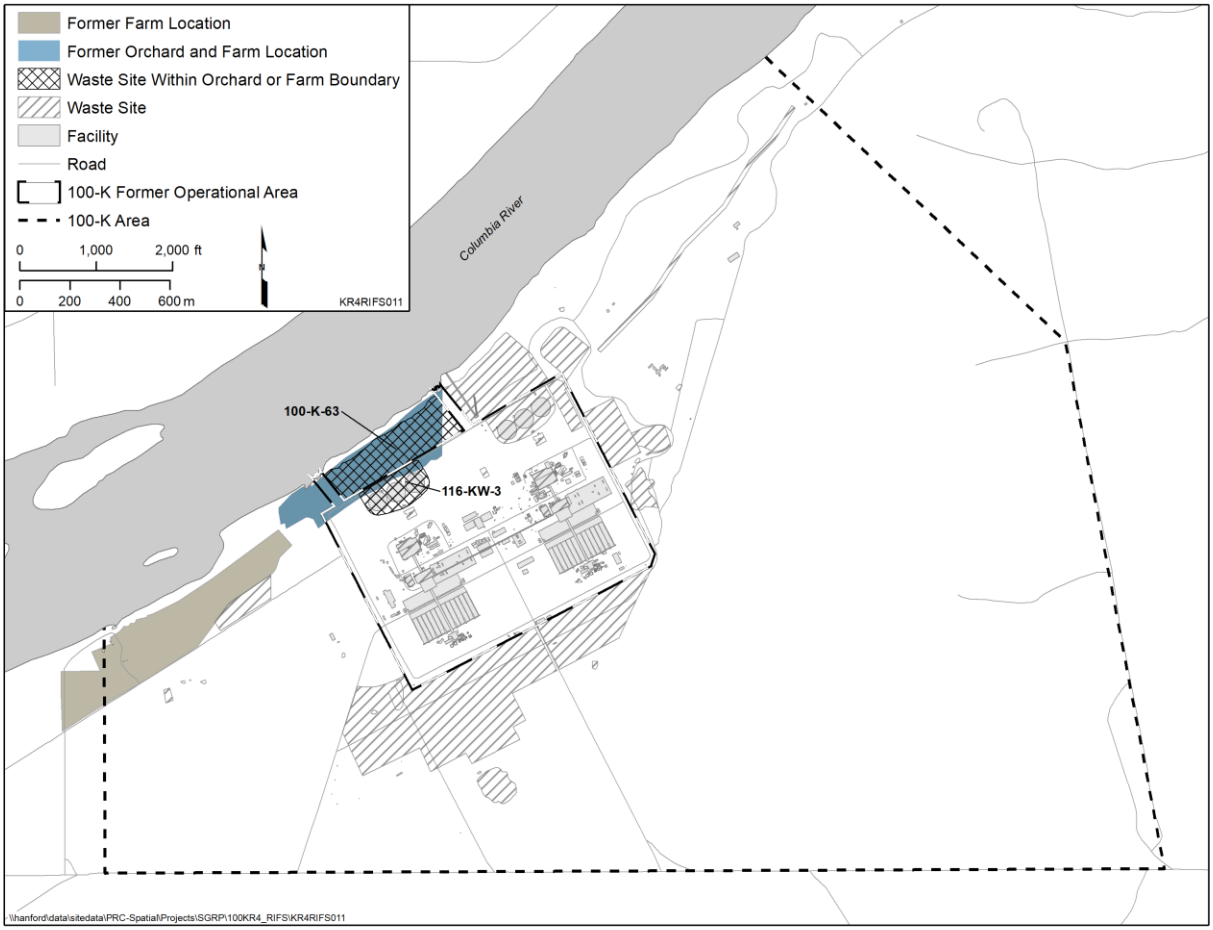


Figure 1-4. Historical Orchard Land Areas at the 100-K Area

1.2.2.1 Hanford Site History Overview

The Hanford Site was selected for plutonium production in 1942 as part of the Manhattan Project primarily because of the availability of water from the Columbia River, and access to power from the Bonneville and Grand Coulee Dams. The remote location and weather conditions, which allowed for nearly year-round construction, contributed to the site selection. Land acquisition for the Hanford Site took place in February 1943 and represented one of the largest land procurements (approximately 1,620 km^2 [625 mi^2]) carried out during World War II. Site construction began in March 1943 and was largely completed with the first three reactors (B, D, and F) online by April 1945.

Between 1947 and 1955, the Atomic Energy Commission added five new reactors (C, H, DR, KE, and KW) at the Hanford Site, while at the same time boosting the output of the three Manhattan Project reactors (B, D, and F). Incremental improvements in the basic components of the World War II reactors and a construction program to build reactors that incorporated these changes accounted for doubling the plutonium output at Hanford in 1952 and 1953.

The period from 1956 through 1964 saw the most intense defense production at the Hanford Site. By the 1960s, the nation's plutonium stockpile was much larger than deemed necessary, and plutonium production at Hanford gradually decreased. In 1964, the Atomic Energy Commission shut down the H, DR, and F Reactors, followed by D Reactor in 1967 and B Reactor in 1968. The C, KE, and KW Reactors

were shut down from 1969 to 1971, along with the fuel manufacturing and separation plants. N Reactor was shut down in 1986 following the Chernobyl explosion in the former Soviet Union, and was transitioned to cold standby in 1989 with the end of the Cold War, signaling the close of the Hanford Site production mission and the start of its cleanup mission. The Hanford Site produced more than 67,000 kg (147,000 lb) of plutonium; 13,000 kg (29,000 lb) were fuel-grade plutonium. The Hanford Site produced the entire nation's nuclear arsenal plutonium between 1945 and 1963, and accounted for more than 65% of all plutonium in the history of United States plutonium production.

Environmental impacts associated with the ultimate disposition of the reactors were evaluated in DOE/EIS-0119F, *Addendum (Final Environmental Impact Statement): Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*. Selection of interim safe storage (ISS) for the reactors was documented in 58 FR 48509, "Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington" (hereinafter called Reactor Decommissioning *National Environmental Policy Act of 1969* [NEPA] ROD). ISS, also known as "cocooning," includes emplacement of an upgraded, weather resistant shell to isolate the reactor core until remedial activities are conducted.

1.2.2.2 100-K Operational History

Construction of the KE and KW Reactors began in tandem in September 1952. Figure 1-5 provides a view of construction in 1954. Operation of the twin reactors began in early 1955 at an initial thermal output of 1,850 megawatts each. However, output was gradually increased until the reactors each reached their maximum authorized power of 4,400 megawatts in 1961.

The operational period for 100-K relates to plutonium production from the KW and KE Reactors occurring from 1955 to 1971. Reactor systems for influent cooling water, reactor pile, effluent waste disposal, and ancillary support services operated during this period. In addition to its plutonium production operational history, 100-K had a second operational period from 1975 until 2007, when the reactor fuel storage basins (FSBs) were repurposed to store spent fuel from the N Reactor. A discussion of these two operating periods follows.

1.2.2.3 Plutonium Production Operations (1955 to 1971)

Producing plutonium for national defense was the primary mission of the Hanford Site reactors. The KW and KE Reactors began operations on January 4 and April 17, 1955, respectively as the seventh and eighth plutonium production reactors at the Hanford Site. Each reactor had a graphite block with 3,220 process tubes compared to the 2,004 process tubes for the older production reactors (B, C, D, DR, F, and H) (HW-74095, *Hazards Summary Report: Process Control and Technical Data Hanford K Production Reactors*, hereinafter called Hazards Summary Report). The increased number of process tubes accounted for most of the operating history differences between the KE and KW Reactors and the older reactors. Each reactor operated with greater volumes of cooling water to and from the reactor pile, an increased volume of inert cover gas recirculated through the graphite moderator block within the pile, and an increased number of fuel elements in the reactor pile compared to the older single-pass reactors.

Materials that passed through the reactors for manufacture, and materials contacting items that passed through the reactors, were considered radiologically contaminated. These materials represent the majority of wastes produced. Active physical barriers and strong administrative measures were in place to minimize radiological hazards throughout the Hanford Site production areas. These measures affected the disposal locations and waste management processes for production operation waste streams.

Figure 1-5. View Southwest of 100-K Construction in 1954

Waste streams from the reactor production process included the following:

- Process inputs:
  - Raw materials processed through the reactor
  - Process chemicals for water conditioning and inhibiting corrosion (for example, sulfuric acid and sodium dichromate) because water management was crucial to reactor operations and represented a major input subsystem
  - Materials used for reactor maintenance, such as acids, solvents, and solid metal components
- Process outputs:
  - Product and waste isotopes, such as plutonium-239 and strontium-90, respectively
  - Radioactively and chemically contaminated materials (solid and liquid wastes)
  - Radioactively and chemically contaminated cooling water

Reactors generated a variety of radionuclides (UNI-946, *Radiological Characterization of the Retired 100 Areas*; WHC-SD-EN-TI-239, *100-K Area Technical Baseline Report*). Principal radionuclides at specific areas in the reactor included:

- Thermal shields—cobalt-60 and nickel-63
- Reactor graphite cores—tritium and carbon-14
- Process tubes (and the film inside the process tubes)—manganese-54, cobalt-60, zinc-65, europium-154, cesium-137, and strontium-90

Liquid wastes from reactor operations and associated facilities were released to the vadose zone and the Columbia River. Solid wastes were disposed in burial grounds associated with the facilities. Sites for wastes intentionally or unintentionally released to or buried within 100-K included trenches, cribs, French drains, retention basins, pipelines, burial grounds, and unplanned spills and releases, each of which is described in the following text. Chapter 4 discusses the nature and extent of the contaminants associated with these processes.

Trenches. Shallow, narrow, unlined surface liquid waste sites of variable length received limited quantities of sludge and/or liquid wastes (cooling water, contaminated water and sludge, sodium dichromate, fuel cladding failure effluent, and decontamination solutions [i.e., citric acid, nitric acid, and solvents]). Trenches typically were 15 to 40 m (50 to 130 ft) long, 3 to 5 m (10 to 17 ft) wide, and 2 to 6 m (6 to 20 ft) deep. The largest trench at 100-K was a 1,250 m (4,100 ft) trench (116-K-2) constructed to dispose of large volumes of reactor effluent waste (Figure 1-6).

Figure 1-6. Mile Long Trench (116-K-2) Excavation in 1955

Cribs. These were subsurface liquid waste disposal sites that percolated wastewater into the ground without exposure to the atmosphere. The cribs typically were 3×3×3 m (10×10×10 ft) boxes, shored with wooden railroad ties, and filled with gravel (e.g., the 116-KE-1, 116-KE-2, and 116-KW-1 Cribs). Early waste management practices used cribs to receive low-level radioactive waste for disposal and to provide a physical barrier against surface exposure. Cribs received contaminated water and sludge, contaminated process tube effluent, fuel storage effluent, spent laboratory solutions, and potassium borate solutions. The 116-K-1 Crib shown in Figure 1-7 was a combination crib/trench design.

Figure 1-7. 116-K-1 Crib During Construction (1954)

French Drains. These were subsurface liquid waste disposal sites designed to percolate wastewater into the ground without exposure to the atmosphere (e.g., 100-K-36). These sites were usually constructed with a 1 m (3 ft) diameter, open or gravel-filled pipe placed vertically to less than 5 m (16 ft) below ground surface (bgs). French drains typically received low volumes of low-level radioactive waste for disposal.

Solid Waste Burial Grounds. These areas were used for near-surface disposal of solid waste containing radioactive and nonradioactive hazardous substances, construction debris (such as steel, concrete, and wood) from reactor modifications, contaminated construction equipment, contaminated vadose zone material, irradiated reactor parts, and low-level radioactive combustible material (WHC-EP-0087, *Estimates of Solid Waste Buried in 100 Area Burial Grounds*; RL-REA-2247, *Historical Events—Reactors and Fuels Fabrication*).

Unplanned Release Sites. Wastes unintentionally released to the environment created sources of contamination at these sites. Waste sites in this group typically related to liquid waste spills (e.g., UPR-100-K-1).

Retention Basins. These were large, open, compartmentalized, reinforced concrete structures designed to temporarily hold cooling water from reactor operations then discharge it to the Columbia River after thermal cooling and decay of short-lived radioactive contaminants. Although retention basins are sometimes considered liquid waste sites because they leaked to the surrounding vadose zone, they were not designed to percolate liquids into the vadose zone.

Pipelines. These were closed transfer lines between facilities or structures used to transfer chemicals or waste effluent and included lines that may have leaked.

1.2.2.4 Spent Fuel Storage Operations (1975 to 2007)

The KW Reactor shut down on February 1, 1970, and the KE Reactor shut down on January 29, 1971. Work then followed to remove their fuel and stabilize subsystems, including the effluent waste disposal sites. The KE and KW Reactors' FSBs were repurposed beginning in 1973 to temporarily store spent fuel from the N Reactor. This storage activity included plans for spent fuel removal and reprocessing in the 200 Area.

The Plutonium Uranium Extraction (PUREX) reprocessing plant in the 200 East Area was restarted in 1983 and began reprocessing the spent N Reactor fuel. The last shipment of N Reactor spent fuel was received and stored in the FSBs in 1989. However, when the decision was made in 1992 to stop spent fuel reprocessing at the Hanford Site, the PUREX plant was shut down, leaving approximately 2,100 metric tons (2,300 tons) of spent fuel stored in the KE and KW FSBs. The spent fuel was later consolidated in the KW FSB, where it remained until 2004, when it was transferred for storage in the 200 Area. Fuel rods and debris were removed from the K Basins by 2008, and the KE FSB and associated substructure and crib were removed in 2009.

The operation of the KE and KW FSBs from 1975 until 2007 resulted in additional long-lived fission product contamination of the vadose zone and groundwater beneath the FSBs. This was due to spent fuel contamination of the FSB water and leaks from the FSBs to the vadose zone (PNNL-14033, *Groundwater Monitoring and Assessment Plan for the 100-K Fuel Storage Basins*).

1.2.2.5 Reactor Mechanics and Layout

The KW and KE Reactors were graphite-moderated, "single-pass," water-cooled reactors used to produce weapons-grade plutonium. The reactors produced plutonium with the same operating materials and processes used at the other single-pass production reactors in the 100 Area, but were larger. The KW and KE Reactors' construction and layout were identical except for the 1706-KER Test Loop (i.e., cooling water test system) installed at the KE Reactor.

The KW and KE Reactors were installed in parallel, about 610 m (2,000 ft) apart, roughly 750 m (2,500 ft) from the Columbia River (Figure 1-5). At grade, each reactor building was 65 m (213 ft) long, 84 m (275 ft) wide, and 32.6 m (107 ft) high. The lowest floor in each building was 6.3 m (20.8 ft) below grade. Each reactor building had an associated 91 m (300 ft) tall ventilation stack. Each reactor building was designated as Building 105.

Reactor Pile. A steel box with a graphite moderator block in the center was surrounded by the thermal shield, which in turn was surrounded by biological shields. The KE and KW Reactor piles had 3,220 process tubes penetrating them from front to back. Each process tube was 13 m (44 ft) long and had a 4.3 cm (1.7 in.) outer diameter (HW-74095). The process tubes contained aluminum-clad uranium metal fuel elements containing uranium-235 that fissioned, releasing neutrons slowed by the graphite and absorbed by uranium-238 to transmute to plutonium-239 (the intended reactor product).

During the production of plutonium, fission neutrons captured by the reactor operating equipment and materials produced radioactive activation products. The fission products and activation products included radionuclides with very short to long half-lives (Table 1-1). The very short half-life radionuclides were a concern during operations because they were discharged to the river. Long half-life radionuclides became COPCs for Hanford restoration activities. During KE and KW Reactor operations (1955 to 1971), the short-lived radioisotopes (e.g., manganese-54, iodine-131, and zinc-65) represented more than 98% of the radioactivity in the reactor effluents (DOE/RL-97-1047, *The Hanford Site Historic District – Manhattan Project 1943-1946, Cold War Era 1947-1990*, Table 1). These very short half-life radionuclides have decayed since the operations period to concentrations below cleanup standards. Long-lived radioisotopes (e.g., cobalt-60, strontium-90, cesium-137, europium-152, carbon-14, and tritium) were those with a decay half-life greater than 3 years (DOE/RL-97-1047, Table 2) and are historically the radioactive contaminants for 100-K.

Table 1-1. Half-Lives of Selected Radionuclides Present at Hanford

Radionuclide	Half-Life
Short-Lived	
Manganese-54	312.5 days
Iodine-131	8.04 days
Zinc-65	243.9 days
Long-Lived	
Cobalt-60	5.27 years
Strontium-90	29.12 years
Cesium-137	30.0 years
Europium-152	13.33 years
Carbon-14	5,730 years
Tritium	12.6 years

Graphite Moderator. As the KE and KW Reactors' production rates increased after startup in 1955, the operating temperatures increased within the reactor piles. The cover gas used in the graphite moderators changed from carbon dioxide-helium to nitrogen-helium for improved protection of the graphite at the higher temperatures.

The inert cover gases were continuously recirculated over the graphite block and through a drying and filtration system (115-KE and 115-KW Buildings) that removed and disposed cooling water in-leakage to the deep below-grade 115-KE and 115-KW Condensate Cribs (116-KE-1 and 116-KW-1, respectively).

The 115-KE Crib received approximately 800,000 L (211,338 gal) of condensate and other waste from the reactor gas purification systems. At the KW Reactor area, the 115-KW Condensate Crib also received approximately 800,000 L (211,338 gal) of condensate and wastewater from the reactor gas purification systems. Both waste sites operated from 1955 to 1971. The radionuclide inventory for both cribs is documented in WHC-SD-EN-TI-239.

1706-KER Test Loop. The 1706-KER Building was a process improvement laboratory. The 1706-KER test loop supported cooling water process improvements and involved 12 of the 3,220 KE Reactor process tubes. Of these 12 tubes, 8 processed cooling water as "once through" process tubes, while the other four operated in a "closed loop" configuration where the effluent wastes were disposed to the 1706-KER waste disposal system (116-KE-2 Crib).

Pressure drops on any process tube (including the 1706-KER Test Loop tubes) prompted defilming purges using diatomaceous earth/water slurries that discharged through the reactor effluent pipelines to the retention basins and then diverted to the 116-K-2 Trench. Sharp increases in tube effluent radioactivity signaled a fuel cladding failure event, which prompted collection and diversion of the reactor cooling water to a retention basin and then diversion to the 116-K-2 Trench. Reactor pile instruments were used to monitor the pile reactivity. The pile reactivity was maintained within acceptable ranges using horizontal control rods (HCRs) and shims. In the event of an emergency shutdown condition, the reactor was "scrammed" by releasing the vertical control rods (VCRs). The cooling water from the HCRs and the VCRs drained to the radioactive process sewer.

Fuel Storage Basins (1955 to 2007). The FSB at each reactor was a belowground, reinforced-concrete, rectangular pool with dimensions of approximately 38.1×20.4 m (125×67 ft). The walls of the basin were 6.3 m (20.75 ft) high and up to 0.7 m (2.3 ft) thick. The basin floors were 0.6 m (2 ft) thick (nominal) reinforced concrete. Reinforcing steel connected the basin floor to the walls.

The FSB pool water retained radioactive particulate and soluble radionuclide materials released from damaged spent nuclear fuel (SNF). The FSBs contained water about 5 m (17 ft) deep to shield workers from stored spent fuel radiation. The water clarity in the FSB was maintained by removing settled solids with a centrifugal pump and discharging the waste to the radioactive process sewers (100-K-55 and 100-K-56). The water was also maintained by a feed-and-bleed water supply that continuously overflowed at the surface of the basin to the contaminated process sewer (HW-74095). The volume and frequency of contaminated waste water discharges to the process sewer were substantially reduced after operation of KE and KW Reactors was discontinued.

When plutonium concentrations in the fuel reached the desired product levels, the reactor was shut down and fresh fuel was used to push the spent fuel out of the reactor pile into the FSBs. The spent fuel was typically stored in the FSBs for 90 days to allow short-lived fission products to decay. The decayed spent fuel was then loaded into casks, transferred to water-filled railroad cars, and transported to the 200 Area for reprocessing.

The reactor process tubes also contained "spacers" and "dummy fuel elements" (dummies). These were used to ensure the fuel was within the moderated region of the reactor pile and to ensure uniform cooling water flow during operations. Used spacers and dummies were also stored in the FSBs to allow for activation product decay and were later transferred to casks for decontamination and reuse or for disposal as solid waste.

The KE and KW FSBs had a sub-basin leak collection system installed beneath the FSB concrete floors during construction, but the collection systems did not extend under the discharge chute area where fuel discharged from the reactors was collected in the FSBs. This sub-basin leak collection system was comprised of an asphaltic membrane with perforated collection pipes on top of the membrane and compacted gravel around the collection pipes that would collect any basin leakage from beneath the FSBs and direct that water to cribs (116-KE-3 or 116-KW-2). The cribs had reverse/injection wells that discharged any leaks below the unconfined aquifer (in the water table). For these cribs, the reverse/injection well was the means for disposing the sub-basin leaks, while the crib structure provided surge capacity. Based on reactor operating experience, most FSB leaks occurred at the concrete joint between the FSB and the reactor wall, an area not covered by the asphaltic membrane.

Beginning in 1975 and 1981, the KE and KW FSBs respectively, were used to store spent fuel from the N Reactor (WHC-SD-WM-SAR-062, *K Basins Safety Analysis Report*). The FSBs were modified in advance for storing N Reactor fuel by incorporating a filtration and ion exchange system to reduce the residual contamination in the basin water. This system recirculated the FSB water through filters and ion exchangers, and allowed water additions to replace water lost due to leaks and evaporation to the building ventilation system. The replacement water to the FSBs was processed through an ion exchange system to remove dissolved solids. An important aspect of the FSB modifications in advance of storing N Reactor spent nuclear fuel involved isolating the FSB process sewers from the reactor process sewers and effluent systems. The contaminated process sewer collection box was modified to drain to a new underground waste storage tank. The piping for the original basin leakage collection system that fed to the cribs with reverse/injection well systems was intercepted by a collection sump (D Sump), which was designed to pump any water collected in the sump to the FSBs. The D Sump design retained an overflow routing to the 116-KW-2 and 116-KE-3 Cribs via the original discharge pipe between the sump and the crib. Instrumentation was also installed to monitor FSB water levels, temperatures, and gamma radioactivity.

The spent fuel from N Reactor was initially received and stored at the KE FSB in mid-1975, and then at KW FSB starting in 1981. From 1983 to 1989, N Reactor spent fuel was shipped to the PUREX plant in the 200 East for reprocessing. The last shipment of spent fuel was received at 100-K in 1989, but the PUREX plant was shut down before all the spent fuel stored at 100-K was reprocessed.

There have been two documented periods of leakage from KE FSB. The first occurred during the early phase of converting the basin from its original purpose during reactor operations to that of storage of fuel from the N Reactor. The second period occurred approximately 13 years later (PNNL-14033).

KE FSB (1976 to 1979). Approximately 56.8 million L (15 million gal) of shielding water are estimated to have been lost to the underlying soil column during the period 1976 to 1979.

- Water loss during this period was monitored using drawdown tests in the basin, and the leakage rate was determined to be dependent on water temperature (i.e., higher leak rates were associated with cooler temperatures). Peak water loss rate was 1,819 L (480 gal) per hour, which occurred during 1977 to 1978.
- The refurbishing of KE FSB identified the construction joint between the storage basin and reactor building as the potential leakage site. The construction joint in the KW FSB was also refurbished.
- Sealing the construction joint in the KE FSB was completed in May 1980.

Radionuclide concentrations in the KE FSB were relatively low during leakage in the late 1970s before the basin was modified. The modification eliminated the once through cooling system used to cool the spent nuclear fuel and replaced it with a basin water recirculation cooling and treatment system in advance of storing N Reactor fuel. Approximately 2,500 Ci of radionuclides, exclusive of tritium, were estimated to have been released prior to refurbishment of the construction joint in the discharge chute.

KE, KW FSB (1993). Leakage from KE FSB was identified in February 1993, when water balance calculations showed an increased loss rate that could not be caused by evaporation alone. Leakage was suspected from January through August 1993, with an average water loss rate estimated at 95 L (25 gal) per hour. The construction joint in the pickup chute structure was the suspected leak location. Measures to seal it were undertaken by installing isolation barrier doors to separate the FSB from the reactor, and later filling the discharge chute with grout. By March 1995, the loading chute structure was physically isolated from the main storage basin.

Contamination from this period of leakage was recorded as it passed by downgradient groundwater monitoring wells. Vadose zone contamination was apparently remobilized in the late 1990s by above-normal surface water infiltration caused by fire hydrant utility line breaks.

All spent fuel was removed from the basins in 2004. Contaminated sludge removal has been completed in the KE FSB, basin demolition is complete, and the underlying vadose zone was interim remediated. Consolidation of the KE and KW Basins sludge into the KW Basin has been accomplished. The result is about 23 m^3 (30 yd^3) of sludge temporarily stored in six engineered containers in the KW Basin. About 5 m^3 (6.5 yd^3) of sludge in the settler tubes was removed in April 2010 and is stored in one of the engineered containers. The sludge generated from fuel packaging operations in the KW Basin resides in particulate capturing equipment, including strainers, knockout pots, and settler tubes that are part of the KW Integrated Water Treatment System (IWTS). Sludge currently stored in the KW Basin is planned for removal and subsequent treatment in the 200 Area prior to disposal. TPA Milestones associated with the KW FSB sludge removal and basin removal include the following:

- M-016-175: Begin Sludge Removal from 105-KW Fuel Storage Basin, due date is September 30, 2018
- M-016-176: Complete sludge Removal from 105-KW Fuel Storage Basin, due date is December 31, 2019
- M-016-178: Initiate deactivation of 105-KW-Fuel Storage Basin, due date is December 31, 2019
- M-016-181: Complete deactivation, demolition, and removal of 105-KW Fuel Storage Basin, due date is September 30, 2023
- M-016-186: Initiate soil remediation under 105-KW Fuel Storage Basin, due date is December 31, 2023

Process Sewers. Each reactor had two sewers—a "chemical sewer" that collected liquid wastes from nonradioactive facilities and a "contaminated sewer" that collected potentially radioactive liquid wastes.

Chemical sewer lines drained to a sump, discharged to the 1908-K Outfall and, finally, went to the Columbia River pipelines. These sewers received the discharge from process equipment drains from the water treatment plant, including sedimentation basin sludge and filter backwashes. These sewers also received wastes from ancillary facility floor drains (e.g., 183-KE and 183-KW operating galleries, 100-K-79 pipe tunnel, and 190-KE and 190-KW Pump Houses).

The volume and disposition of chemical wastes generated after 1975 is unknown. The 183-KE water treatment plant continued to operate and discharge to the river until Fall 2011. A new water treatment plant was installed to maintain water levels in the FSB and provide project water needs during waste site remediation and facility deactivation, decontamination, decommissioning, and demolition (D4) activities.

Additional discharge sources to the chemical sewer included the 150-K Heat Recovery System heat exchangers (operated with ethylene glycol), the 166-K Control Buildings (diesel fuel oil tanks for generators and steam boilers), the 1607-K Septic Systems, the 1706-KEL laboratory drains, and the 100-K support buildings (e.g., administrative offices and maintenance garage).

Contaminated sewer lines drained to a collection sump (100-K-71 or 100-K-75), normally discharged to the 1908-KE radiation monitoring station, then discharged to the 1908-K Outfall and, finally, to the Columbia River pipelines. The radiation monitoring station detected radioactivity levels that required diversion of sewer flow to the 116-K-2 Trench. Decontamination solutions, which generally contained both radionuclide and chemical contaminants, were occasionally combined with reactor cooling water and discharged to the contaminated sewer. The contaminated sewer sump received liquid wastes from the FSBs overflow, the FSBs floor cleaning pump discharge, the Railroad Cask loading area floor drain, the

117-KE and 117-KW Exhaust Air Filtration Buildings water seal overflow, and the reactor building floor drains.

From 1973 to 1975, the contaminated sewer was isolated from the reactor effluent disposal systems, and 76,000 L (20,000 gal) underground waste storage tanks (100-K-70 and 100-K-74) were installed to receive and store any remaining radioactive process sewer wastes. The contaminated sewer collection Sump C piping at each reactor was modified to discharge to the waste storage tank or recycled back into the FSBs as described previously.

KE and KW Buildings Ventilation. Prior to 1960, reactor ventilation air was released directly to the atmosphere through the 116-KE Stack. In 1960, air filtering systems were added to minimize the release of radionuclides, and all building exhaust passed through particulate and activated charcoal filters before discharge to the atmosphere via a 91 m (300 ft) tall concrete stack. The 117-KE Building housed the KE Building exhaust air filters and airflow control system. The KE Reactor was connected to the 115-KE Building via a gas-piping tunnel and to the 117-KE Building by way of a ventilation duct. The tunnel and ducts are each about 60 m (200 ft) long. A similar system was used for the KW Reactor ventilation system.

There were also ventilation systems associated with each of the reactors that circulated fresh air from the staffed areas into zones of increasing contamination levels, and upward past the reactors to overhead ducts and exhaust stacks. Ventilation air became contaminated with radionuclides that were present as radioactive gases, entrained vapors, and particulates generated by the cascade of cooling water in the reactors.

These emissions may have resulted in surface contamination, as indicated in part by the presence of carbon-14 in vegetation (WHC-SD-EN-TI-239). Other radionuclides included tritium and iodine-129. Two types of filter banks were used: a high-efficiency particulate bank and a halogen (activated charcoal) bank. These filtering systems were placed underground in the 117-KE and 117-KW Buildings just east of the reactor buildings.

Sections of the 115-KE/KW and 117-KE/KW Buildings and associated tunnels were contaminated, primarily with cobalt-60, cesium-137, carbon-14, and tritium, and to a lesser extent with strontium-90, cesium-134, europium-152, europium-154, and europium-155.

The seal water for the 117-KE and 117-KW Buildings drained to the contaminated sewer. Figure 1-8 provides a pictorial representation of the airflow through the structures and systems.

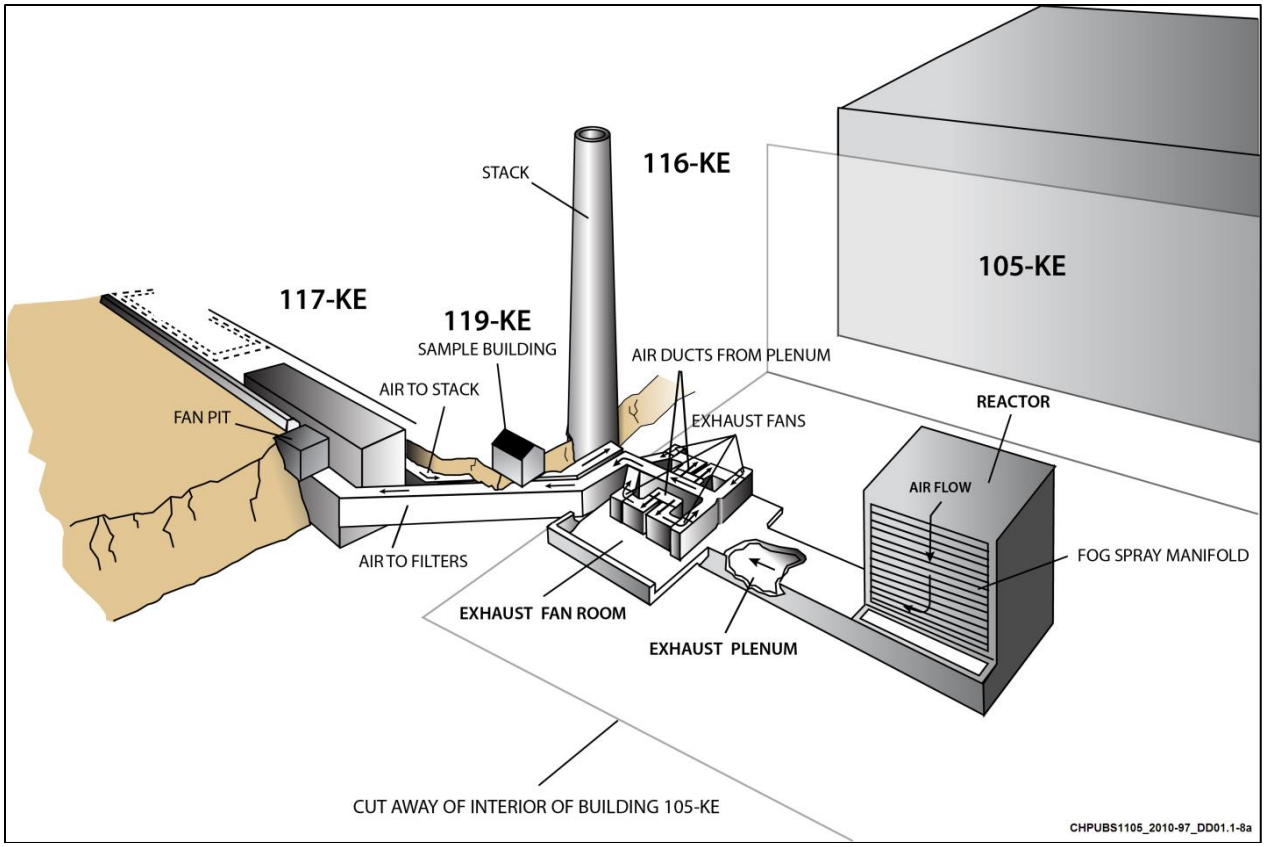


Figure 1-8. Diagram of the KE Reactor Exhaust System

1.2.2.6 Cooling Water

The KE and KW Reactors were cooled using water from the Columbia River. Reactor operations required a continuous supply of high-quality cooling water to prevent reactor core damage from heat generated by fission reactions. The KE and KW Reactors initially required about 570,000 L/min (150,000 gal/min) of cooling water each (1955 to 1956). As plutonium production increased, the power levels and cooling water requirements were proportionately greater. Facility and pump upgrades increased cooling water flow to about 760,000 L/min (200,000 gal/min) at each reactor by 1971.

Water Treatment and System Infrastructure. Figure 1-9 illustrates the cooling water treatment process for 100-K. The cooling water supply was provided from the Columbia River via river pump houses (181-KW and 181-KE), a water treatment plant (flocculation, sedimentation, and filtration) (183-KW and 183-KE) with sodium dichromate injection pumps (aluminum corrosion inhibitor), and a main pump house (190-KW and 190-KE). Figure 1-10 is a schematic depiction of facilities that stored and transferred liquid sodium dichromate solution. Except for sodium dichromate, the water treatment chemical additives and wastes were primarily flocculating agents to improve the sedimentation of suspended river water solids and surfactants to improve filtration. Alum, an aluminum sulfate solution, and sodium hydroxide were added to the raw water feed to enhance the settling of suspended solids and the performance of the filtration system in removing the remaining solids. Sulfuric acid was also added to the raw water feed for pH adjustment. The sulfuric acid also contained other metals (e.g. mercury, lead, and zinc). These additives and the filter backwash materials were periodically flushed with the sedimentation solids to the process sewer that discharged to the river.

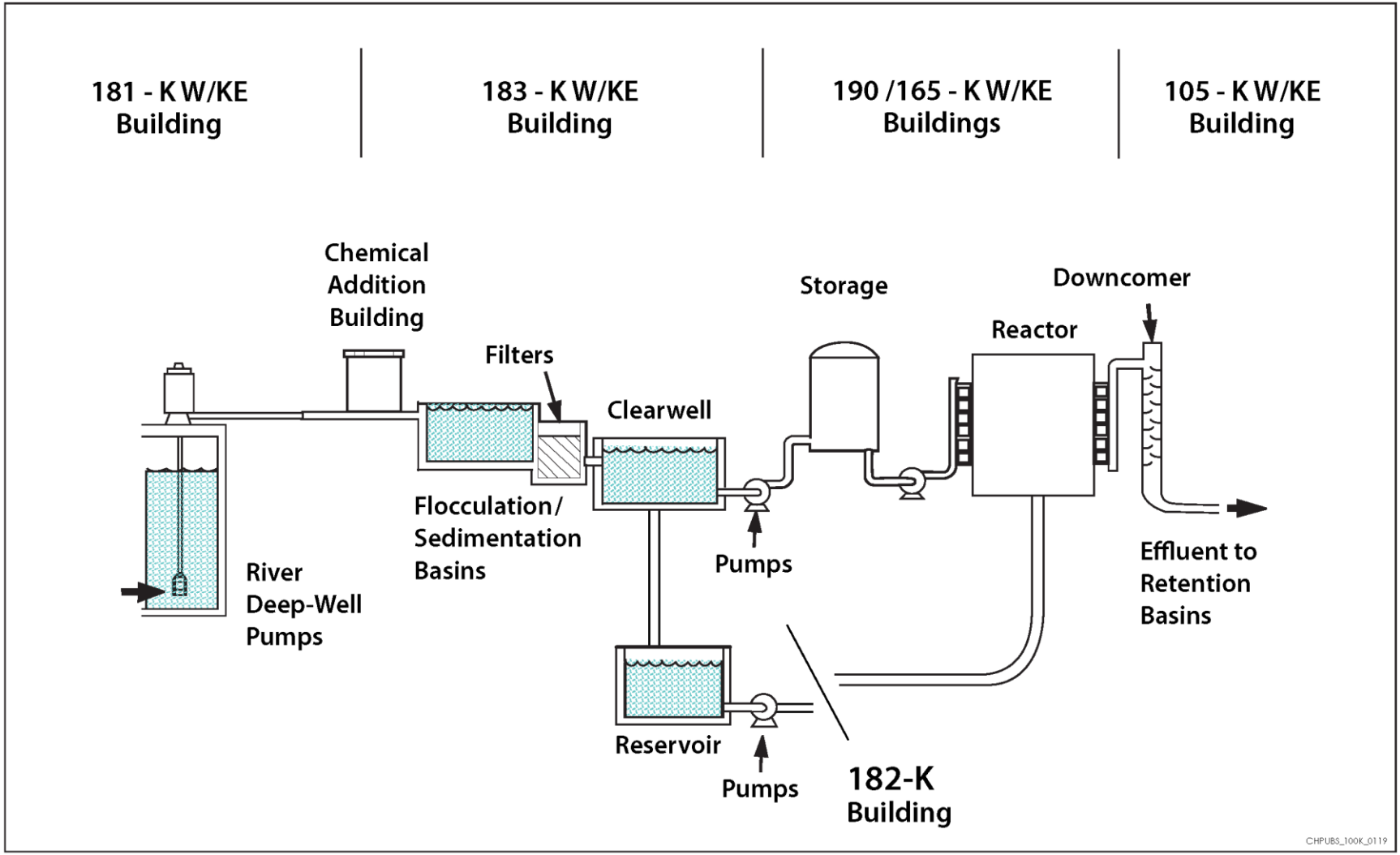


Figure 1-9. Illustration of the Cooling Water Treatment Process

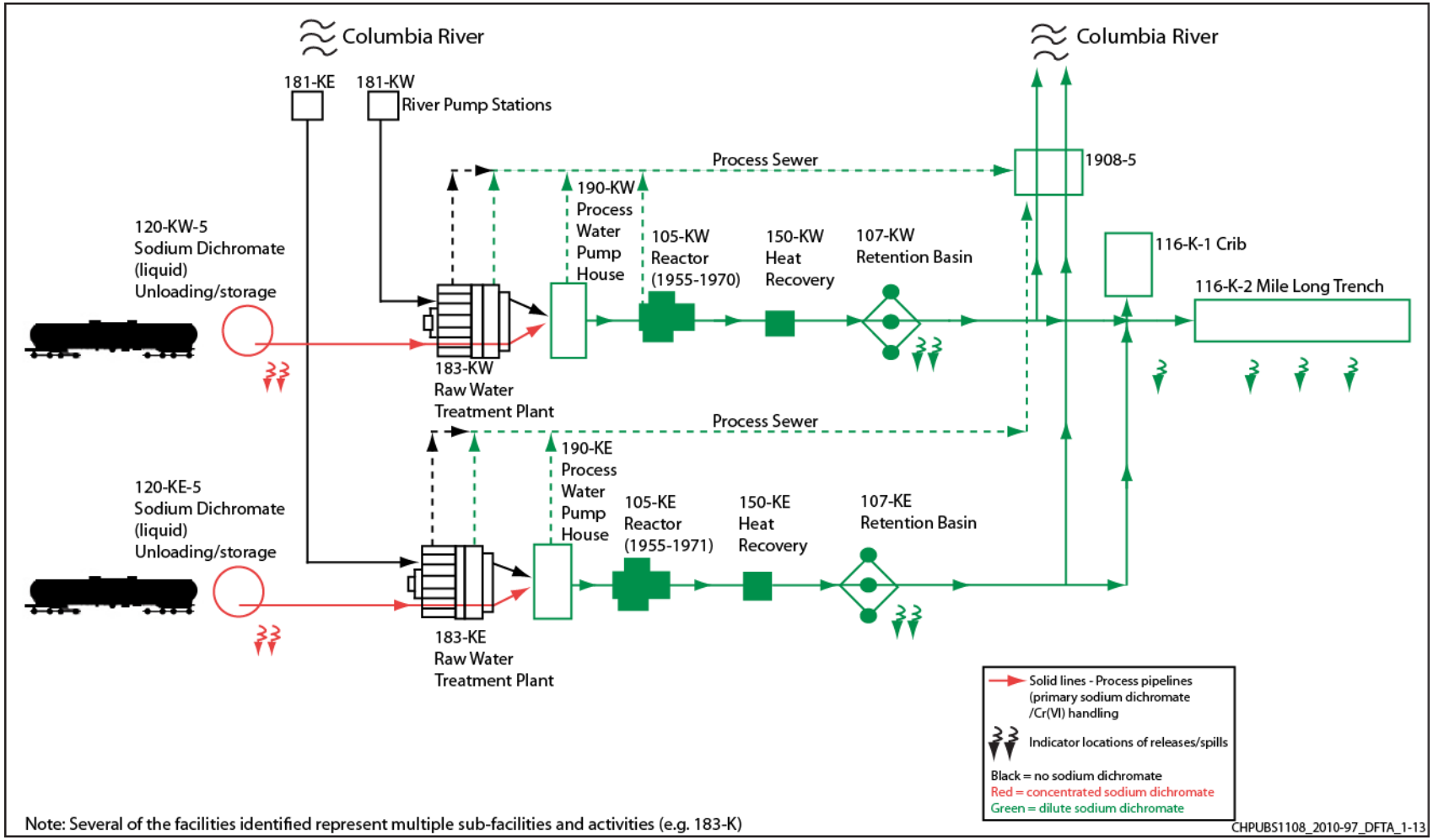


Figure 1-10. Schematic Flow Diagram of 100-K Reactor Cooling Water

Sodium dichromate solution, a source of Cr(VI), was added to the reactor coolant water to inhibit aluminum corrosion. More than 6 million kg (14 million lb) of sodium dichromate were used in the cooling water between 1955 and 1971 for the KE and KW Reactors. The cooling water volumes at 100-K were greater than the other 100 Area reactors and required a larger amount of sodium dichromate during operations. A concentrated sodium dichromate solution (about 70% by weight) was delivered to the site by railcar. The solution was then transferred to two 158,987 L (42,000 gal) tanks (120-KW-5 and 120-KE-6) located adjacent to the 183.2-KW and 183.2-KE Flocculation and Sedimentation Basins and 183.3-KW and 183.3-KE Sand Filter Basins, which treated and stored Columbia River water. The concentrated sodium dichromate solution had a pH of 1.5 to 2, a specific gravity of about 1.7 g/cm^3, and Cr(VI) concentrations of about 466 g/L (PNNL-17674, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*). Figure 1-11 presents the facilities and waste sites where high (70% solution) and low (less than 2 ppm) concentration Cr(VI) was used or disposed.

The concentrated sodium dichromate solution was transferred from the storage tanks to metering pumps in the basement of the 183.1-KW and 183.1-KE Head Houses. The solution was then transferred via feed lines in the 183.7-KW and 183.7-KE Pipe Tunnels to the 190-KW and 190-KE process water pump houses. Concentrated sodium dichromate solution was then mixed into reactor cooling water to generate a sodium dichromate concentration of 2 mg/L (700 µg/L of Cr(VI)) (Figure 1-10). By 1964, sodium dichromate concentrations were decreased to about 1 mg/L (350 µg/L of Cr(VI)), and then decreased further in 1968 to 0.5 mg/L (175 µg/L of Cr(VI)) (DUN-6205, *Chemicals Discharged to the Columbia River from DUN Facilities Fiscal Year 1969*). During sodium dichromate solution transfer from the railcars to the storage tanks, some sluicing of fluids into a nearby French drain occurred, as did unintentional spills.

Reactor Cooling Water Effluent Disposal. After passing through the reactors, the cooling water discharged via underground pipelines to the 107-KW and 107-KE retention basins. Storage in the retention basins allowed thermal cooling and decay of short-lived radionuclides prior to discharge to the river. From the retention basins, the water was transferred through pipes to the 116-K-3 (1904-K) Outfall and then into 84 in. pipes that discharged at the bottom center of the Columbia River. Overflow from the outfall structures could also discharge directly to the river shore through a concrete-lined spillway and earthen ditch.

Of the three retention basins for each reactor, one was empty for use during fuel cladding failure events. Fuel cladding failures occurred when corrosion or swelling of the aluminum cladding covering a uranium fuel slug caused it to break open, releasing uranium and an array of fission products into the reactor core cooling water. During a fuel failure event, the cooling water was diverted through the empty basin and then to the 116-K-2 Trench, rather than being discharged to the Columbia River.

The 116-K-1 Crib was designed to receive the diverted cooling water or chemical sewer effluent. The 116-K-1 Crib had a horizontal inlet distributor pipe about 6 m (20 ft) belowgrade that was installed over rock/gravel fill to enhance the percolation of liquid wastes into the vadose zone (Figure 1-7). The 116-K-1 Crib had a unique large, open, abovegrade impoundment with soil banks to operate as a process trench during high-volume waste disposals in the event of fuel failures. It flooded and overflowed in 1955, likely during initial tests with diversion flows. The 116-K-2 Trench replaced the 116-K-1 Crib in 1955, before the first 100-K fuel failure (PNWD-2161 HEDR, *Fuel-Element Failures in Hanford Single-Pass Reactors 1944-1971*).

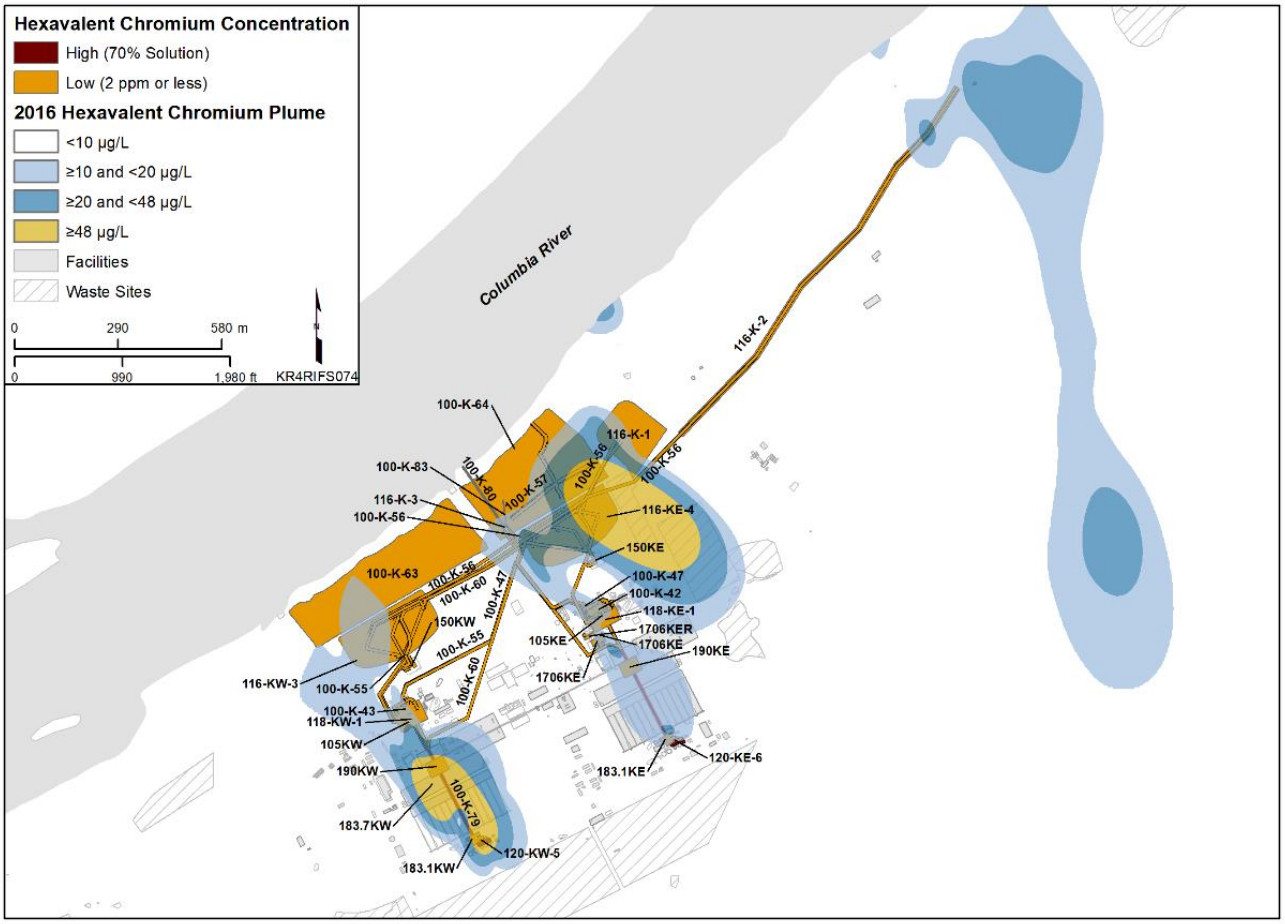


Figure 1-11. Facilities and Waste Sites Where Sodium Dichromate was Handled at 100-K

The 116-K-2 Trench (also known as the "Mile Long Trench") was 5.3 m (17.5 ft) deep, 1,250 m (4,100 ft) long, 17.2 m (56.5 ft) wide at the top, and 1.2 m (4 ft) wide at the bottom. The trench was used during reactor operations from 1955 until 1971 to percolate liquid wastes into the vadose zone from the reactor subsystems. The 116-K-2 Trench received reactor cooling water diverted during fuel failure events.

At times, the 116-K-2 Trench overflowed or lost water to the surface through its sides and, occasionally, into the 116-K-1 Crib area. Aerial photos after 1965 show the 116-K-1 Crib and the 116-K-2 Trench containing water. By 1967, leaks were also observed in the open area between the diversion valves near the 107-KW and 107-KE Retention Basins and the river shore. Leaks also occurred as the retention basins' piping systems degraded, causing effluent releases to the floodplain directly north of the retention basins and contaminating the surface at the 100-K-63 and 100-K-64 waste sites.

1.2.2.7 Other Waste Streams

Cooling water was the largest volume primary waste stream at 100-K. Other radioactive waste streams (solid radioactive and nonradioactive wastes) also contributed to vadose zone and groundwater contamination in 100-K. Figures 1-12 through 1-14 present the facilities and waste sites where key contaminants carbon-14, strontium-90, and tritium were used or disposed. Groundwater plumes are also shown on figures for reference.

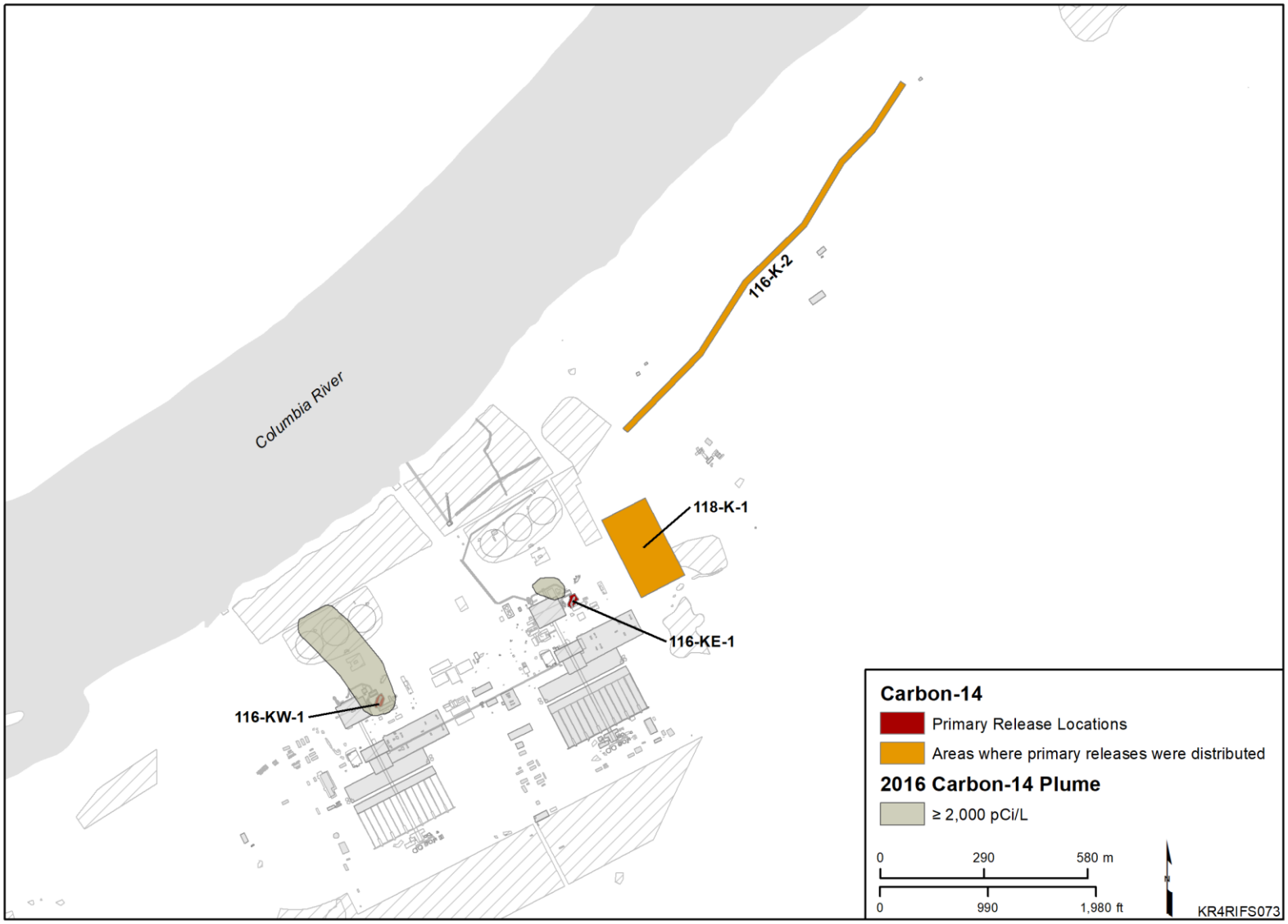


Figure 1-12. Facilities and Waste Sites Known to Have Carbon-14 Present

Figure 1-13. Facilities and Waste Sites Known to Have Strontium-90 Present

Figure 1-14. Facilities and Waste Sites Known to Have Tritium Present

1.2.2.8 Radioactivity Sources

Radioactivity entered the cooling water at several stages of the production process. The reactors contributed the most radioactivity to the cooling water through the fuel elements and discharge of cooling water to various storage facilities.

Fuel Elements and Failures. An operating system was devised to prevent both the bulk effluent and the water from an affected process tube from discharge directly to the river during fuel failures. The diversion system involved discharging the liquid to subsurface soil via trenches and cribs (e.g., 116-K-2 Trench and 116-K-1 Crib). Each retention basin was constructed with three compartments that were filled sequentially. This allowed cooling water to be diverted and segregated in an empty compartment if elevated contamination levels were indicated by the monitoring equipment. From February 1955 to May 1956, the segregated cooling water was then transferred to the 116-K-1 Crib for disposal. The 116-K-1 Crib was abandoned in 1956, and replaced by the 116-K-2 Trench through the end of plutonium production operations in 1971. Increased flows from upgraded operating conditions and structural temperature stresses resulting from discharging hot cooling water caused leaks in the basins and piping. These leaks and overflows from the basins resulted in discharges to the ground surface.

During reactor operations, fuel-cladding failures sometimes occurred while the fuel elements were in the process tubes. The first such failures at KE and KW Reactors occurred in 1956. Fuel failures for both the KE and KW Reactors are documented in PNWD-2161 HEDR. When fuel cladding failed, the cooling water in the affected process tube became radioactively contaminated with longer-lived radionuclides. Elevated radiation levels were observed in the cooling water exiting the reactor core, which was then diverted to the 116-K-2 Trench. During production, fuel element failures and infrastructure failures (e.g., pipe leaks) led to losses of contaminated materials to the environment.

1.2.2.9 Radioactive Waste Streams

Wastes resulting from supporting production operations were similarly disposed in each area according to phase (liquids or solids), quantity (high/low mass or volume), radioactivity (high level or low level), and composition (e.g., chemical or septic). Thus, liquid and solid waste disposal locations were constructed, and waste management practices were developed to handle these materials.

Radioactive Sludge and Solid Wastes. Several thousand metric tons (millions of pounds) of both radioactive and nonradioactive sludge accumulated at 100-K. The radioactive sludge was generated during reactor operations in the pipes and the cooling water effluent system, in the 116-KE-4 and 116-KW-3 Retention Basins, and in the reactor FSBs. Smaller volumes of sludge also collected in water traps located in the 115-KE and 115-KW Gas Recirculation Facility and in the 117-KE and 117-KW Exhaust Air Filter Buildings. The sludge included diatomaceous earth, which was used periodically to scour internal surfaces of the reactor process tubes, and fine particulate matter, which originated from pipe slag, rust, failed fuel elements, graphite powder, dissolved and suspended solids in river water, and other undefined solids. The sludge was contaminated with radionuclides and various chemical contaminants (WHC-SD-EN-TI-239). After termination of reactor operations in 100-K, a number of irradiated uranium fuel elements were found in the basins during removal of FSB sludge in 1975. These fuel elements were not processed through the PUREX Plant during the final separation runs that occurred from 1983 to 1988 and in 1992.

Radioactive solid wastes generally consisted of reactor components, contaminated equipment, tools, and miscellaneous contaminated items (paper, rags, and structural concrete). The source of these wastes was reactor operations, and the most highly contaminated solid wastes were the reactor components. These included aluminum spacers, lead cadmium reactor neutron-poison pieces, boron splines, graphite, control rods, nozzles, Zircaloy 2 tubing, Grifflon material, and cadmium sheets (WHC-SD-EN-TI-239).

Other radioactive solid waste included air filters used in the 115-K Gas Recirculation Buildings and the 117-K Exhaust Air Filter Buildings, equipment used in connection with the cooling water effluent system, sludge from the retention basins, and contaminated dirt removed from near the effluent lines. Most of the radioactive solid wastes generated in 100-K were buried in the 118-K-1 Burial Ground. Figure 1-15 shows a track-mounted probe surveying radioactive materials.

Figure 1-15. Track-Mounted Probe Identifying Radioactive Materials at the 118-K-1 Burial Ground

Decontamination Solutions. During reactor operations and reactor shutdowns, large quantities of decontamination solutions were routinely used to remove radionuclides from reactor equipment and facility surfaces. Decontamination solutions at 100-K included chromic, citric, oxalic, nitric, and sulfamic acids, fluoride, and organic chemicals. The majority of these solutions were disposed in the 116-K-2 Trench.

The solutions contained both radionuclide and chemical contaminants. Some of the compounds used in the decontamination solutions, such as oxalate and organic complexants, may have dissolved and transported radionuclides and metals. The quantities of decontamination solutions, as well as other disposal locations, are not precisely known (WHC-SD-EN-TI-239). These solutions were generally disposed in cribs, trenches, and French drains near the buildings where they were used.

1.2.2.10 Nonradioactive Waste Streams

Nonradioactive wastes generated at 100-K had the potential to contribute to vadose zone and groundwater contamination, and included septic system wastes, a variety of other liquid wastes, and solid wastes.

Sanitary Liquid Wastes. Sanitary wastes were produced in the various buildings equipped with sanitary facilities. These wastes were routed by sewer lines to six known septic systems in 100-K.

Nonsanitary wastes, such as detergents, cleaning compounds, and solvents, likely entered some of these sewer systems. There are no records of radiological wastes being disposed to these systems, but leaks in the sewer lines transferring these materials may have occurred and may have contributed to discharges of contaminants to the vadose zone, particularly petroleum hydrocarbons and trichloroethene (TCE). All six sanitary systems (1607-K1, 1607-K2, 1607-K3, 1607-K4, 1607-K5, and 1607-K6) were located in the 100-KR-2 OU and consisted of reinforced concrete septic tanks with associated drain fields. The 1607-K2, 1607-K3, and 1607-K4 waste sites were interim closed prior to April 2017.

Nonradioactive Liquid Wastes. Nonsanitary, nonradioactive liquid chemicals that were used at 100-K potentially contributed to contamination. These included hazardous wastes and hazardous substances. Contamination from liquids, including gasoline, diesel fuel, solvents, and other chemical compounds, would be expected near aboveground or underground storage tanks and their piping systems and in areas where these materials were used or stored. Releases could have resulted from leaks, spills, or disposal. The following items may have resulted in the generation of nonradioactive liquid wastes (WHC-SD-EN-TI-239):

- Water treatment chemicals (such as alum, sulfuric acid, chlorine, sodium hydroxide and sodium dichromate) used and stored near the 183-KE and 183-KW Buildings. Section 1.2.2.6 provides additional discussion of cooling water treatment and the use of sodium dichromate.
- Wet-type electrical transformers and hydraulic machinery containing oil contaminated with polychlorinated biphenyls (PCBs).
- Boiler water treatment chemicals for the 165-KE and 165-KW Power Houses, including sodium sulfate, trisodium phosphate, and chromates. These chemicals ended up in boiler sludge. The volume of boiler sludge generated and the disposal methods are not known.
- Zeolite water softener regeneration solutions containing salt from the 165-KE and 165-KW Powerhouses and 183-KE and 183-K Buildings. Sodium chloride solutions were used to regenerate the zeolite ion exchange (IX) beds in the water softener tanks. Disposal methods are unknown, but process knowledge suggests that these wastes (zeolite water and sodium chloride) were discharged to the process sewer.
- Diesel fuel stored in underground tanks at the 166-KE/KW Fuel Bunkers adjacent to the 165-KE/KW Power Stations, north of the 182-KE/KW Building (130 K-3A and 130-K-3B), east of the KE Reactor (130-KE-1A and 130-KE-1B), and east of the KW Reactor (130-KW-1A and 130-KW-1B).
- Gasoline stored in an underground tank northwest of the 1717-K Building (130-K-1).
- Waste oil stored in an underground tank northwest of the 1717-K Building (130-K-2).
- Oil stored in underground tanks south of the 166-KE and 166-KW Buildings (130-KE-2 and 130-KW-2).
- Demineralizer regeneration, research, and development wastes from the 1706-KER Building that were routinely disposed in the 116-KE-2 Crib.
- Diesel and batteries for the Ball 3X systems. The diesel storage tank was located on the east side of the reactor buildings.

- Oils, paints, and solvents used and stored in the 1706-KE, 1717-K, 190-KE, 190-KW, 1713-KE, and 1713-KW Buildings.
- Herbicides used throughout 100-K. In the 1970s, there were ground and aerial applications of herbicides and ground sterilant.

Nonradioactive solid waste. Nonradioactive solid waste included miscellaneous materials such as paper, trash, pieces of metal, and plastic parts. The 128-K-1 Burn Pit is a site where combustible wastes were burned and their residue (e.g., ash and incompletely combusted materials) disposed. Other solid wastes consisted of uncontaminated concrete, metal parts, and other materials generated during decommissioning and demolition (D&D) activities.

Sludge was disposed from water treatment facilities, including sulfuric acid sludge from the periodic draining of the concentrated sulfuric acid storage tanks to the nearby neutralization pit (100-K-34). The sulfuric acid sludge was also disposed in French drains and percolation trenches adjacent to the 183-KE and 183-KW Buildings. In 1971, about 5,443 kg (12,000 lb) of sulfuric acid sludge was removed from percolation trenches. Analysis indicated that about 14% of the sludge weight was mercury, an impurity in the sulfuric acid purchased at the time (WHC-SD-EN-TI-239).

1.2.3 Previous and Ongoing Investigations and Remediation

This subsection includes summaries of 100-K investigation and remediation activities for facilities, waste sites, and groundwater. During reactor operations, waste disposal locations were constructed and operated as needed. Eventually, these locations were each assigned an identification number. As technology evolved, computer databases were developed to store and track waste site information. Waste Information Data System (WIDS) is the database of waste site information for the Hanford Site. It assigns standardized identification numbers (site codes) and tracks the status of each waste site.

Since the beginning of reactor operations, investigations were conducted to determine effects to the environment, including the Columbia River. With the issuance of the TPA in 1989 (Ecology et al., 1989a), investigation activities transitioned to CERCLA cleanup activities.

Data and conclusions from investigations and remediation activities (see Appendix B) provide supporting information analyzed and evaluated in this RI and FS. The following are examples of the various data sets used:

- Vadose zone contaminants
- Groundwater contaminants
- Geologic contact information, fate and transport parameters (e.g., distribution coefficient [K_d], dispersivity, hydraulic conductivity, and soil bulk density)
- Well and borehole information (e.g., drill depth, screen length, and screen depth)
- Groundwater elevations and river stage
- Geographic information system shape files (e.g., aerial photography, Columbia River, and locations of wells and boreholes, salmon redds, facilities, roads, and waste sites)

Table 1-2 presents summaries of some 100-K investigation and decision documents. Appendix B presents an annotated bibliography of CERCLA documentation for 100-K and the River Corridor.

Table 1-2. Summary of Selected Previous Investigations and Remedial Action Decisions

Document Title	Document Number; Date	Summary of Observations and Conclusions
Radiological Characterization of the Retired 100 Areas	UNI-946; 1978	Radiological characterization of select waste sites was conducted in the mid-1970s to establish radionuclide inventories and contaminant distributions. Radiological contaminants were generally detected to the maximum extent of the investigations at 11.6 m (38 ft) bgs. Data from this report were also used to prepare the LFI Reports for the 100-KR-1 and 100-BC-2 OUs. Radiological inventory estimates are presented in the report.
Remedial Investigation/ Feasibility Study Work Plan for the 100-KR-1 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-90-20; 1992	The RI work plan proposed investigations into known and suspected areas of contamination identified as high priority sites that warranted interim remedial measures. The RI included characterization of the vadose zone, geology, and hydrogeology, with a focus on four of the six high-priority sites. The investigation included four boreholes, four test pits, field screening, geophysical surveys, and sample analyses. An LFI report (DOE/RL-93-78) presented investigation results. The geologic investigation compiled existing data and collected data during borehole installation, and the vadose zone investigation characterized the horizontal and vertical extent of contamination.
Remedial Investigation/ Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-90-21; 1992	The RI work plan proposed investigations into the site vadose zone, geology, and hydrogeology. Surface water and sediments, air, and ecological investigations were conducted under a separate 100 Area assessment. The investigation strategy focused on collecting data for decisions leading to interim remedial measures. Seven locations were identified for well installation, with well locations prioritized to define groundwater quality at exposure points and downgradient of potential sources, and fill data gaps needed for a ROD. Surface water and sediment sampling was identified for exposed seep areas.
Limited Field Investigation Report for the 100-KR-1 Operable Unit	DOE/RL-93-78; 1994	This LFI assessed the applicability of IRMs for reducing human and environmental risk within the 100-KR-1 OU. COPCs were identified and samples were collected and analyzed to support the assessment. Radionuclides were identified as contaminants of concern because their activities exceeded potential applicable relevant and appropriate requirements. The QRA concluded that the human health risk was high to medium for the high priority waste sites, and identified cobalt-60, cesium-137, europium-152, and europium-154 as the main contributors to overall human health risks via the direct exposure pathway. Based on the risk, the six sites were recommended IRM candidates.
Limited Field Investigation Report for the 100-KR-4 Operable Unit	DOE/RL-93-79; 1994	This LFI presented results from soil sampling during installation of seven monitoring wells, geophysical logging, and four rounds of groundwater sampling and analysis. The human health QRA indicated low- to medium-risk from carcinogens and hazard quotients >1 for a frequent-use scenario. For the ecological QRA, carbon-14 was the only radionuclide with a calculated exposure >1 rad/day, and chromium, iron, lead, silver, and zinc concentrations exceeded either acute or chromic LOEL. The LFI recommended continuation along the IRM pathway based on ecosystem risk.

Table 1-2. Summary of Selected Previous Investigations and Remedial Action Decisions

Document Title	Document Number; Date	Summary of Observations and Conclusions
Approach and Plan for Cleanup Actions in the 100-KR-2 Operable Unit of the Hanford Site	DOE/RL-94-151; 1995	This focus package proposed a new administrative approach to reach a cleanup decision for solid and liquid waste sites in the 100-KR-2 OU. The proposed approach presented the work plan in the focus package, and combined the LFI and QRA into the focused feasibility study.
100-KR-1 Operable Unit Focused Feasibility Study Report	DOE/RL-94-66; 1994	This FFS identified remedial actions for high priority waste sites investigated through the LFI (116-K-1, 116-K-2, 116-KW-3, 116-KE-4) and pipelines. A comparative analysis of remedial alternatives was also presented.
Proposed Plan for Interim Remedial Measure at the 100-KR-4 Operable Unit	DOE/RL-94-113; 1995	This proposed plan presented a summary of the alternatives evaluation and recommended P&T for chromium contamination as the preferred alternative for the 100-KR-4 OU. The preferred alternative was selected to minimize effects to ecological receptors.
Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington	EPA/ROD/R10-95/126; 1995	This document, also referred to as the Liquid Effluent Waste Sites ROD, identifies selected remedial actions that addressed 37 high-priority waste sites that received liquid radioactive effluent discharges in the 100-BC-1, 100-DR-1, and 100-HR-1 OUs, as well as adjacent contaminated sites within the area required for remediation. The major components of the selected remedy included removing contaminated soil, structures, and debris using the observational approach; treatment by soil washing and/or as needed to meet waste disposal criteria; and disposal of contaminated materials at ERDF and backfill of excavated areas followed by revegetation. A subsequent 1997 amendment to this ROD (EPA/AMD/R10-97/044, *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*) expanded the scope of the remedy to include 12 sites in the 100-KR-1 and 100-KR-2 OUs. This ROD amendment also eliminated soil washing as a treatment option based on pilot-scale treatability studies.
Treatability Test Report for Calcium Polysulfide in the 100-K Area	DOE/RL-2006-17; 2006	This report presented results from the 2005 calcium polysulfide treatability test, conducted following the procedures in DOE/RL-2005-05, *Treatability Test Plan for Fixation of Chromium in the Groundwater at 100-K*. The test evaluated the practicality and cost-effectiveness for using calcium polysulfide to remediate chromium in groundwater. The test also included aquifer parameters characterization.
Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington	EPA/ROD/R10-96/134: 1996	The interim action ROD specified installing a P&T system in the 100-KR-4 OU to intercept portions of the Cr(VI) plumes that affect the Columbia River. The KR4 P&T system began operating in 1997 with seven extraction wells, four injection wells, and an ion exchange resin treatment train. The KW P&T system began operating near and downgradient of the KW Reactor in 2007 using four extraction and two injection wells. The KX P&T system began operating in 2008 to treat the K north plume, located between the 116-K-2 Trench and 100-N Area. KX included 21 extraction wells and 10 injection wells.

Table 1-2. Summary of Selected Previous Investigations and Remedial Action Decisions

Document Title	Document Number; Date	Summary of Observations and Conclusions
Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)	EPA/ROD/R10-99/039; 1999	This ROD, also referred to as the 100 Area Remaining Sites ROD, presents the selected interim remedial actions for portions of the DOE Hanford 100 Area. This ROD included three types of sites: those with contaminated media and sufficient information to indicate that remediation was needed to protect human health and the environment; those with potentially contaminated media but insufficient information to determine if remediation was warranted; and sites with hazardous and radioactively contaminated equipment and debris from various 100 Area reactor buildings. The selected remedy included removing contaminated media, treatment as required to meet waste acceptance criteria, and disposal at ERDF. For those sites where sufficient information was not available to establish a need for remediation, a candidate site process was established whereby the sites would be evaluated and could then be "plugged-in" to the selected remedy. This ROD also established that any sites discovered in the future could be similarly "plugged in." The ESDs for this ROD (EPA et al., 2004, Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision; EPA et al., 2009a, Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision: Hanford Site Benton County, Washington) identified additional waste sites addressed under the selected remedy.
Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, WA	EPA/ROD/R10-00/121; 2000	This document, also referred to as the 100 Area Burial Grounds ROD, presents the selected interim remedial actions for the 100 Area Burial Grounds. The selected remedy included removing contaminated media, treatment as required to meet waste acceptance criteria, and disposal at ERDF, followed by backfill and revegetation of excavated areas.

Table 1-2. Summary of Selected Previous Investigations and Remedial Action Decisions

Document Title	Document Number; Date	Summary of Observations and Conclusions
Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site	PNNL-17674; 2008	The objectives of this study were to determine the leaching characteristics of Cr(VI) from sediments collected from 100 Area spill sites, elucidate possible Cr(VI) mineral and/or chemical associations that may be responsible for Cr(VI) retention in 100 Area soil, and provide information to construct a conceptual model of Cr(VI) geochemistry in the 100 Area vadose zone. Results from column experiments indicated that most of the Cr(VI) traveled quickly through the column sediments and appeared in the effluent. Calculated retardation coefficients are close to one. Calcium polysulfide solutions readily reduced Cr(VI) to trivalent chromium in column experiments. However, a significant amount of the Cr(VI) was mobilized prior to the polysulfide solution front. The experiments suggested it would be difficult to design a remedial measure using infiltration of liquid phase reductant without increasing Cr(VI) transport toward the water table. The microscopic characterization results were consistent with the column studies. Cr(VI) was found as ubiquitous coatings on sediment grain surfaces. This study also indicated that small, higher-concentration Cr(VI) sites were generally associated with secondary clay mineral inclusions with occasional barium chromate minerals, and the Cr(VI) was reduced to trivalent chromium in association with iron oxides that are most likely magnetite primary minerals. Within the restricted access domains of the sediment matrix, ferrous iron could also diffuse from in situ, high surface area minerals to cause the reductive immobilization of chromate. This process may be favored at micro-scale geochemical zones where ferrous iron could be supplied.
Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site, Benton County, Washington	EPA et al., 2009b	This ESD was issued to provide notice of revisions to the cost estimate and reinjection locations associated with the P&T interim action. An expansion of the P&T system was identified in the future cost estimate. The ESD also revised the reinjection standards and location requirements for treated water.

COPC	=	contaminant of potential concern	LFI	=	limited field investigation
Cr(VI)	=	hexavalent chromium	LOEL	=	lowest observed effects level
DOE	=	U.S. Department of Energy	OSE	=	orphan sites evaluation
EPA	=	U.S. Environmental Protection Agency	OU	=	operable unit
ERDF	=	Environmental Restoration Disposal Facility	P&T	=	pump and treat
ESD	=	explanation of significant difference	QRA	=	qualitative risk assessment
FFS	=	focused feasibility study	RI	=	remedial investigation
IRM	=	interim remedial measure	ROD	=	record of decision

Summaries of facility demolition activities, vadose zone investigation and remedial activities, groundwater investigation and remedial activities, and previous risk assessments are provided below.

1.2.3.1 Previous Facility Demolition Activities

At 100-K, numerous facilities were used or constructed. These facilities include the KE and KW Reactor Buildings, office and storage buildings, retention basins, reactor stacks, maintenance shops, process plants, an electric substation, storage tanks, pump stations, and outfall structures.

Many of the facilities have been demolished or removed. Removal activities were conducted under two Action Memoranda (Table 1-3). Most of the facilities demolished or removed were used during reactor operations, including the retention basins, KE Reactor stack, office and storage buildings, maintenance shops, process plants, and storage tanks. The action memoranda also identify adjacent waste sites that are potentially affected by the facilities. Until the structures over a waste site have been removed, vadose zone remediation cannot be completed. Therefore, the facilities (including contaminated pipelines associated with them) are and have been undergoing removal to clear the way for the remedial work that focuses on contamination in the vadose zone. In addition, facility decontamination, demolition, and disposal remove contaminants that could otherwise be released to the environment.

Table 1-3. Summary of Removal Action Documents at 100-K

Document Number	Date	Document Title	Summary of Conclusions
EPA, 2005	11/15/2005	*Action Memorandum for the Non-Time-Critical Removal Action for the 100-K Area Ancillary Facilities*	This action memorandum documents approval of the non-time-critical removal action for 27 buildings and structures located in the 100-K Area. The preferred removal action is to deactivate, decontaminate, and demolish the facilities. The action memorandum also identifies adjacent waste sites potentially affected by the facilities. Waste generated from the removal action that meets ERDF waste acceptance criteria will be disposed at ERDF.
EPA, 2007a	01/30/2007	*Action Memorandum for the Non-Time-Critical Removal Action for the 105-KE and 105-KW Reactor Facilities and Ancillary Facilities*	This action memorandum documents approval of the non-time-critical removal action for the remaining buildings and structures, including the KE and KW Reactor Buildings, located in the 100-K Area. The preferred alternative for the KE and KW Reactors and Ancillary Facilities was Interim Safe Storage of the reactors followed by long-term surveillance and maintenance, and D4 of the ancillary facilities and portions of the KE and KW Reactor Facilities. Waste generated from the removal action that meets ERDF waste acceptance criteria will be disposed at ERDF.

D4 = deactivation, decontamination, decommissioning, and demolition
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility

KE and KW Reactors. DOE issued a draft Environmental Impact Statement (EIS) (DOE/EIS-0119D, *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*) in March 1989 to analyze alternatives for reactor decommissioning. The five alternatives analyzed for the surplus reactors included no action, immediate one-piece removal, safe storage followed by deferred one-piece removal, safe storage followed by deferred dismantlement, and in situ decommissioning. Following public review and comment on the EIS, a December 1992 addendum (DOE/EIS-0119F, *Addendum (Final Environmental Impact Statement) Decommissioning of Eight Surplus Reactors at Hanford Site Addendum*) identified DOE responses to public comments on the draft EIS (DOE/EIS-0119D) and provided text changes that form the final EIS (DOE/EIS-0119F). The preferred decommissioning alternative identified in the final EIS was safe storage followed by deferred one-piece removal.

DOE issued NEPA ROD (FR 58 48509, *Record of Decision; Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*) in 1993 based on consideration of environmental impacts, benefits and costs, and programmatic needs associated with decommissioning of eight surplus Hanford Site reactors. The NEPA ROD indicated DOE's decision at that time for safe storage followed by one-piece removal. The NEPA ROD also identified DOE's intent to evaluate the priority of decommissioning actions relative to CERCLA and RCRA remediation of the Hanford Site 100 Area, and re-evaluate the appropriateness of the course of action on an OU basis. The NEPA ROD also stated DOE's intent to integrate and prioritize the decision with CERCLA remediation activities under the TPA (Ecology et al., 1989a).

DOE uses the CERCLA process to decommission and dismantle reactors based on the joint EPA/DOE policy on decommissioning signed in 1995 (DOE and EPA, 1995, *Policy on Decommissioning of Department of Energy Facilities Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)*) and incorporated into the TPA (Ecology et al., 1989a). Since the Reactor Decommissioning NEPA ROD (58 FR 48509) in 1993, documentation has been prepared and implemented under CERCLA, resulting in placement of six of the eight surplus reactors (C, D, DR, F, H, and N) into ISS designed to prevent deterioration and release of contamination from the reactors.

DOE issued 75 FR 43158, "Amended Record of Decision for the Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, WA," on July 23, 2010. DOE broadened the decommissioning approach for these eight surplus reactors, including the KE and KW Reactors, retaining the deferred one-piece removal option, and added an option for immediate dismantlement based on DOE/EIS-0119F-SA-01, *Supplement Analysis: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington.*

DOE evaluates the coordination of decommissioning actions with the completion of remaining actions in 100-K, including remedial alternatives for waste sites near reactors. As of April 2017, placement of the KE and KW Reactors into ISS was planned for 2021 and 2023, respectively. Investigation and remediation of waste sites near reactors requires coordination with the CERCLA decision on reactor remediation activities.

100-K Fuel Storage Basins—Spent Fuel Removal and Cleanup. The major components of the selected remedy in the 100-KR-2 OU interim action ROD (EPA/ROD/R10-99/059, *Interim Remedial Action Record of Decision for the 100-KR-2 Operable Unit K Basins, Hanford Site, Benton County, Washington*, hereinafter called 100-KR-2 OU ROD) include removing SNF and sludge from the basins, water treatment and removal, debris removal, basin deactivation, and institutional control (IC) implementation and maintenance.

The selected remedy directed transport of the SNF to the Cold Vacuum Drying (CVD) facility, with an expectation that the dried fuel would then be transported to the 200 Area and ultimately disposed offsite at the national geologic repository. Sludge was designated for separation into transuranic (TRU) and non-TRU fractions during removal, with the TRU waste managed in the 200 Area with ultimate disposal offsite, and the non-TRU fraction disposed to ERDF. The *Amendment to the Record of Decision for the U.S. Department of Energy Hanford Site 100 K Area K Basins Interim Remedial Action* (EPA et al., 2005; hereinafter called the 100-KR-2 OU ROD Amendment, changed the sludge disposition by requiring the sludge be treated and packaged for disposal, and shipped off-Hanford to a national repository.

The 100-KR-2 OU interim action ROD (EPA/ROD/R10-99/059) also selected debris removal and treatment as required to meet disposal facility requirements, and water treatment and removal. The expectation for debris was disposal at ERDF, or storage at a permitted facility in the 200 Area as necessary for waste not meeting disposal facility acceptance criteria. The 100-KR-2 OU interim action ROD did not specify the details of debris retrieval; however, the anticipated process was to be an item-by-item removal, with any treatment completed outside the basin. The 100-KR-2 OU ROD Amendment also amended the remedy for some of the debris. The amendment allowed some debris remaining in the basins to be included in the basins while they are filled with a cement-based grout and removed in conjunction with the basins. The ROD specified water treatment in the basins followed by transport in tanker trucks to the Effluent Treatment Facility (ETF). DOE/RL-99-89, *Remedial Design Report and Remedial Action Work Plan for the K Basins Interim Remedial Action*, presented the design and work plan for remediation. HNF-20632, *End Point Criteria for the K Basins Interim Remedial Action*, established end-point criteria for completion of the remedial action.

Implementation of the provisions in the 100-KR-2 OU interim action ROD (EPA/ROD/R10-99/059) and 100-KR-2 OU ROD Amendment (EPA et al., 2005) is currently in progress. The basins' floor and pits were inspected to identify fuel fragments mixed in with the sludge and debris. Treatment and removal of water from the KE Basin was initiated in 2004 and has been completed. The sludge in KE Basin was transferred to KW Basin. The KE Basin was demolished and disposed in ERDF. Remedial activities have begun to support sludge removal and the eventual decontamination and demolition of the KW Basins.

The emptied and deactivated basins resulting from this remedial action have been and will be remediated under 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). Deactivation, demolition, and removal of the KW FSB is expected to be completed in September 2019.

100-K Facilities—Deactivation, Decontamination, Decommissioning, and Demolition. Following the deactivation of the KE and KW Reactors in 1970 and 1971, respectively, some 100-K facilities have remained active to support the long-term storage of SNF and sludge in the K Basins. Numerous 100-K facilities also provide ancillary support to 100-N operations, and the 100-KR-4 groundwater P&T system uses several 100-K buildings for system support. Table 1-4 identifies 100-K facilities that have been removed and those that are pending demolition. Through December 2016, 78 of 111 facilities have been demolished or removed.

The remaining structures include the KE and KW Reactors, parts of the water treatment infrastructure, and support buildings such as the 151-KE Substation, 1713-KE and 1713-KW Warehouses, 142-K Cold Vapor Drying Facility, and ancillary buildings. Figures 1-16 and 1-17 show the KE Reactor area. Most of the structures have been removed. The KE and KW Reactor Buildings will be placed in interim safe storage before a remediation decision is implemented.

Table 1-4. Status of 100-K Facilities

Status	Facility
Removed (78)	107-KE, 107-KW, 110-KE, 110-KW, 115-KE, 116-KE, 117-KE, 118-KE-2, 118-KW-2, 119-KE, 150-KE, 150-KW, 181-KE, 181-KW, 182-K, 183-KE, 183.1-KE, 183.2-KE, 183.3-KE, 183.4-KE, 183.5-KE, 183.6-KE, 183.7-KE, 183-KW, 183.1-KW, 183.2-KW, 183.3-KW, 183.4-KW, 183.5-KW, 183.6-KW, 183.7-KW, 185-K, 190-KE, 190-KW, 1614-KE, 1701-KA, 1702-KE, 1702-KW, 1704-K, 1706-KE, 1706-KEL, 1706-KER, 1713-KE, 1713-KER, 1714-KE, 1717-AKE, 1717-K, 1720-K, 1724-KB, 1908-KE, 1909-KE, MO-048, MO-054, MO-060, MO-101, MO-102, MO-205-K, MO-214, MO-236, MO-237, MO-286, MO-293, MO-323, MO-382, MO-401, MO-402, MO-420, MO-442, MO-474-K, MO-495, MO-767-K, MO-827, MO-827-K, MO-854, MO-907, MO-928, MO-955, MO-969
Pending demolition (33)	115-KW, 116-KW, 117-KW, 119-KW, 142-K, 142-KA, 166-KE, 166-KW, 1701-K, 1909-K, 1909-KW, 1506-K1, 151-K, 151-KE, 151-KW, 165-KE, 165-KW, 166A-KE, 166A-KW, 167-K/167-KE, 296-K-105, 296-K-142, 1605-K, 1705-KE, 1713-KW, 1714-KW, 1724-K, 1724-KA, 1733-K, MO-500, MO-506, MO-507, MO-917

Note: Status in December 2016.

Figure 1-16. KE Reactor Before Remediation Activities

Figure 1-17. KE Reactor Area (March 2011)

1.2.3.2 Vadose Zone Remedial Actions and Waste Site Investigations

The behavior of contaminants in the vadose zone has been an important consideration in Hanford plant operations since the 1940s. Some reports (e.g., HW-9671, *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area*; HW-17088, *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington*; UNI-946) examined the issues related to waste disposal at injection wells, shallow burial cribs, and surface ponds. Groundwater monitoring via wells began in the late 1940s to evaluate contaminant migration rates through the vadose zone and in the aquifer. Although most attention was focused on radionuclides, primarily within the 200 Area, groundwater monitoring around the 107-F Waste Disposal Trench (in the 100-F Area) and the 108-B Crib (in the 100-BC Area) was reported for some chemicals. Waste site designs sometimes included wells where geophysical logging could assess radionuclide movement through the aquifer. Waste site use depended on the vertical migration of contaminants, and sites were shut down when contamination reached certain predetermined concentrations in groundwater at these wells. Hydrologic and geochemical processes in the vadose zone were of interest, but were not well understood.

Vadose Zone Investigations. The vadose zone at the Hanford Site has been studied since the 1950s. An overview of the status of vadose zone studies in 1985 is provided in PNL-5428, *Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography*. By 1992, data had been collected from lysimeters at a wide range of sites at Hanford (Gee et al., 1992, "Variations in Recharge at the Hanford Site"). Recharge (sometimes called deep percolation) measurements using lysimetry and other techniques at the Hanford Site has been extensive over the past two decades (PNNL-17841, *Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates*). Recharge rates applicable to different soil and surface cover conditions at the Hanford

Site are listed in DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection.*

During the construction, operations, and remediation periods, the topsoil was scraped off a large portion of 100-K. Based on results from "Variations in Recharge at the Hanford Site" (Gee et al., 1992), this condition affected a change in vadose zone dynamics with an increase in vadose zone water flux since construction. Under native vegetation, the recharge rate would typically be expected to be 4.0 mm/yr (0.16 in.) or less (DOE/RL-2011-50), while bare (unvegetated) ground would be subject to a greater recharge. For example, Ephrata sandy loam soil with native shrub steppe vegetation would be expected to yield a recharge of 1.5 mm/yr (0.06 in.). The same Ephrata sandy loam soil in a disturbed state and without vegetative cover can be expected to yield a recharge rate of 17 mm/yr (0.67 in.) (DOE/RL-2011-50). Localized recharge rates could be even higher where buildings, tanks, and other structures divert precipitation laterally. In addition, water has been added to historical waste site locations for dust control during remediation activities. Once remediation is complete and native vegetation cover is reestablished, the recharge flux will return to low-recharge conditions.

Vadose zone contaminant (radiological and nonradiological) characterization studies started at 100-K in 1975 to evaluate contaminant inventories, concentrations, and distribution at inactive solid and liquid waste sites, reactors, and associated facilities. LFIs assessed the nature and extent of effluent discharges to the vadose zone at high-priority waste sites in the early 1990s.

Initial Vadose Zone Radiological Characterization—1975. The purpose of this initial investigation was to establish approximate radionuclide inventories, distribution, and concentrations at inactive solid and liquid waste sites, reactors, and associated facilities (UNI-946). The focus of the sampling activities was the retention basins, the 116-K-1 Crib, and the 116-K-2 Trench. Shallow boreholes were drilled at 29 locations near the 107-KE and 107-KW Retention Basins, and 35 locations at and around the 116-K-1 Crib and 116-K-2 Trench. Five characterization boreholes were also drilled at the 116-KE-1, 116-KE-2, and 116-KW-1 Cribs. An additional component of this study involved collecting samples from retention basin sludge and concrete, and from effluent line scale and sludge. Samples were analyzed for select radionuclides, and the residual radionuclide inventories were calculated. No chemical contaminants were assayed as part of this investigation.

100-K Vadose Zone Limited Field Investigation. An LFI was performed in the 100-KR-1 OU in the early 1990s. Results of the investigation are presented in DOE/RL-93-78. The primary purpose of the LFI report was to recommend the high-priority sites that should, or should not, remain candidates for interim remedial measures (IRMs). LFI findings were based on data compilation, intrusive investigation at selected sites, nonintrusive investigations, summaries of existing 100 Area aggregate studies, and data evaluation. The LFI report summarized the data collection and analysis activities and identified contaminant and location specific ARARs and their respective qualitative site-specific risk assessments that support the IRM candidate identification.

Samples were collected from four boreholes and two test pits at the 116-K-1 Crib, the 116-K-2 Trench, and the 116-KE-4 and 116-KW-3 Retention Basins and analyzed for radionuclide and chemical contaminants as part of the LFI. Based on evaluation of the data and consideration of information for analogous 100 Area sites, the LFI affirmed the 116-K-1 Crib, the 116-K-2 Trench, the 116-K-3 Outfall Structure, the 116-KE-4 and 116-KW-3 Retention Basins, and the process effluent pipelines as high-priority sites. No low priority sites were identified.

Interim Remedial Action. Waste site remediation at 100-K began in 2002 under an amendment to an interim action ROD (EPA/AMD/R10-97/044) and expanded and continued under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) and 100 Area Burial Grounds ROD (EPA/ROD/R10-00/121). The interim

remedial actions (RAs) are ongoing, consisting mainly of removal, treatment (as necessary), and disposal (RTD) of vadose zone material and debris, followed by backfill and revegetation of excavated areas.

RAs are designed to achieve RAOs and goals specified in interim action RODs for direct exposure applicable to soil 0 to 4.6 m (0 to 15 ft) bgs and protection of groundwater and the Columbia River. In practice, this involves excavating wastes and soil that exceed remedial action goals (RAGs), followed by disposal in the ERDF located in the Central Plateau. Characterization is included as a component of waste site remediation and consists primarily of sample collection and analysis to assess the nature and extent of contamination, guide remediation decision making, and verify achievement of interim RAOs. Residual contamination remaining after excavation is evaluated to assess potential impacts to groundwater and the Columbia River. Where RAOs and the interim RAGs are achieved, the waste site is reclassified as interim closed out.

Under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039), not all waste sites were identified as requiring remediation. Sites for which a remedial action determination could not be made at the time of interim action ROD issuance were termed as “candidate sites” or “confirmatory sites” under the interim action framework. A process was established whereby these sites and any future newly discovered waste sites could undergo confirmatory evaluation to determine if remedial action was warranted. If required, those sites were then remediated under the existing RTD remedy using a plug-in mechanism established in the 100 Area Remaining Sites ROD. Application of the plug-in remedy mechanism for candidate sites and new waste sites is documented in subsequent explanations of significant difference and annual fact sheets.

Figure 1-18 shows the 100-K Area in 2006 after remediation and backfill of multiple high-priority liquid effluent waste sites: the 116-KE-4 and 116-KW-3 Retention Basins, 116-K-1 Crib, 116-K-2 Trench, and the associated 100-K-55:1 and 100-K-56:1 effluent pipelines. Figure 1-19 shows the 100-K Area in 2016, during active remediation and removal activities at and near the 183-KE Water Treatment Plant Headhouse (left foreground).

Waste Site Cleanup Documentation. A cleanup verification document is prepared following completion of the interim remedial actions or confirmatory investigations at a waste site. These documents are referred to either as cleanup verification packages (CVPs) or remaining sites verification packages (RSVPs), depending on the applicable interim action ROD. This document contains verification sampling results and other supporting information to demonstrate that the attainment of interim RAGs and interim RAOs has been achieved. The CVP or RSVP usually includes a description of the site, contaminants and waste forms requiring action, interim remedial action conducted, disposal information, sampling plan and subsequent data and risk calculations, and comparison of closeout data to RAGs and risk requirements.

The exposure factors and assumptions used in the rural residential scenario were defined in DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (hereinafter called 100 Area remedial design report/remedial action work plan [RDR/RAWP]). Soil interim RAGs for protection of groundwater were intended to achieve state or federal DWSs. RAGs were also developed to protect aquatic organisms in the Columbia River. However, RAGs were not developed for the protection of terrestrial ecological receptors because of the absence of regulatory guidance at that time.

Figure 1-18. High-Priority Liquid Effluent Waste Sites Following Remediation (2006)

Figure 1-19. 100-K Area Remediation Progress (2016)

To support interim closure of waste sites, soil samples were typically collected and analyzed from the exposed surface at the bottom and sidewalls of an excavation. The analytical data were evaluated and, as appropriate, used to determine statistical values for comparison to RAGs and, if appropriate, in site-specific modeling calculations. The primary statistical calculation to evaluate compliance with interim RAGs is the 95% upper confidence limit (UCL) on the arithmetic mean of the data. Maximum analyte concentrations were also used as appropriate to demonstrate that interim RAGs had been achieved. Appendix E provides the CVP or RSVP reference for applicable waste sites, as well as summary remediation information.

1.2.3.3 Waste Site Summary

Table 1-5 summarizes the classification/reclassification status of 100-K waste sites as of April 2017. Some waste sites are administratively divided into smaller subsites. In this table and throughout this document, subsites are considered individually (e.g., 100-K-55:1 and 100-K-55:2 are accounted for as two sites rather than as the single 100-K-55 waste site). Different subsites may have subsite-specific circumstances that distinguish how they have previously been addressed and how they will be addressed through the RI/FS process. Sites are listed by name under their assigned classification/ reclassification status for the 100-KR-1 OU in Table 1-6 and for the 100-KR-2 OU in Table 1-7. Appendix A provides a map of waste site locations.

Table 1-5. Summary Information on 100-K Waste Sites

Operable Unit	Number of Sites [a]	Closed Out [b]	Interim Closed Out [c]	Interim No Action [d]	Not Accepted [e]	Rejected [f]	Consolidated [g]	Accepted [h]
100-KR-1	18	0	5	1	0	0	1	11
100-KR-2	179	1	62	5	24	17	0	70
Total 100-K	197	1	67	6	24	17	1	81

Reference: *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b).

Notes: Additional information provided in Appendix E. Classification/reclassification statuses as of April 2017, except for the 100-K-100 site, which is accounted for as "rejected" based on reclassification in July 2017.

a. Total Number of Sites. Summary metrics are based on accounting for subsites as individual sites.

b. Closed Out: A reclassification status indicating that because of actions taken, a waste management unit meets applicable cleanup standards or closure requirements.

c. Interim Closed Out: A reclassification status indicating that because of actions taken, a waste management unit meets cleanup standards specified in an interim action ROD or Action Memorandum, but for which a ROD has not been issued. Further actions may be necessary.

d. Interim No Action: A reclassification status indicating a waste site does not require any further remedial action under interim cleanup standards based on an assessment of quantitative data collected for the waste site. Existing "interim no action" reclassifications have been made under interim action RODs, and further actions may be necessary.

e. Not Accepted: A classification status indicating an assessment was made that a WIDS site is not a waste management unit and is not within the scope of Ecology et al., 1989b.

f. Rejected: A reclassification status indicating a waste site does not require remediation under CERCLA based on qualitative information such as a review of historical records, photographs, drawings, walkdowns, ground-penetrating radar scans, and intrusive investigations. Such investigations do not include quantitative measurements.

g. Consolidated: A reclassification status indicating a waste site is a duplicate of, physically located within, or adjacent to another WIDS site and will be dispositioned as part of that other WIDS site.

h. Accepted: A classification status indicating an assessment has been made that a WIDS site is a waste management unit as defined in Ecology et al., 1989b. Sites accounted for as "accepted" are those for which no further reclassification has been approved.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

ROD = record of decision

WIDS = Waste Information Data System

Table 1-6. Classification/Reclassification Status of 100-KR-1 OU Waste Sites

Status	Waste Sites	Total
Closed Out	None	0
Interim Closed Out	100-K-63, 116-K-1, 116-K-2, 116-KE-4, 116-KW-3	5
Interim No Action	100-K-78	1
Not Accepted	None	0
Rejected	None	0

Table 1-6. Classification/Reclassification Status of 100-KR-1 OU Waste Sites

Status	Waste Sites	Total
Consolidated	100-K-93	1
Accepted	100-K-57, 100-K-64, 100-K-80, 100-K-81, 100-K-83, 100-K-94, 100-K-96, 100-K-111, 100-K-113, 100-K-114, 116-K-3	11

Notes: Classification/reclassification statuses as of April 2017. See Table 1-5 for description of classification/reclassification statuses.
OU = operable unit

Table 1-7. Classification/Reclassification Status of 100-KR-2 OU Waste Sites

Status	Waste Sites	Total
Closed Out	1607-K4	1
Interim Closed Out	100-K-3, 100-K-4, 100-K-6, 100-K-14, 100-K-18, 100-K-19, 100-K-29, 100-K-30, 100-K-31, 100-K-32, 100-K-33, 100-K-34, 100-K-36, 100-K-37, 100-K-38, 100-K-46, 100-K-50, 100-K-53, 100-K-55:1, 100-K-56:1, 100-K-62, 100-K-68, 100-K-69, 100-K-70, 100-K-71, 100-K-77, 100-K-79:1, 100-K-79:2, 100-K-84, 100-K-86, 100-K-87, 100-K-89, 100-K-91, 100-K-92, 100-K-95, 100-K-97, 100-K-102, 100-K-106, 100-K-109, 116-KE-5, 116-KE-6A, 116-KE-6B, 116-KE-6C, 116-KE-6D, 116-KW-4, 118-K-1, 118-KE-2, 118-KW-2, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, 120-KW-7, 126-KE-2, 128-K-1, 128-K-2, 130-KE-1, 132-KE-1, 1607-K2,1607-K3, 600-29	62
Interim No Action	100-K-85, 100-K-88, 100-K-90, 100-K-105, 100-K-110	5
Not Accepted	100-K-7, 100-K-8, 100-K-9, 100-K-10, 100-K-11, 100-K-12, 100-K-15, 100-K-16, 100-K-20, 100-K-21, 100-K-22, 100-K-23, 100-K-24, 100-K-28, 100-K-39, 100-K-44, 100-K-52, 100-K-58, 100-K-59, 100-K-76, 100-K-117, 126-KE-3, 130-K-1, 130-K-3	24
Rejected	100-K-2, 100-K-51, 100-K-61, 100-K-66, 100-K-67, 100-K-100, 100-K-112, 100-K-118, 100-K-121, 100-K-122, 100-K-130, 118-KE-1, 118-KW-1, 126-K-1, 132-KW-1, 600-4, 600-55	17
Consolidated	None	0

Table 1-7. Classification/Reclassification Status of 100-KR-2 OU Waste Sites

Status	Waste Sites	Total
Accepted	100-K-1, 100-K-5, 100-K-13, 100-K-25, 100-K-27, 100-K-35, 100-K-42, 100-K-43, 100-K-47, 100-K-48, 100-K-49, 100-K-54, 100-K-55:2, 100-K-56:2, 100-K-56:3, 100-K-60, 100-K-72, 100-K-73, 100-K-74, 100-K-75, 100-K-79:3, 100-K-79:4, 100-K-79:5, 100-K-79:6, 100-K-79:7, 100-K-79:8, 100-K-79:9, 100-K-82, 100-K-98, 100-K-99, 100-K-101, 100-K-103, 100-K-104, 100-K-107, 100-K-108, 100-K-115, 100-K-116, 100-K-119, 100-K-120, 100-K-123, 100-K-124, 100-K-125, 100-K-126, 100-K-127, 100-K-128, 100-K-129, 100-K-131, 100-K-132, 116-KE-1, 116-KE-2, 116-KE-3, 116-KW-1, 116-KW-2, 120-KE-1, 120-KE-2, 120-KE-3, 120-KE-4, 120-KE-5, 120-KE-6, 120-KE-8, 120-KE-9, 120-KW-6, 130-K-2, 130-KE-2, 130-KW-1, 130-KW-2, 1607-K1, 1607-K5, 1607-K6, UPR-100-K-1	70

Notes: Classification/reclassification statuses as of April 2017, except for the 100-K-100 site, which was reclassified as "rejected" in July 2017. See Table 1-5 for description of classification/reclassification statuses.
OU = operable unit

1.2.3.4 Waste Site Consideration in the RI and FS

All 100-K waste sites were considered part of this RI/FS process to determine whether the sites are protective of human health and the environment. While the unique factors of each site were considered individually, the overall consideration of waste sites can be described generally based on the following classification/reclassification status:

- Sites with a "closed out" status were reviewed to confirm that this determination has been made appropriately. Where a closed-out status was appropriate, no further review of site information was performed, and the site will not be considered further within the RI/FS process.
- A reclassification status of "rejected" indicates a waste site does not require remediation under CERCLA based on qualitative information such as a review of historical records, photographs, drawings, walkdowns, ground-penetrating radar scans, and intrusive investigations. These investigations do not include quantitative measurements. A classification status of "not accepted" indicates an assessment was made that a WIDS site is not a waste management unit and is not within the scope of the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b). Sites with a "rejected" or "not accepted" status were reviewed to determine whether new information was available that contradicts the existing documented basis for rejection or nonacceptance. Where the existing classification/reclassification was appropriate, the site will not be considered further in the RI/FS process. No rejected or not accepted sites at 100-K were found to have information that contradicted the existing determinations.
- A reclassification status of "consolidated" indicates a waste site is a duplicate of, physically located within, or adjacent to another WIDS site and will be dispositioned as part of that other WIDS site. Sites with a "consolidated" status are addressed as part of the site they were consolidated into, and are not considered further as separate sites within the RI/FS process.
- A reclassification status of "interim no action" indicates a waste site does not require any further remedial action under interim cleanup standards based on an assessment of quantitative data collected for the waste site. Existing "interim no action" reclassifications have been made under interim action

RODs, and further actions may be necessary. A reclassification status of "interim closed out" indicates that because of actions taken, a waste management unit meets cleanup standards specified in an interim action ROD or Action Memorandum, but for which a ROD has not been issued. Further actions may be necessary. Sites with an "interim no action" or "interim closed out" reclassification status based on confirmatory and/or verification data are all considered within the overall RI and have been quantitatively evaluated against PRGs as appropriately described in Chapters 5 through 7. Sites with an "interim no action" or "interim closed out" reclassification with a basis other than direct data (for example, historical decommissioning data) were considered on a site-by-site basis.

- A classification status of "accepted" indicates an assessment has been made that a WIDS site is a waste management unit as defined in Ecology et al., 1989b. Sites accounted for as "accepted" are those for which no further reclassification has been approved. Sites with no reclassification beyond "accepted" status are considered on a site-by-site basis.

Any new discovery sites will be addressed through an appropriate CERCLA decision.

1.2.3.5 Waste Sites Requiring No Further Consideration at 100-K

Waste sites with a "closed out," "consolidated," "rejected," or "not accepted" classification/ reclassification status were reconsidered to determine if there was an adequate existing basis for this determination. Table 1-8 identifies the 43 sites for which the existing basis was sufficient. These sites do not require a final remedy decision and will not be addressed further in this RI/FS.

Table 1-8. Sites Not Addressed Further in the RI and FS

Classification/ Reclassification Status	Waste Sites
Closed Out	1607-K4
Consolidated	100-K-93
Rejected	100-K-2, 100-K-51, 100-K-61, 100-K-66, 100-K-67, 100-K-100, 100-K-112, 100-K-118, 100-K-121, 100-K-122, 100-K-130, 118-KE-1, 118-KW-1, 126-K-1, 132-KW-1, 600-4, 600-55
Not Accepted	100-K-7, 100-K-8, 100-K-9, 100-K-10, 100-K-11, 100-K-12, 100-K-15, 100-K-16, 100-K-20, 100-K-21, 100-K-22, 100-K-23, 100-K-24, 100-K-28, 100-K-39, 100-K-44, 100-K-52, 100-K-58, 100-K-59, 100-K-76, 100-K-117, 126-KE-3, 130-K-1, 130-K-3

FS = feasibility study
RI = remedial investigation

1607-K4. This site is a septic system that was abandoned in place per WAC 246-272, "Wastewater and Reclaimed Water Use Fees," requirements and reclassified as closed out per TPA-MP-14, *Maintenance of the Waste Information Data System (WIDS)* (RL-TPA-90-0001, *Tri-Party Agreement Handbook Management Procedures)*.

100-K-93. This site was a small area (1.6 m^2 [17 ft^2]) around a 208 L (55 gal) drum remnant and solidified tar-like substance within the larger 100-K-111 site. The drum, tar substance, and immediately underlying

soil were excavated by hand and removed, and the 100-K-93 site was consolidated into the 100-K-111 site in accordance with TPA-MP-14 (RL-TPA-90-0001).

100-K-2, 100-K-51, 100-K-61, 100-K-66, 100-K-67, 100-K-100, 100-K-112, 100-K-118, 100-K-121, 100-K-122, 100-K-130, 118-KE-1, 118-KW-1, 126-K-1, 132-KW-1, 600-4, and 600-55. These sites were reclassified as rejected in accordance with TPA-MP-14 (RL-TPA-90-0001). No new or conflicting information was identified to suggest that these sites should be reconsidered as waste management units.

100-K-7, 100-K-8, 100-K-9, 100-K-10, 100-K-11, 100-K-12, 100-K-15, 100-K-16, 100-K-20, 100-K-21, 100-K-22, 100-K-23, 100-K-24, 100-K-28, 100-K-39, 100-K-44, 100-K-52, 100-K-58, 100-K-59, 100-K-76, 100-K-117, 126-KE-3, 130-K-1, and 130-K-3. These sites were not accepted as waste sites at the discovery phase of TPA-MP-14 (RL-TPA-90-0001). No new or conflicting information was identified to suggest that these sites should be reconsidered as waste management units.

The remaining 154 100-K sites are considered in the scope of this RI and FS. Of these 154 sites, 22 (listed in Table 1-9) will not be considered for further action based on site-specific considerations, as described below. These sites are not addressed further in the RI, but are included in the FS and will be included in a ROD for the final remedy decision to be documented.

Table 1-9. 100-K Sites Not Considered for Further Action Based on Site-Specific Considerations

Classification/ Reclassification Status	Waste Sites
Interim Closed Out	100-K-37, 100-K-38, 100-K-87, 116-KE-6A, 116-KE-6B, 116-KE-6C, 116-KE-6D, 118-KE-2, 118-KW-2
Accepted	100-K-42, 100-K-115, 100-K-116, 100-K-119, 100-K-120, 100-K-123, 100-K-124, 100-K-125, 100-K-126, 100-K-127, 100-K-128, 100-K-129, 100-K-131

100-K-37 and 100-K-38. These sites were aboveground stainless steel tanks used for storage of sulfuric acid and sodium hydroxide, respectively, located at the 1706-KE facility. Residual contents of the tanks were removed from 1991 to 1992, the tanks were removed in 2009, and the waste sites were reclassified as interim closed out. The foundations and underlying soil were later removed as part of the removal action for the 1706-KE facility and remedial action for the 100-K-3 and 100-K-36 waste sites from 2009 to 2011. The 100-K-3 and 100-K-36 waste sites are considered further in the RI and FS; no further action is warranted for the 100-K-37 and 100-K-38 sites based on complete removal.

100-K-87. This site was an area of suspect asbestos-containing pipe lagging near the former 100-K construction laydown area. The lagging and underlying soil was excavated and removed, and no other suspect hazardous debris was identified at the location. Therefore, no further action is warranted for this site.

116-KE-6A, 116-KE-6B, 116-KE-6C, and 116-KE-6D. These sites were individual components of the 1706-KE waste treatment system, located within the former 1706-KER Recirculation Test Facility. The waste treatment system was a RCRA treatment, storage, and disposal (TSD) unit used from 1986 to 1987 to treat mixed waste from the laboratories in the 1706-KE and 1706-KER facilities. The components were removed and disposed in 2009 under a combined corrective action and remedial action. The 1706-KER facility was then demolished and removed from 2009 to 2011, and the underlying soil footprint was included as part of verification sampling for the 100-K-3 waste site. The 1706-KE waste

treatment system TSD has been closed; no further action is warranted for the 116-KE-6A, 116-KE-6B, 116-KE-6C, and 116-KE-6D based on complete removal.

118-KE-2 and 118-KW-2. These sites were bunkers used for temporary storage of radioactive rod tips from the reactors. Each bunker consisted of steel pipe sections cut in half lengthwise, placed on grade-level concrete slabs and covered with an earthen berm. The bunkers were demolished and removed in 2009 and 2010, and the waste sites were reclassified as interim closed out based on radiological surveys of underlying soil that showed no elevated residual contamination. These determinations remain appropriate for final action purposes, and no further action is warranted.

100-K-42. This site is the former KE Reactor FSB. Removal of the residual contents and demolition and removal of the FSB structure have been completed as described in Section 1.2.3.1. Based on removal, no further action is warranted for the 100-K-42 site. Soil contamination underlying the former FSB is considered further in the RI and FS as the separate UPR-100-K-1 waste site.

100-K-115, 100-K-116, 100-K-119, 100-K-120, 100-K-123, 100-K-124, 100-K-125, 100-K-126, 100-K-127, 100-K-128, 100-K-129, and 100-K-131. These sites were identified to address potential residual asbestos-containing debris materials following demolition and removal of various 100-K Area facilities. Soil and potential asbestos-containing materials were removed, and the sites were inspected by a certified asbestos contractor to verify that no suspect materials remained. No other hazardous materials were identified during remediation or inspection; therefore, no further action is warranted at these sites.

1.2.3.6 Nonoperational Area Evaluation

The Nonoperational Area evaluation is provided in Appendix L. The nonoperational evaluation considered the five transport mechanisms, physical features, and climate conditions that could influence transport and used surface and near-surface information from the following available sources:

- Orphan sites evaluations
- Air emissions reports
- Environmental monitoring programs
- Orchard land investigations
- Statistical modeling

Most waste sites associated with 100-K are located near the decommissioned reactors. The 100-K Area was evaluated to assess potential contaminant migration into the nonoperational areas. Five credible contamination transport mechanisms were identified:

- Human disposal of materials
- Biological vectors
- Point source dispersal (e.g., stack emissions)
- Wind dispersal
- Overland flows

The nonoperational evaluation considered these transport mechanisms, physical features, and climate conditions that could influence transport, and used surface and near-surface information from a number of available sources. The evaluation also used statistical modeling to support the data analyses and development of technical recommendations (e.g., additional sampling) for the River Corridor nonoperational areas.

The nonoperational evaluation incorporates information from the orphan sites evaluations (OSEs) and uses established approaches and datasets in an approach similar to that adopted by the Central Plateau with specific River Corridor issues such as potential overland flow and impacts on riparian and nearshore areas. The OSEs includes air emission reports and data from environmental monitoring.

Orphan Sites Evaluations. The purpose of the nonoperational evaluation and the OSEs is to increase confidence that waste disposal or releases requiring characterization and cleanup within a given land parcel of the Hanford Site River Corridor have been identified. Key elements of the OSE include a comprehensive review of historical information and a field investigation. Results from these activities are reviewed with DOE-RL and the lead regulatory agency. Potential "orphan" sites are evaluated under the TPA-MP-14 (*Tri-Party Agreement Handbook Management Procedures* [RL-TPA-90-0001]) discovery site process. The 100-K decision area was addressed by a combination of three separate OSE reports including all of the 100-K OSE (OSR-2008-0003, *100-K Area Orphan Sites Evaluation Report*), parts of the Segment 1 OSE (OSR-2009-0002, *100-F/IU-2/IU-6 Area – Segment 1 Orphan Sites Evaluation Report*), and the Segment 4 OSE (OSR-2011-0001, *100-F/IU-2/IU-6 Area – Segment 4 Orphan Sites Evaluation Report*). Within the 100-K decision area, 22 orphan sites (new discovery sites) were identified through the OSEs and are addressed and evaluated in this report.

Air Emission Reports. Two source groups of Hanford Site stack air emissions had the potential to affect the River Corridor by air deposition. The first source group, where most of the Hanford Site stack air emissions occurred between 1944 and 1972, were the facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel. The second source group, the nine production nuclear reactors in the 100 Area, had stacks to exhaust ventilation air from the working areas of the reactor facilities. The 100 Area stacks were minor sources of emissions compared to the 200 Area facilities that separated plutonium and uranium from irradiated reactor fuel (DOE/RL-2005-49, *RCBRA Stack Air Emissions Deposition Scoping Document*). Aerial radiation surveys of the Hanford Site and widespread sampling over many years support this conclusion (EGG-10617-1062, *An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington*).

Environmental Monitoring Programs. Data from ongoing monitoring programs and investigations were also used as described in Appendix I. A number of these programs are described in Chapter 2, starting in Section 2.1.5 and continuing through Section 2.1.13.

Statistical Modeling. Statistical modeling was used to support the data analyses and development of technical recommendations such as additional sampling for the nonoperational areas in the River Corridor. The modeling used established approaches and data sets used in the Hanford Site Central Plateau and adapted to the River Corridor. In addition to the CSMs developed for the Central Plateau, the CSM for the River Corridor addressed potential for overland flow, and effects on riparian and nearshore areas. Statistical analysis was used to represent the conceptual models and incorporate the available data to support a quantitative basis for the probability that a (undiscovered) waste site might exist in the nonoperational areas. As a result of these efforts, no additional waste sites were found in the nonoperational areas of 100-K that pose a threat to human health and the environment. Appendix I describes the nonoperational evaluation process for the River Corridor, data and information used, and conclusions and recommendations. It includes results and conclusions for 100-K.

1.2.3.7 Previous Groundwater Investigations and Remediation

Groundwater monitoring projects are established under DOE Order 5400.1 Chg 1, *General Environmental Protection Program*, to meet the requirements of DOE Order 5400.5 Chg 2, *Radiation Protection of the Public and the Environment*, which pertains to radiation protection of the public and the environment, and federal and state regulations.

The earliest well installations at 100-K were from 1952 to 1956, prior to or early in the reactor operations. Wells 199-K-1 through 199-K-26 were installed during this time near the 100-K Reactors and near the 116-K-2 Trench. Many of these wells penetrated only into the vadose zone. The emphasis was on detection of radionuclides, but by 1962, at least a few of the wells (e.g., 199-K-10, 199-K-11, 199-K-19, 199-K-20, and 199-K-21) were sampled for nitrate. Wells 199-K-11, 199-K-20, and 199-K-25 were sampled as early as 1969 for Cr(VI), but most wells from that era have been abandoned with no record of contaminant concentrations. Concentrations of Cr(VI) from 5.3 to 17.5 µg/L were reported at well 199-K-11, along with total chromium concentrations ranging from nondetect to 34.3 µg/L. Well 199-K-20, which lies between the 116-K-2 Trench and the Columbia River, had Cr(VI) concentrations from 1 to 4 µg/L for 11 sample events, and 64 µg/L in one sampling event between 1969 and 1973. Many of these wells have been decommissioned, and only wells 199-K-11, 199-K-13, 199-K-18 through 199-K-22, and 199-K-25 remained in active status as of December 2016. Wells were installed in the 600 Area from 1966 to 1981 to evaluate overall conditions in the 100 Area, including near 100-K.

General aquifer characteristics of the Hanford Site, including early sitewide groundwater flow maps showing general directions and average rates of groundwater flow were published in 1959 (HW-60601, *Aquifer Characteristics and Ground-Water Movement at Hanford*). HW-60601 evaluated and summarized aquifer testing and aquifer properties. Hanford operations actively discharged a variety of water and liquid wastes to the surface at locations such as B Pond and Gable Mountain Pond in the 200 Area, as well as the 100 Area retention basins and trenches. Groundwater mounds developed at these locations and affected groundwater flow across much of the Hanford Site, including at 100-K. Changes in the water table from 1950 to 1980 are documented in a 1986 report (PNL-5506, *Hanford Site Water Table Changes 1950 Through 1980: Data Observations and Evaluation*). The report describes water level changes at five-year intervals at a network of wells across the Hanford Site.

In 1967, a test disposal of reactor coolant effluent to trenches was conducted for 100-F and 100-D (DUN-3259, *Program Review—Ground Disposal of Reactor Effluent*). Testing discharges were made to the 116-F-14 and 116-DR-1&2 Trenches. Discharge rates to the trenches ranged from 30,280 to 60,560 L/min (8,000 to 16,000 gal/min) at 100-F and 17,000 to 104,000 L/min (4,500 to 27,500 gal/min) at 100-D. In the 1970s, concerns increased about radiological contamination of groundwater at Hanford, and researchers began to investigate various groundwater issues, from the vertical distribution of radioactive contamination (PNL-2724, *Vertical Contamination in the Unconfined Groundwater at the Hanford Site, Washington*) to general radiological groundwater contamination (PNL-3768, *Radiological Status of the Ground Water Beneath the Hanford Site January – December 1980*).

Wells 199-K-27 to 199-K-30 were installed in 1979 to determine effects from the KE FSB, and well 199-K-31 was installed in 1986 to supplement the 1979 wells (DOE/RL-90-21, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington*). Seven additional wells were installed in 1992 to enhance monitoring near the KE and KW FSBs. These included wells 199-K-32A, 199-K-32B, and 199-K-33 through 199-K-37. Additional wells 199-K-106A, 199-K-107A, and 199-K-108A were installed in 1994, and wells 199-K-112A through 199-K-119A were installed in 1996 (WHC-SD-EN-AP-153, *Installation of Groundwater Monitoring Wells in Support of the 100-K Area Fuel Storage Basins*).

By the mid-1980s, routine sampling included nonradiological constituents such as nitrate and chromium, but Cr(VI) was not regularly included until the early 1990s. Routine sampling for Cr(VI) began from 1992 to 1996.

By 1988, it was determined that groundwater remedial action would be needed under CERCLA or RCRA in the 100 Area. The initial work plan (DOE/RL-90-21) was developed under RCRA and was compatible with CERCLA. The 100-KR-4 LFI and a qualitative risk assessment (WHC-SD-EN-RA-010, *Qualitative Risk Assessment for the 100-KR-4 Groundwater Operable Unit*) were completed in 1994.

Construction of the 100-KR-4 OU interim remedy started after approval of the 100-HR-3 and 100-KR-4 OU ROD (EPA/ROD/R10-96/134) in 1996. Concurrent with the startup of the KR-4 P&T system, DOE/RL-96-90, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*, hereinafter referred to as the Interim Action Monitoring Plan (IAMP), was completed. The IAMP identified monitoring for the 100-HR-3 and 100-KR-4 P&T systems. The IAMP was modified in 1998 by a letter from Ecology to DOE (Wanek, 1998, "Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Units (OU)"). Wells were also added to the monitoring system through the TPA Change Notice process. The SAP for 100-KR-4 was updated in 2016 (DOE/RL-2013-29, *Sampling and Analysis Plan for 100-KR-4 Groundwater Operable Unit Monitoring*) to incorporate changes to the well network and align sampling needs with the interim actions. Wells added at 100-K for the interim RA are discussed under Groundwater Remediation later in this section.

Historical groundwater monitoring results for 100-K are presented in Chapter 4, and Appendix A shows the locations of 100-K groundwater wells. Groundwater monitoring wells in 100-K are routinely sampled for a variety of analytes as identified in DOE/RL-2013-29. Sample collection intervals are based on data needs. Groundwater data are used to evaluate treatment system performance, create maps and plots that illustrate groundwater flow and water table elevations, and assess geochemistry, contaminant concentration trends, and distribution. The results have been published annually in Hanford Site Groundwater Monitoring Reports since 1980 (e.g., DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*) and are discussed in Chapter 4.

In addition to the groundwater investigations, several pore water, aquifer tube, and Columbia River studies have been performed that are relevant to 100-K (summarized in the following paragraphs and in Appendix B, Table B-1). These studies addressed the entire River Corridor and have direct relevance to activities at 100-K.

Columbia River Studies. River Corridor studies involving groundwater (often referred to in this context as *groundwater seeps, pore water* or *groundwater upwelling*) that are pertinent to Columbia River water quality and ecological risk include the following:

- DOE/RL-92-12, *Sampling and Analysis of 100 Area Springs*
- BHI-00778, *Chromium in River Substrate Pore Water and Adjacent Groundwater: 100-D/DR Area, Hanford Site, Washington*
- WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*, hereinafter called Columbia River RI Report
- CRC (DOE/RL-2010-117, Volumes I and II)

The nature and extent of groundwater contaminants entering the Columbia River is of great interest, especially regarding the effect to water quality and aquatic plants and animals. Groundwater seeps (small water streams flowing across shoreline areas during low river stage periods) have been identified and studied in the 100 Areas (DOE/RL-92-12) and 300 Area. Pore water or groundwater upwelling (groundwater entering into the space between rocks and sediment of the riverbed) were studied in the 100 and 300 Areas. Upwelling areas were identified using specific conductivity and/or water temperature data (riverbed locations with higher conductivities and/or warmer temperatures than the Columbia River water column are indicative of groundwater entering the bottom of the river) and subsequently characterized to determine contaminant concentrations in surface water, sediment, and pore water at those locations.

The first pore water study in the Hanford Reach of the Columbia River was conducted in 1994 (BHI-00778). It was designed to collect pore water quality/contaminant data for determining the potential exposure and risk to ecological receptors, particularly from Cr(VI) (BHI-00156, *Preliminary Determination of Chromium Concentration Within Pore Water and Embryonic Chinook Salmon at Hanford Reach Spawning Area in Proximity to 100-HR-3 Operable Unit*). Embryonic Chinook salmon were selected as the target receptor for the study because during their early life stages (egg and sac-fry), they have limited mobility, spend most of their time within or near the river substrate, and thus could be exposed to Cr(VI) in pore water. The appropriate season for pore water sampling was determined to be Fall (during low river stage, relatively high groundwater discharge to the river, and active salmon spawning). Salmon redds were identified by aerial surveys to establish when salmon spawning began and to determine locations where pore water samples should be collected for Cr(VI) analysis.

More recent surface water, pore water, and sediment studies were conducted in 2009 and 2010 in the River Corridor (WCH-380). The sample locations for this investigation include sites adjacent to 100-K, and results are provided in Chapters 2 and 4 of this RI.

Aquifer Tubes. Suites of aquifer tubes were installed along the Columbia River throughout the River Corridor between 1997 and 2008 for measurement of water quality of the groundwater/surface water interface. Aquifer tubes are small-diameter tubes with stainless steel screens that are driven into the aquifer along the Columbia River shoreline. They are used to monitor the uppermost, unconfined aquifer and typically terminate one to two meters below the water table in unconsolidated, permeable sediments. Ringold Formation upper mud (RUM) sediments typically cannot be penetrated using the percussion method for tube installation. Sampling of these tubes is governed by DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*, hereinafter called SAP for Aquifer Sampling Tubes, revised in 2009. Aquifer tube results are provided in Chapters 2 and 4.

Aquifer Testing in 100-K. Pumping tests were conducted in the early 1990s at wells downgradient of the 116-K-2 Trench, notably wells 199-K-18 to 199-K-22. In addition, slug tests were performed at existing wells during drilling campaigns from 1992 to 1994. These pumping and slug test results are summarized in SGW-41213, *100-KR-4 Remedial Process Optimization Modeling Data Package*. Ringold Formation unit E saturated hydraulic conductivities measured at 17 100-K wells ranged from 0.88 to 44 m/day (3 to 145 ft/day).

Additional withdrawal slug test data were analyzed for 15 wells in 100-K (ECF-100KR4-12-0010, *Analysis of Slug Test Data at the 100-KR-4 OU*). The estimated hydraulic conductivities ranged from 0.7 to 28 m/day (2.3 to 92 ft/day) for Ringold Formation unit E aquifer properties for 14 wells.

Other Groundwater Studies. A treatability test using calcium polysulfide for chromium reduction was performed at a well cluster northeast of the 116-K-2 Trench. The test plan (DOE/RL-2005-05, *Treatability Test Plan for Fixation of Chromium in the Groundwater at 100-K*) describes the reduction of Cr(VI) to trivalent chromium as an immobile, nonhazardous hydroxide through interaction with

the polysulfide. The additional reaction of sulfate reducing bacteria with precipitated sulfate further reduced the Cr(VI). The best results required adding an organic food source as part of the treatment. A five-well "spot test" array used a central well as an extraction point and a surrounding diamond pattern of injection wells to feed the calcium polysulfide and a vegetable oil food source into the aquifer. Results are in DOE/RL-2006-17. The test was successful in eliminating Cr(VI) from local groundwater, as observed when sampling groundwater at the extraction well and at the injection wells. Dissolved oxygen (DO) and oxidation/reduction potential were also reduced, leading to the local formation of a persistent, permeable reactive barrier. Arsenic, manganese, and iron were mobilized during the treatment. Arsenic and manganese increased in concentration in the extraction well and injection wells. Monitoring after the test indicated arsenic concentrations decreased soon after pumping ceased from the extraction well, but continued rising in three of the four injection wells. Manganese concentrations continued to rise in the extraction well, but not in the injection wells. Iron remained at low levels throughout the test, but increased after the test ended. Concentrations of these constituents remained below DWSs. One effect noted in the test was precipitation of chemicals in pumps, piping, and flow meters that lowered flow rates in the system.

As described in DOE/RL-2013-33, *Remedial Design/Remedial Action Work Plan for the 100-KR-4 Groundwater Operable Unit* (hereafter referred to as the 100-KR-4 remedial design/remedial action work plan [RD/RAWP]), once concentrations are below the interim remedial action target concentration, a rebound study will be initiated to determine if contaminant concentrations will remain below target levels when the aquifer is no longer under the influence of active remedial processes. In January 2016, the groundwater wells (including extraction wells and monitoring wells) near the KW pump and treat system exhibited Cr(VI) concentrations less than the 20 µg/L groundwater target concentration level. A statistical trend analysis confirmed that the groundwater Cr(VI) concentrations were expected to continue to decrease from their measured concentrations. The results of this analysis indicated it was appropriate to conduct a Cr(VI) rebound test to assess potential Cr(VI) concentration rebound due to potential secondary contamination sources in the periodically rewetted zone (PRZ) and in the overlying vadose zone. Results of the rebound test are in SGW-62061, *KW Rebound Study Summary Report and Assessment*, with further descriptions in Section 4.4.

Groundwater Remediation. In 1995, DOE/RL-94-48, *100-KR-4 Operable Unit Focused Feasibility Study* and DOE/RL-94-113, *Proposed Plan for Interim Remedial Measure at the 100-KR-4 Operable Unit* were issued. A pilot-scale P&T treatability test report DOE/RL-95-83, *The Pilot-Scale Treatability Test Summary for the 100-HR-3 Operable Unit* was completed at the end of 1995, and the interim action ROD followed in April 1996. The RDR/RAWP (DOE/RL-96-84, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*) was issued in September 1996. Construction of the initial KR-4 P&T system was completed in June 1997, and full-time operation began in September 1997. The P&T system uses a series of extraction wells equipped with submersible pumps to draw groundwater from the unconfined aquifer. Extracted groundwater is conveyed through aboveground piping to collection tanks. Groundwater is pumped from the collection tanks to an enclosed treatment system where Cr(VI) is removed by IX. Treated groundwater is returned to the aquifer by transfer through aboveground pipes to injection wells.

The P&T systems are designed to prevent discharge of Cr(VI) to the Columbia River at concentrations that would result in exceedance of the state surface water quality standard of 10 µg/L, as identified in the interim action ROD (EPA/ROD/R10-96/134). The initial design placed extraction wells immediately upgradient of locations where Cr(VI) was detected in the near river substrate to achieve the RAO for river protection. As the CSM has been further developed and the Cr(VI) plumes have been better defined, the interim RA has targeted inland locations to prevent discharge of Cr(VI) contaminated groundwater to the

Columbia River, limit plume migration, and remove contaminant mass from inland areas of the plumes. An additional RAO for this interim remedy was to provide information that would lead to a final remedy.

The KR-4 P&T system was designed to meet the RAOs by providing hydraulic containment of the Cr(VI) plumes and preventing discharge to the Columbia River. As additional information on the distribution of Cr(VI) contamination was identified, the remedy has been expanded with addition of the KW and KX systems. The KW P&T system addresses Cr(VI) around the KW Reactor, as described in DOE/RL-2006-52, *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*. The KX system began operating in February 2009, as described in DOE/RL-2006-75, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System*, hereinafter called Supplement to the 100-HR-3 and 100-KR-4 RDR/RAWP. Similar to the KW expansion, the KX system increases the P&T system capacity. Table 1-10 presents a chronological summary of actions for the 100-KR-4 OU Cr(VI) interim RA.

Table 1-10. Chronological Summary of 100-KR-4 CERCLA Actions and Associated Activities

Month/Year	Activity	Documentation
September 1994	A qualitative risk assessment was completed, identifying Cr(VI) as a contaminant of concern for ecological receptors in the Columbia River.	DOE/RL-93-79, L*imited Field Investigation Report for the 100-KR-4 Operable Unit* WHC-SD-EN-RA-010, *Qualitative Risk Assessment for the 100-KR-4 Groundwater Operable Unit*
August 1995	The proposed plan recommended the use of a P&T system as an interim remedial action to mitigate Cr(VI) migration to the Columbia River.	DOE/RL-94-48, *100-KR-4 Operable Unit Focused Feasibility Study* DOE/RL-94-113, *Proposed Plan for Interim Remedial Measure at the 100-KR-4 Operable Unit*
December 1995	The pilot-scale treatability test report indicated that removing Cr(VI) from extracted groundwater in the 100-HR-3 OU using an IX resin treatment was viable. The treatability test results also applied to the 100-KR-4 OU.	DOE/RL-95-83, *The Pilot-Scale Treatability Test Summary for the 100-HR-3 Operable Unit*
April 1996	The interim action ROD (EPA/ROD/R10-96/134) specified installing a P&T system in the 100-KR-4 Groundwater OU to intercept portions of the Cr(VI) plumes that affect the Columbia River.	EPA/ROD/R10-96/134, *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington*
September 1996	The RDR/RAWP identified the design and work to accomplish the interim remedial action using P&T.	DOE/RL-96-84, Rev. 0, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*

Table 1-10. Chronological Summary of 100-KR-4 CERCLA Actions and Associated Activities

Month/Year	Activity	Documentation
September 1997	The KR4 P&T system began full-time operation. The KR4 system processes extracted groundwater through an IX system to remove Cr(VI) and returns treated groundwater to the aquifer. IX resin is regenerated offsite.	TPA (Ecology et al., 1989a) Milestone M-16-11
April 2003	This RD/RAWP revision included updated reporting requirements and an addendum with a summary of major modifications made to the systems after 1997.	DOE/RL-96-84, Rev. 0-A, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*
January 2007	The KW P&T system began operation to address contamination around the KW Reactor. The KW P&T system processes the extracted groundwater through an IX system that removes the Cr(VI) and returns the treated groundwater to the aquifer. IX system resin is regenerated onsite.	DOE/RL-2006-52, Rev. 1, *The KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*
August 2008	Installed wells 199-K-165, 199-K-166, 199-K-168, and 199-K-173 for P&T expansion.	SGW-39635, *Borehole Summary Report for Installation of Four Groundwater Wells at 100-KW, FY 2008*
February 2009	The KX P&T system began operation, expanding the area of influence around the 116-K-2 trench. The KX P&T system processes the extracted groundwater through an IX system that removes Cr(VI) and returns treated groundwater to the aquifer. IX system resin is regenerated onsite.	DOE/RL-2006-75, *Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Work Plan for the Expansion of the 100-KR-4 Pump-and-Treat System*
August 2009	An ESD was issued to provide notice of revisions to the cost estimate and reinjection locations associated with the P&T interim action. An expansion of the P&T system was identified in the future cost estimate. The ESD also revised the reinjection standards and location requirements for treated water.	EPA et al., 2009b, *Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision: Hanford Site, Benton County, Washington*
October 2009	The RI/FS SAP was approved.	DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*
March 2010	The RI/FS Work Plan was approved. Field work began for drilling 13 boreholes and installing 15 monitoring wells. Two trenches were completed, and 3 aquifer tubes were installed. Field work was completed in February 2011.	DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*

Table 1-10. Chronological Summary of 100-KR-4 CERCLA Actions and Associated Activities

Month/Year	Activity	Documentation
September 2011	100-K RI/FS Report (Draft A) was submitted.	DOE/RL-2010-97, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*
September 2011	100-K Proposed Plan (Draft A) was submitted.	DOE/RL-2011-82, *Proposed Plan for Remediation of the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*
November 2012	Summary of DOE Actions Meeting Milestone M-016-110-T01.	12-AMRP-0172, "Completion of Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Target Milestone M-016-110-T01, 'DOE Shall Take Actions Necessary to Contain or Remediate Hexavalent Chromium Groundwater Plumes in Each of the 100 Area National Priority List Operable Units Such That Ambient Water Quality Standards for Hexavalent Chromium are Achieved in the Hyporheic Zone and River Water Column'"
2020*	TPA milestone for DOE to take actions necessary to remediate Cr(VI) groundwater plumes such that Cr(VI) will meet DWSs in each of the 100 Area NPL operable units due by 12/31/2020.	TPA (Ecology et al., 1989a) Milestone M-016-110-T02

*Indicates TPA milestone date and a planned future activity.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
DWS = drinking water standard
ESD = explanation of significant difference
IX = ion exchange
NPL = National Priorities List
P&T = pump and treat
RI/FS = remedial investigation/feasibility study
SAP = sampling and analysis plan
TPA = Tri-Party Agreement

The 100-K Cr(VI) plume is divided into four plume areas based on likely contaminant sources. The two largest plumes, associated with the former 116-K-2 Trench, are being remediated by the KX and KR-4 systems. The third-largest plume being remediated by the KW system is located around the KW Reactor. The smallest plume area, located downgradient of the KE Reactor, is also being remediated by the KX system. Figures 1-20 and 1-21 illustrate the Cr(VI) plume in 2009, and Figure 1-22 shows remediation progress through calendar year 2016. Progress of the interim RA is provided in annual reports, such as DOE/RL-2016-68, *Calendar Year 2016 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation*. Figure 1-22 shows the P&T systems configurations in 2016.

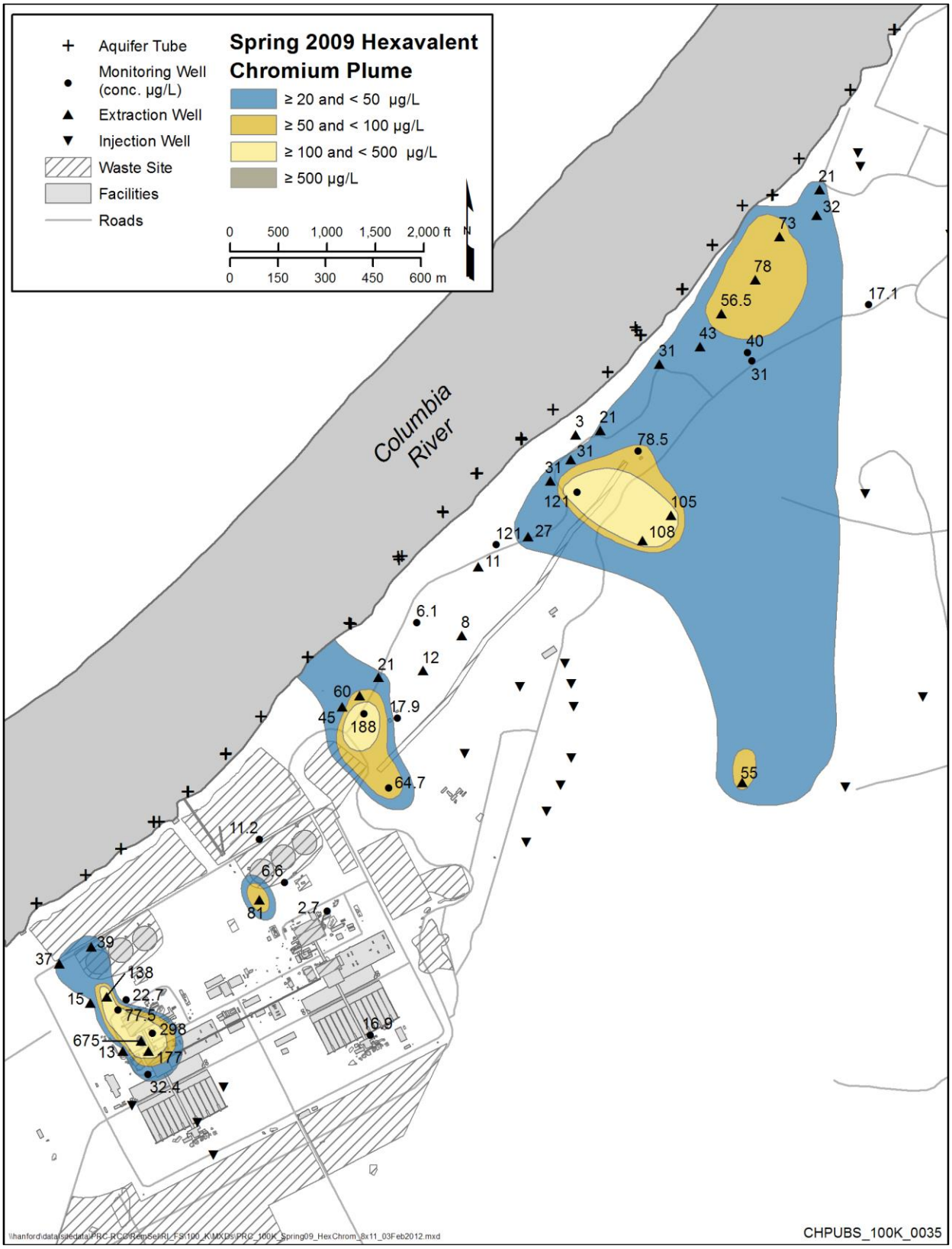


Figure 1-20. 100-K Cr(VI) Plume Remediation Progress in Spring 2009

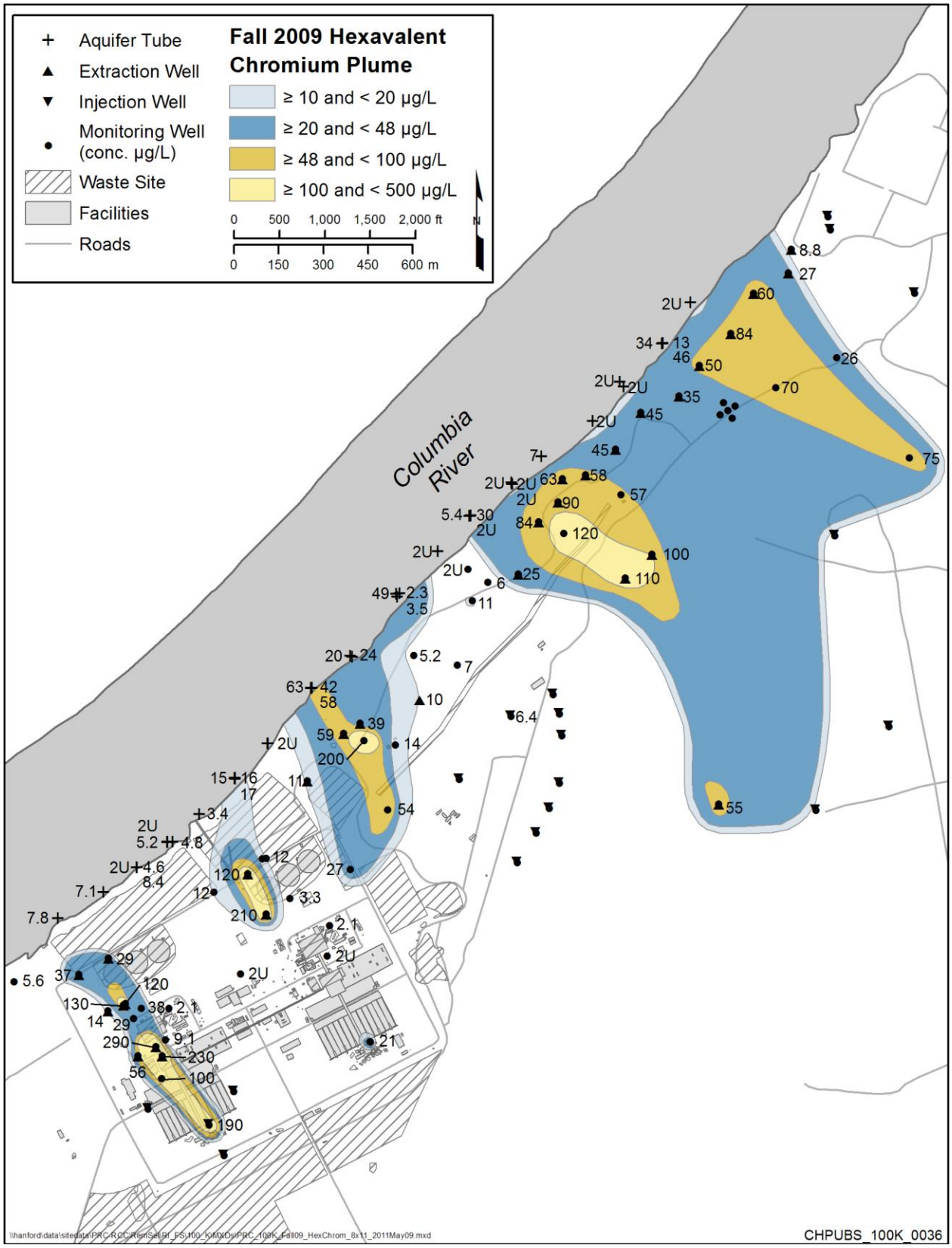


Figure 1-21. 100-K Cr(VI) Plume Remediation Progress in Fall 2009

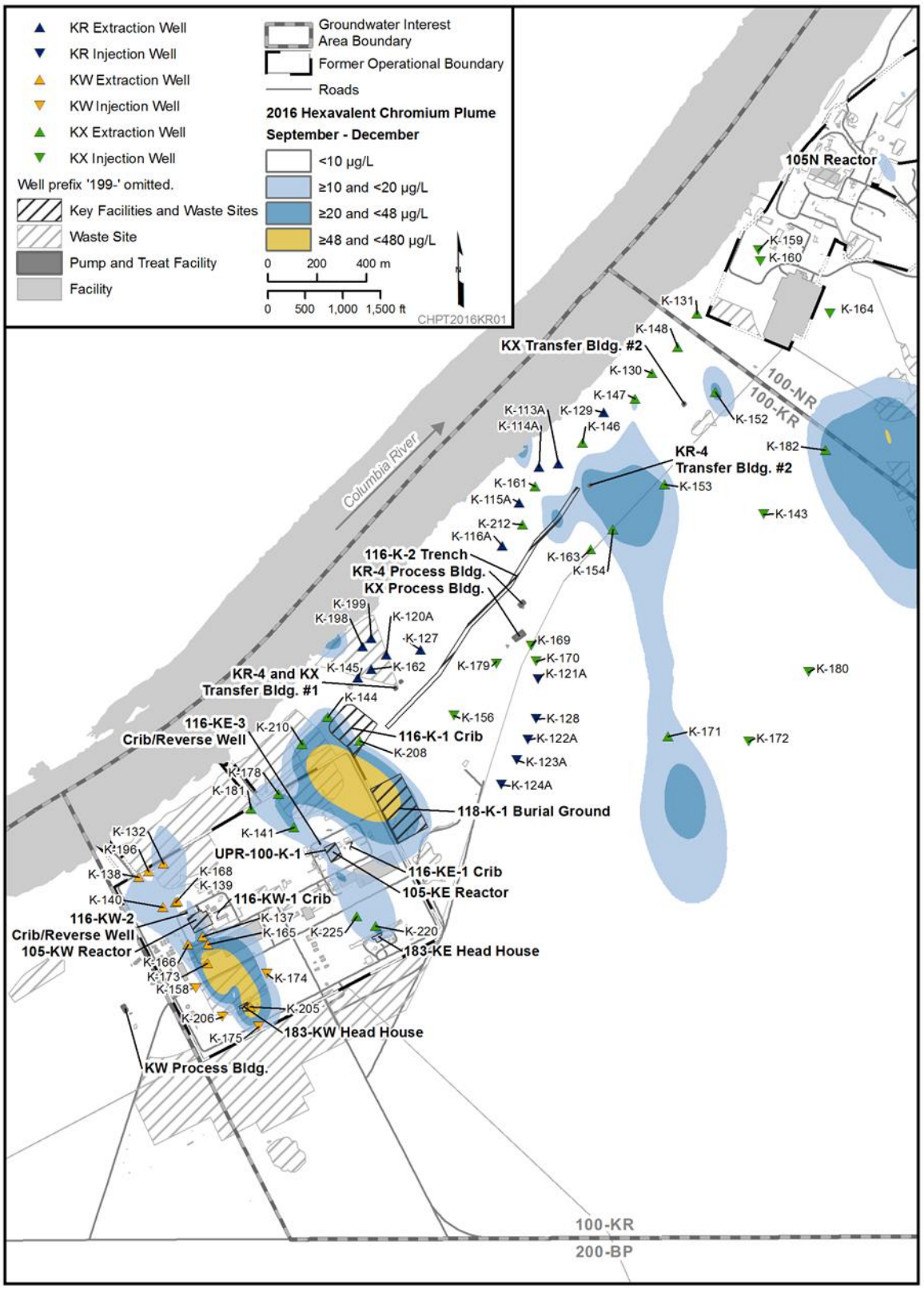


Figure 1-22. 100-KR-4 OU P&T Systems Layout (as of December 31, 2016)

The KR-4 P&T system began operating in 1997 with seven extraction wells, four injection wells, and an IX resin treatment train to remediate the Cr(VI) plume between the former 116-K-2 Trench and the Columbia River. As additional monitoring wells and aquifer tubes were added since 1997, plume boundary interpretations also changed, and the P&T network was modified. A series of modifications was made to the KR-4 network between 1997 and 2008, as described in DOE/RL-2006-75. In addition, well realignments (changes from monitoring to extraction, extraction to monitoring, extraction to injection, and injection to monitoring) have been implemented as part of remedial process optimization (RPO). A 2009 realignment was made to control a tritium plume. The alignment created a partial recirculation system that contains and localizes the tritium within a smaller area. Additional realignments and system improvements are described in annual reports. At the end of 2016, the KR-4 P&T system included 11 extraction wells, 5 injection wells, and an average pumping rate of 1,116 L/min (295 gal/min). From startup through the end of calendar year (CY) 2016, the KR-4 P&T system treated 8.48 billion L (2.24 billion gal) and removed 378 kg (833 lb) of Cr(VI).

High Cr(VI) concentrations discovered in well 199-K-137, one of the originally proposed injection wells, resulted in preparation of DOE/RL-2006-52 and installation of the KW P&T system. The 379 L/min (100 gal/min) capacity KW P&T system began treating Cr(VI) in groundwater near and downgradient of the KW Reactor in January 2007, using the same IX process employed in the KR4 system. The original KW system extracted groundwater from four wells and returned the treated groundwater to the subsurface via two wells. The KW P&T system was expanded by 2011 to increase the initial design treatment capacity up to 760 L/min (200 gal/min). As part of this expansion, the well network was modified to connect a total of 11 extraction wells and 4 injection wells. From startup through the end of CY 2016, the KW P&T system treated 3.81 billion L (1.01 billion gal) of groundwater and removed 241 kg (531 lb) of Cr(VI).

The KX P&T system was primarily designed to treat Cr(VI) located between the northern end of the 116-K-2 Trench and the N Reactor fence line (also known as the K North plume). The system began treating groundwater in November 2008, using the same IX process as KR-4. The initial design included 14 extraction wells, 9 injection wells, and a treatment capacity up to 2,300 L/min (600 gal/min). The injection wells on the northeastern plume border were located to minimize Cr(VI) plume migration further into 100-N. Over the past several years, optimization activities have increased the operational capacity to 3,407 L/min (900 gal/min). From startup through the end of CY 2016, the KX P&T system treated 8.99 billion L (2.37 billion gal) of groundwater and removed 248 kg (548 lb) of Cr(VI).

Table 1-11 summarizes the P&T system capacities at the end of 2016. The removal efficiency and treatment performance of the KR-4, KW, and KX systems are presented in annual groundwater monitoring reports. Section 4.4 provides additional discussion of groundwater remedial action progress.

Groundwater Ion Exchange Resin Evaluations. Several resin evaluations and process alternatives analyses were performed to develop SGW-46621, *100 Area Groundwater Chromium Resin Management Strategy for Ion Exchange Systems*. Development of the strategy included a decision analysis workshop in May 2010 to select the optimal IX resin management process for 100-K with extension to the entire 100 Area. The decision analysis considered the following regeneration options:

- Offsite—remote regeneration (current practice)
- Offsite—near-site regeneration
- Onsite—at a central regeneration facility
- In-vessel regeneration

Table 1-11. 100-KR-4 OU Pump and Treat Systems Summary as of December 2016

System	System Startup	Original Design Capacity L/min (gal/min)	2016 Operational Capacity L/min (gal/min)	Number of Extraction Wells	Number of Injection Wells
KR-4	October 1997	1,137 (300)	1,249 (330)	11	5
KX	February 2009	2,300 (600)	3,407 (900)	21	10
KW	January 2007	757 (200)	1,249 (330)	11	4
	Totals	4,194 (1,100)	5,905 (1,560)	43	19

A resin skid was located at the KX Plant to test Dowex 21K, which was then in use; Purolite A500®; ResinTech SIR-700; and WBG30-B. The resin testing and subsequent alternatives analysis indicated that ResinTech SIR-700 provided significant savings in terms of life-cycle costs over Dowex 21K. Implementation of SIR-700 began with the expanded KW P&T Facility in 2009. The initial operation was limited to validating predicted Cr(VI) removal, selecting the operating pH range, and confirming compatibility of the vessel lining with the reduced pH. EPA approval for use in the 100-KR-4 P&T facilities was provided in TPA-CN-505, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System, DOE-RL-2006-75 REISSUE, Rev. 1*, through a reissue of DOE/RL-2006-75.

Remedial Process Optimization. Ongoing evaluation of the P&T systems in the 100-KR-4 OU are conducted to implement changes to optimize system performance, referred to as RPO. RPO is an ongoing systematic evaluation that includes an examination of various remedial system components. System elements evaluated include extraction well performance, extracted water conveyance performance, treatment process performance, treated water conveyance performance, and injection well performance. System performance is evaluated annually in conjunction with preparation of the inferred contaminant plume distribution maps to identify specific locations where changes in pumping rates and/or installation of additional extraction and/or injection wells can expedite remedial performance. The evaluations identify opportunities to enhance the system and improve performance in meeting RAOs for river protection, mass removal, and CSM refinements such as plume delineation.

The RPO modifications to the P&T systems at 100-K are summarized in the annual P&T reports (e.g., DOE/RL-2016-68). Changes from 2012 through 2016 include the following:

- 2012 – two extraction wells were converted to monitoring wells and two monitoring wells were converted to extraction wells to improve Cr(VI) mass removal at the KX system. The KW P&T system capacity was increased from 758 L/min (200 gal/min) to 1,61 L/min (280 gal/min). One monitoring well was converted to an extraction well at the KW system. Treatment resin in the KX and KR4 P&T systems was changed from Dowex 21K to SIR-700.

® Purolite A500 is a registered trademark of the Purolite Company, Bala Cynwyd, Pennsylvania.

- 2013 – two monitoring wells were converted to extraction wells at the KW system for river protection and hydraulic control. One monitoring well was converted to an extraction well at the KX system for river protection and hydraulic control, and one monitoring well was installed.

- 2014 – conversion of two monitoring wells to extraction wells for river protection and hydraulic control was completed at the KR4 system. Two extraction well installations, one for mass removal and one for hydraulic control, were completed at the KW system. Four extraction wells, three for river protection and hydraulic control and one for mass removal, were installed at KX. Three monitoring wells were installed near the reactors for plume delineations.

- 2015 – one extraction well for river protection and hydraulic control was installed and one monitoring well was converted to an injection well at KX. Four monitoring wells were installed for plume delineations.

- 2016 – one extraction well and one injection well were realigned from the KR4 to the KX P&T system to improve hydraulic containment and increase injection capacity, and one injection well was realigned to increase injection capacity at the KR4 P&T system. All wells in the KW P&T system were disconnected to perform the KW rebound study. One extraction well was installed and pump capacity was increased at one well to increase mass removal at the KX system.

1.2.3.8 Risk Assessments

Risk assessments were conducted for the 100 Area to provide the foundation for establishing the need for remedial action to protect human health and the environment. The QRAs in the LFIs for the 100-KR-1 and 100-KR-4 OUs identified risk to human health and ecological receptors, which led to implementation of the interim remedial action for waste sites and groundwater. The RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) are summarized in the following paragraphs. RCBRA and CRC results are described and used in Chapters 4, 6, and 7 of this RI.

Qualitative Risk Assessments. QRAs were conducted to define the basis for remedial actions under interim action RODs (DOE/RL-91-40). Human health risks were assessed based on frequent use and occasional use scenarios. COPCs were identified from historical site data and data collected during the LFIs. The QRAs also considered Hanford Site background activity of radionuclides, inorganic contaminant concentrations in the vadose zone, and risk-based screening using residential exposure parameters (DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*). Human health risks presented in the QRAs were based on the maximum concentrations detected in waste site vadose zone material and in groundwater. Human health risks were quantified for a limited set of exposure pathways (soil ingestion, fugitive dust or volatile inhalation, and external exposure). Ecological risks were estimated using a streamlined approach, focusing on a single receptor, the Great Basin pocket mouse, using the assumption that the waste site was the home range.

River Corridor Baseline Risk Assessment. The RCBRA (DOE/RL-2007-21, Volumes I and II) has been conducted to characterize current and potential future risks to human health and the environment that may be posed by releases of contaminants in the River Corridor. The RCBRA supports the current remediation decisions and consists of a human health risk assessment (HHRA) and an ecological risk assessment (ERA), respectively.

The HHRA (DOE/RL-2007-21, Volume II) provides an assessment of residual risks for remediated waste sites using the unrestricted land use exposure scenario that was the basis for the interim action ROD cleanup levels. The RCBRA (DOE/RL-2007-21, Volume II) provides an assessment of residual risks for remediated waste sites and broad areas using a range of hypothetical receptors. A screening level

groundwater risk assessment was also completed to evaluate potential risks associated with exposure to contaminated groundwater.

An ERA was conducted in the RCBRA to determine if the interim actions were protective of ecological receptors (DOE/RL-2007-21, Volume I). The ERA addressed upland areas, including remediated CERCLA waste sites, riparian and nearshore aquatic zones, as well as groundwater and areas of groundwater emergence on the south and west shoreline of the Columbia River. Conclusions from the RCBRA ERA (DOE/RL-2007-21, Volume I) are reviewed in Section 7.5.1.

Columbia River Component Risk Assessment. The CRC (DOE/RL-2010-117) provided a comprehensive HHRA (Volume II) and a screening level ERA (Volume I). The intent of the CRC HHRA (DOE/RL-2010-117, Volume II) was to complete the assessment of the bank-to-bank Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA (DOE/RL-2007-21, Volume I). Human exposure scenarios included an avid angler, casual user, hypothetical future resident, and a Native American (Yakama Nation) subsistence fisher. The CRC HHRA (DOE/RL-2010-117, Volume II) identified fish consumption as the largest potential contribution to overall human health risks. The CRC (DOE/RL-2010-117, Volume I) also used results from surface water, sediment, pore water, island soils, and fish samples to evaluate the potential for risk to ecological receptors. The CRC identified some contaminants (mostly metals) as contaminants of potential ecological concern (COPECs) and considered whether COPECs are attributable to Hanford Site sources. Conclusions from the CRC HHRA (DOE/RL-2010-117, Volume II) are discussed in Section 6.4.2, and the CRC (DOE/RL-2010-117, Volume I) ERA conclusions are reviewed in Section 7.5.2.

1.2.3.9 Riparian and Nearshore Areas

The River Corridor is divided into three environmental zones (upland, riparian, and nearshore aquatic) for purposes of investigation (RCBRA Volume I [DOE/RL-2007-21]; Integrated Work Plan [DOE/RL-2008-46]). The three zones are described in Section 3.10.

Riparian and nearshore environments are of specific interest in the 100 and 300 Areas. The riparian zone contains plant communities requiring more water than the shrub-steppe vegetation of the upland zone, and because of the shallow water table, is generally green throughout the year (PNNL-SA-41467, *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* [hereinafter called RCBRA Literature Review]). While the wildlife and food webs of the upland and riparian zones overlap, some wildlife species occur specifically within the riparian zone (BHI-01757, *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA*). The nearshore zone is more frequently under water, and is capable of sustaining aquatic biota.

Historical investigations conducted in the riparian and nearshore areas of 100-K are summarized in the RCBRA *L*iterature Review (PNNL-SA-41467). In addition to these historical investigations, other sampling and analytical data were collected from riparian and nearshore areas under DOE/RL-91-50, *Environmental Monitoring Plan United States Department of Energy Richland Operations Office*. These data are summarized in the annual environmental reports for the Hanford Site (e.g., DOE/RL-2017-24, *Hanford Site Environmental Report for Calendar Year 2016* [hereinafter called 2016 Sitewide Environmental Report]. Investigations of riparian and nearshore areas were also conducted as part of the RCBRA (Volume I [DOE/RL-2007-21]; DOE/RL-2005-42, *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan*, hereinafter called the RCBRA SAP).

In 1983, riverbank springs and groundwater seeps along the length of the Hanford Site shoreline were identified, and samples of groundwater, riverbank springs, and adjacent surface water were collected

(PNL-5289, *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River*). For 100-K samples, the highest concentrations of tritium reported were 49,000 pCi/L in groundwater, 5,500 pCi/L in springs, and 300 pCi/L in surface water.

In addition to historical investigations, other sampling and analytical data are collected from riparian and nearshore areas under DOE/RL-91-50. The data are presented in annual environmental reports for the Hanford Site (e.g., 2016 Sitewide Environmental Report).

Riverbank springs and adjacent surface water sampling in 1991 detected chromium (14 to 64 µg/L in the springs; 2 to 6 µg/L in surface water), tritium (400 to 8,900 pCi/L in the springs, non-detect in surface water), strontium-90 (one detected concentration of 8.8 pCi/L in the springs; <0.4 to 0.7 pCi/L in the surface water), technetium-99 (2 to 5.2 pCi/L in the springs; 2 to <3 pCi/L in surface water), and total uranium (0.24 to 1.1 pCi/L in the springs; 0.2 to 0.5 pCi/L in surface water). Samples of riverbank spring sediment from 100-K had low concentrations of strontium-90, cesium-137, radium-226, thorium-228, and thorium-232 (WHC-EP-0609, *Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site*).

Five sediment samples were collected from four locations near 100-K in 1991 (WHC-SN-EN-TI-198, *100 Area Columbia River Sediment Sampling*). Maximum concentrations of inorganic constituents detected in these samples included arsenic (10.7 mg/kg), chromium (64.1 mg/kg), lead (59.3 mg/kg), and zinc (454 mg/kg). Cesium-137 (0.45 pCi/g) and europium-152 (0.32 pCi/g) were detected in a single sample.

A riverbank seep location (100-K 63-1) at 100-K is monitored under DOE/RL-91-50. Concentrations of metals in the 2016 seep water sample were less than water quality criteria in WAC-173-201A, “Water Quality Standards for Surface Waters of the State of Washington,” except copper. Concentrations of radionuclides detected in the 2016 seep water sample were similar to those from 2011-2015 (DOE/RL-2017-24).

Investigations of riparian and nearshore areas were conducted in support of the RCBRA (DOE/RL-2007-21, Volume I). Riparian and nearshore areas were selected where affected media (seeps, springs, or runoff) may have created exposure pathways to biota (RCBRA SAP [DOE/RL-2005-42]). Riparian sampling locations also were identified based on radiation field survey results (RCBRA SAP, Appendix C; BHI-01757, Appendix H). The scope of the RCBRA investigations also included an evaluation of potential impacts from upstream contaminant sources on riparian and nearshore areas at Hanford. Radiation survey results and detection of chromium in groundwater, aquifer tube, and biota (bivalve) samples provided the basis for selection of riparian and nearshore study sites in the 100-K decision area (RCBRA SAP, Table C-1). Four nearshore (aquatic) study sites were located near 100-K. These were located downstream of the 100-K operational area, within the discharge zone of a Cr(VI) groundwater plume. One riparian study site was also located downstream of 100-K.

Sample collection rationale and techniques varied by area and medium. Investigation areas characterized by data collected under the RCBRA SAP (DOE/RL-2005-42) included the upland, riparian, and nearshore river zones. Sites selected for sampling were identified based on existing data demonstrating a range of contaminant concentrations. Reference sites were identified using evidence and knowledge of areas not affected by contaminant release and were selected based on physical/ecological similarity to onsite investigation areas.

Media collected in the upland and riparian zones included soil, vegetation, invertebrates, small mammals, and kingbirds (kingbirds in riparian zone only). Nearshore media included sediment, interstitial pore water, surface water, benthic macroinvertebrates, clams, and sculpin. Toxicity testing was performed on

soil, sediment, and water to provide Hanford Site-specific information on the ecological effects of contaminant mixtures and contaminant bioavailability. The results of these tests are used to make informed inferences on the toxicity of contaminants to Hanford Site biota. A more detailed discussion of the results from the RCBRA (DOE/RL-2007-21) in riparian and nearshore areas is presented in Appendix J of this RI.

100-K River Effluent Pipeline Investigations. During operations, water used in fuel production to cool the reactors discharged to the Columbia River via effluent pipelines. Release of this cooling water ended when the associated reactors and facilities shut down. The two river effluent pipelines run parallel and are approximately 112 cm (48 in.) apart. In January 2012, the river effluent pipeline designations were split in WIDS. The portion of the 100-K-80 (KW pipeline) that extends into the river was given a WIDS site code of 100-K-113. The portion of the 100-K-96 (KE) pipeline that extends into the river was assigned a WIDS site code of 100-K-114. The two inactive 100-K effluent pipelines (100-K-113 and 100-K-114) remain in their original locations in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines.

In 1984, UNI-3262, *River Discharge Lines Characterization Report,* discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the C, DR, and F Reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. Radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. Dose rates measured for direct contact with the interior of the pipe surfaces were less than 1 mrem/hr, and readings on the exterior were below the instrument detection capability.

In 1994, a comprehensive geophysical survey (WHC-SD-EN-TI-278, *Columbia River Effluent Pipeline Survey*) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground-penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (BHI-00538, *100 Area River Effluent Pipelines Characterization Report*). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (UNI-3262) and were expected to represent “worst case” conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the B and D/DR Reactors.

1.2.4 CERCLA Five-Year Review

Effectiveness of the interim actions is evaluated through the CERCLA five-year review process. This evaluation determines whether the selected remedies remain protective of human health and the environment. Since the issuance of the first Interim Action ROD, there have been four 5-year reviews for the 100 Area NPL (40 CFR 300, Appendix B) Site.

EPA, 2001, *USDOE Hanford Site First Five Year Review Report*, for the 100 Area NPL noted that cleanup actions reviewed have achieved or were on track to achieve protectiveness. It also identified that "The principal deficiency is that the pump-and-treat remedial action for capturing and treating several chromium-contaminated groundwater plumes has not achieved the required protectiveness criteria because of insufficient capture of the plume. The five-year review recommends optimizing and running the extraction/treatment system more reliably." Action items from the review for the 100-K Area and for the 100-KR-4 OU included:

- Action item SW-1: DOE shall develop a site-wide institutional controls plan for the Hanford Site. EPA will initiate modifications to appropriate remedy selection documents to incorporate the requirements, due July 2001.
- Action item 100-1: DOE shall optimize and complete system enhancements to the 100-HR-3 and 100-KR-4 groundwater pump-and-treat systems for chromium to run more reliably and achieve the required cleanup levels, due May 2002.
  - The overall system up-time must improve.
  - The downtime for individual wells must be dramatically reduced.
  - A much higher percentage of the targeted plume must be captured.
  - For 100-KR-4, the plan to achieve these enhancements was the following:
    - Complete the design for system enhancements by September 2001.
    - Acquire an additional treatment skid and support systems.
    - Build an annex or additional building to house the new treatment skid.
    - Install an extraction well to bridge the gap between existing extraction wells 199-K-120A and 199-K-119A.
    - Install a new injection well.

The second 5-year review indicated that RTD was an effective cleanup remedy for vadose contamination. DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*, listed three 100-K groundwater issues and recommended four actions:

- **Issue 3.** The southeastern (inland) extent of the chromium groundwater plume from the 116-K-2 Trench, northeast of the current injection wells, has not been delineated.
  - **Action 3-1.** Install three additional wells to further delineate the southeastern (inland) extent of the chromium groundwater plume from the 116-K-2 Trench, northeast of the current injection wells. Wells installed as part of the pump and treat system expansion or injection well relocation may count toward this effort if appropriately located. Wells 199-K-153, 199-K-154, and 199-K-163 were drilled in November 2008. This completed the required action.
- **Issue 4.** The small chromium plume at KW Reactor site has reached the Columbia River, as evidenced by nearshore aquifer tubes. There is currently no active remediation system in place for the small chromium plume at the KE/KW Reactor site.
  - **Action 4-1.** Implement the existing remedial action decision (pump and treat) at this location. An IX pump and treat system (capacity of 379 L/min) constructed at the KW Reactor began

operations in January 2007. This completed the required action. (Note that the KW system was expanded to a treatment capacity of 757 L/min in 2008 and 2009, and the expanded system became operational in April 2009.)

- **Issue 5.** Groundwater monitoring indicates that the expansion of the 100-K pump and treat extraction system has not yet achieved the RAO.
  - **Action 5-1.** Expand the 100-K pump and treat system by 378.5 L/min to enhance remediation of the chromium plume between the 116-K-2 Trench and the N Reactor perimeter fence. The KX IX pump and treat system (capacity of 2,271 L/min) began operation in February 2009 and reached full operating capacity by May 2009. This completed the required action.
  - **Action 5-2.** Add wells between the 116-K-2 Trench and the N Reactor perimeter fence for groundwater extraction and connect the additional wells to the pump and treat system. Wells 199-K-148, 199-K-149, and 199-K-150 were drilled in late 2007 and early 2008 and, along with existing wells 199-K-130 and 199-K-131, were converted to extraction wells, and connected to the KX treatment system. This completed the required action.

The third 5-year review was published in March 2012 (DOE/RL-2011-56, *Hanford Site Third CERCLA Five-Year Review Report*). There were no issues identified for the 100-K Area. The fourth five-year review was published in March 2017 (DOE/RL-2016-01, *Hanford Site Fourth CERCLA Five-Year Review Report*). The fourth five-year review identified the following for the 100-KR-2 and 100-KR-4 OUs:

- **Issue Category**: Changed Site Conditions
- **Issue**: Several 100-KR-2 waste sites near the 105-KE and 105-KW Reactors likely serve as continuing sources of 100-KR-4 OU groundwater contamination.
- **Recommendation**: Incorporate supplemental characterization data and risk evaluation in a draft RI/FS report and transmit for regulator review.

This RI and associated FS report provide the characterization data and risk evaluation to meet the recommendation for the identified issue from the fourth five-year review. Analytical data used in this RI and FS (provided in Appendix D) include the data reduction protocols and quality assurance (QA) reports.

1.2.5 Summary

Chapter 1 summarized historical information, prior assessments and remediation work, treatability tests, and other relevant studies. This information provides a picture of current 100-K site conditions and establishes a foundation for the remainder of the RI document.

2 Study Area Investigation

EPA approved the 100-K Work Plan (DOE/RL-2008-46-ADD2) in January 2010. The work plan identified additional information needed to understand the nature and extent of contamination in the OUs and to support a remedial alternative evaluation and decision.

The following field studies were part of the RI field investigation performed between 2010 and 2011:

- Nine unconfined aquifer monitoring wells and three aquifer tubes were installed to characterize the nature and extent of contamination.
- Four soil borings were drilled into the RUM unit to determine the extent of contaminants beneath the unconfined aquifer. A confined aquifer water-bearing unit was identified in only one of these four borings.
- The nature and extent of contamination at 16 unremediated waste sites was assessed through completing interim remediation.
- Two soil borings were drilled to characterize the extent of contamination beneath the 116-K-2 Trench.
- A subset of existing wells was sampled three times between October 2, 2009, and June 30, 2010, to determine spatial and temporal variations in groundwater contamination.

DOE and EPA identified in 2012 that additional characterization activities near the KE Reactor and select waste sites were needed to inform decisions on remediation. Two soil characterization boreholes were drilled and wells were installed in 2015 near the KE Reactor to characterize contaminants within the UPR-100-K-1 and 116-KE-3 vadose zone and groundwater as part of the RI.

Additional RA activities were completed between 2012 and April 2017. These activities included:

- 15 wells were installed and additional annual well realignments were completed for groundwater interim action P&T system optimization
- A rebound study was completed at the KW Headhouse area for secondary source characterization
- Interim action RTD and waste site characterization was completed, and the nature and extent of contamination was assessed at 38 waste sites

Developing the 100-K Work Plan (DOE/RL-2008-46-ADD2) was based on review and evaluation of relevant documented information and data. Previous data included soil analyses from waste site remediation and field investigations, groundwater monitoring, results from interim action groundwater remediation, and geological information from wells and boreholes. The RI combines previous studies, monitoring, and interim remediation results, with vadose zone and groundwater data collected under the 100-K Work Plan. This chapter presents the data gaps, identifies data collected to fill those gaps, and the corresponding scope of work (including field activities, tests, analyses, and data sources) designed and carried out for the RI.

Chapters 3, 4, and 5 present results of the RI activities. These chapters include data from previous studies and historical information to identify the nature and extent of contamination. Details of the RI/FS scope of work are documented in the 100-K Work Plan (DOE/RL-2008-46-ADD2) and the 100-K SAP (DOE/RL-2009-41), with modifications approved via Tri-Party Agreement Change Notice (TPA-CN) documents.

Section 2.1 describes the RI field activities, other investigations, and ongoing activities that contributed to this RI. The additional investigations include those with the potential to affect the development of alternatives, including the RCBRA Volumes I and II (DOE/RL-2007-21), ongoing groundwater and aquifer tube monitoring, and interim remedial actions. Section 2.2 summarizes the field activity documentation. Subsequent chapters of this report describe the results and integrate it with existing information (Chapter 1) to update the CSM and to identify and evaluate options for achieving RAOs.

2.1 Remedial Investigation Activities

The RI field effort included boreholes, groundwater monitoring well installations, spatial and temporal groundwater monitoring, and the associated sampling and analysis for each activity. Modifications to the 100-K SAP (DOE/RL-2009-41) were approved and documented in TPA-CNs (Table 2-1).

Table 2-1. Changes to the 100-K Sampling and Analysis Plan

Change Notice	Date	Associated Document	Subject
TPA-CN-357	May 5, 2010	DOE/RL-2009-41	Changed location for well 9. Reduced frequency of field transfer blanks and duplicates for boreholes and soil/sediment samples. Increased number of soil sampling intervals for wells 2, 4, 5, 9, R1, R3, and R5. Modified total sample depth for trench boreholes. Modified construction for well R3 from stainless steel to PVC. Reduced the laboratory standard compound list for gamma energy analysis.
TPA-CN-384	Sep. 20, 2010	DOE/RL-2009-41	Modified language for boreholes at the 116-K-2 Trench to allow completion as temporary monitoring wells to facilitate collection of representative groundwater samples. Modified construction requirements for wells R3 and R4 from stainless steel to PVC based on need to decommission within 1 year for site D&D activities.
TPA-CN-405	Nov. 15, 2010	DOE/RL-2009-41	Modified construction requirements for well 9 from stainless steel to PVC based on need to decommission within 1 year for site D&D activities.

References: DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study.*

TPA-CN-357, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0.*

TPA-CN-384, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0 (As amended by TPA-CN-257, June 1, 2010).*

TPA-CN-405, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0 (As amended by TPA-CN-384, October 6, 2010).*

D&D = decommissioning and demolition

PVC = polyvinyl chloride

Table 2-2 summarizes Data Gaps 1 through 13 identified in the 100-K Work Plan (DOE/RL-2008-46-ADD2), describes how they were filled, and shows the report section where the information is discussed. Table 2-3 includes the supplemental investigations identified in the Integrated Work Plan (DOE/RL-2008-46) and other investigations that provide information for 100-K waste site and groundwater contamination.

The following sections describe the RI scope of work in detail, including deviations from the 100-K Work Plan (DOE/RL-2008-46-ADD2). Tables 2-4 and 2-5 present a summary of the RI field sampling, and Appendix C includes specific information for boreholes and sampling intervals. Figure 2-1 shows the RI field sampling locations. Included in the sections are investigation details from activities conducted under other scopes of work, which may affect FS decisions. These investigations include DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (hereinafter called the Columbia River RI Work Plan), and RCBRA Volumes I and II (DOE/RL-2007-21).

2.1.1 Work Plan Deviations

Work plan deviations are as follows:

- **Well 199-K-189 location.** The planned location for well 199-K-189 interfered with the access roads for ongoing demolition and waste site remediation activities. The well was moved approximately 75 m (250 ft) to the north to resolve this conflict.

- **Well 199-K-186 location.** Well 199-K-186 was relocated from the location presented in the 100-K Work Plan (DOE/RL-2008-46-ADD2). The initial planned location was within a defined culturally sensitive area, and permission to drill the well at this location was not granted during cultural resource reviews. The new location was selected to provide additional characterization for the KE Reactor area, and was approved via TPA-CN-357, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0*. Completion requirements for this well were changed from stainless steel to polyvinyl chloride (PVC) based on planned decommissioning for D&D work. This change was approved in TPA-CN-405, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0 (As amended by TPA-CN-384, October 6, 2010)*.

- **Vadose zone boreholes.** The boreholes advanced into the 116-K-2 Trench were converted to temporary wells to obtain water samples beneath the trench. Water samples were not obtained during drilling due to low groundwater yield from the aquifer, which prevented representative sample collection. This change was approved in TPA-CN-384, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0 (As amended by TPA-CN-257, June 1, 2010)*.

- **Well completions.** Wells 199-K-192 and 199-K-195 were planned for construction with stainless steel. Both were constructed as temporary wells using PVC based on the need to decommission the wells for future D&D work. This change was approved in TPA-CN-384.

- **Soil samples.** Split-spoon samples sometimes yielded insufficient sample volume for a full set of chemical and physical analyses. This was due to unconsolidated sediments and insufficient fine materials in some intervals.

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Table 2-2. Data Gaps and 100-K Remedial Investigation Work Conducted

Data Gap	Data Need	Scope of Work	Work Conducted/Section with Discussion	Data Gap Filled?
1. Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath unremediated waste sites.	Characterize below unremediated waste sites to assess the nature and extent of contamination in the vadose zone.	Continue contaminated soil removal and sampling at waste sites in 100-K. *Special Case: Petroleum Hydrocarbons in the 100-KW area.* There is no work scope for the unplanned release related to the 166-KW Oil Storage and Oil Pump Equipment facility. The associated waste site, 100-KW-2, is currently an accepted site and will be remediated. The plume will be chased laterally until sufficient contamination is removed.	CVP and RSVP data for 54 interim remediated waste sites were evaluated through the risk assessment activities. Chapter 5, "Contaminant Fate and Transport" Chapter 6, "Human Health Risk Assessment" Chapter 7, "Ecological Risk Assessment"	Yes
2. Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath remediated waste sites.	Characterize beneath remediated waste sites to assess the nature and extent of contamination in the vadose zone.	Drill two boreholes within the trench and sample according to the target analyte list provided in Table 2-10. Collect soil samples continuously from the bottom of the waste site (or the maximum depth of remedial action) to the water table. Collect groundwater samples and aquifer sediment samples for analysis.	Two borings (C7831 and C7832) were drilled within the 116-K-2 Trench. Temporary monitoring wells (199K-200, 199-K-201) were installed per TPA-CN-384. Soil and groundwater samples were collected as shown in Tables 2-4 and 2-5. Two borings were drilled and monitoring wells were installed in 2015, one each at the UPR-100-K-1 and 116-KE-3 Crib waste sites. CVP and RSVP data for 54 interim remediated waste sites was evaluated through the risk assessment activities. Section 2.1.9, "Geologic Investigations" Section 3.6, "Hydrogeology" Section 4.2, "Vadose Zone" Chapter 5, "Contaminant Fate and Transport"	Yes
3. Vadose zone contaminant nature and extent needed to assess protection of human health, ecological resources, and groundwater around reactor structures.	Characterize around the reactor structures to assess the nature and extent of contamination in the vadose zone.	Continue contaminated soil removal and sampling at waste sites associated with the KE and KW Reactor sites. Appendix A shows the locations of these waste sites.	Remediation was initiated and observational data collected to respond to this data gap. Two borings were drilled and monitoring wells were installed in 2015, one each at the UPR-100-K-1 and 116-KE-3 Crib waste sites to characterize contamination near the KE Reactor. Section 4.2.2, "RI Waste Site Characterization Results" DOE/RL-2018-22, Chapter 2, "Development and Screening of Alternatives"	Yes
4. Unidentified waste sites (orphan/ discovery sites) exist in 100-K.	Identify new waste sites and additional sources of contamination.	Complete OSE process inside the fence line. The discovery site process will continue until waste site and facility removal are complete.	Completed OSEs within the 100-K decision area. The results of the OSE are documented in three reports (OSR-2008-0003, OSR-2009-0002, and OSR-2011-0001). The OSEs identified 22 new waste sites addressed in the RI and FS.	Yes

Table 2-2. Data Gaps and 100-K Remedial Investigation Work Conducted

Data Gap	Data Need	Scope of Work	Work Conducted/Section with Discussion	Data Gap Filled?
5. The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been defined in select areas.	Define the extent of groundwater contamination above cleanup standards in select areas of the unconfined aquifer.	Drill nine new monitoring wells and install three aquifer tubes. Install five wells to better define the extent of Cr(VI) in groundwater. Install one well to better define a Cr(VI) hot spot. Install two wells and the aquifer tubes to better define the extent of Cr(VI), strontium-90, carbon-14, trichloroethene, and tritium downgradient of the KE Reactor area. Replace well 199-K-109A to further monitor and define the extent of the strontium-90 hot spot. Install one well to better define the extent of Cr(VI) and tritium near the 116-K-2 Trench. Collect groundwater samples and analyze for constituents on Table 2-11.	Nine monitoring wells were drilled and sampled to define the extent of contamination: • 199-K-183 (C7683, well 1)—Defined extent of Cr(VI) in groundwater • 199-K-185 (C7685, well 2)—Defined extent of Cr(VI), strontium-90, carbon-14, trichloroethene, and tritium downgradient of KW Reactor • 199-K-186 (7686. well 9)—Defined extent of Cr(VI) in groundwater • 199-K-187 (C7687, well 3)—Defined extent of Cr(VI) in groundwater • 199-K-189 (C7689, well 5)—Replacement well for 199-K-109A further defined extent of strontium-90 hot spot • 199-K-190 (C7690, well 4)—Defined Cr(VI) hot spot • 199-K-191 (C7691, well 6)—Defined extent of Cr(VI) and tritium near the 116-K-2 Trench • 199-K-193 (C7693, well 7)—Defined extent of Cr(VI) in groundwater • 199-K-194 (C7694, well 8)—Defined extent of Cr(VI) in groundwater Installed and sampled three aquifer tubes: (C7641, C7642, and C7643) Locations shown on Figure 2-1. Chapter 3, “Physical Characteristics of the Study Area” Section 4.3, “Groundwater Contamination” Section 4.4, “Distribution of Groundwater Contaminants” Soil and groundwater samples collected as shown in Tables 2-4 and 2-5.	Yes
6. The level of groundwater contamination entering the Columbia River has not been defined and characterized.	Collect groundwater upwelling data and information per the Columbia River RI Work Plan (DOE/RL-2008-11).	Collect groundwater upwelling (pore water) samples in the Columbia River. Focus on sites where contamination was detected in previous pore water sampling and where specific conductance indicates groundwater upwelling. Continue routine sampling of existing aquifer tubes. Install and sample three new aquifer tubes to provide better coverage.	Pore water samples collected for six stations to define the extent of contamination entering the Columbia River. Installed and sampled three new aquifer tubes (C7641, C7642, and C7643). Section 2.1.8.1, “Surface Water/Groundwater Interaction” Section 2.1.8.2, “Pore Water, Surface Water, and Sediment Sampling” Section 4.5, “Columbia River Surface Water and Sediment”	Yes
7. The fate and transport of contaminants beneath the unconfined aquifer has not been evaluated.	Collect physical and hydrogeologic parameters from soil samples to further support determination of contaminant fate and transport beneath the unconfined aquifer.	Drill and sample soil and groundwater from four groundwater monitoring wells drilled through the unconfined aquifer to approximately 15 m (50 ft) within the RUM unit.	Installed and sampled four new monitoring wells into the RUM: • 199-K-184 (C7684, R1)—completed and screened in Ringold Formation unit E • 199-K-188 (C7688, R2)—completed and screened in Ringold Formation unit E • 199-K-192 (C7692, R3)—completed and screened in the RUM • 199-K-195 (C7695, R4)—completed and screened in Ringold Formation unit E Locations shown in Figure 2-1. Soil and groundwater samples collected as shown in Tables 2-4 and 2-5. Section 2.1.9, “Geological Investigations” Section 2.1.10, “Vadose Zone Investigations” Section 2.1.11, “Groundwater Investigations” Section 3.4, “Geology” Section 3.6, “Hydrogeology” Section 4.3, “Groundwater Contamination” Section 4.4, “Distribution of Groundwater Contaminants” Chapter 5, “Contaminant Fate and Transport”	Yes

Table 2-2. Data Gaps and 100-K Remedial Investigation Work Conducted

Data Gap	Data Need	Scope of Work	Work Conducted/Section with Discussion	Data Gap Filled?
8. It is unknown if contamination within the RUM unit will adversely affect aquatic receptors in the Columbia River.	Update bathymetric data for the river within 100-K to support calculations of contaminant transport to the river and ecological receptors.	Aquatic ecological receptors have been identified in the river. Updated and accurate bathymetric data for the river have been obtained to evaluate flow paths of contaminants to receptors from the RUM unit.	Evaluation of the top of the RUM unit surface using near-shore river wells indicated the top of the RUM unit does not intersect the Columbia River. Section 2.1.9.2, "Bathymetric Data"	Yes
9. The hydraulic rate of exchange between the groundwater and the river is unknown.	Collect geochemical and hydrogeologic data to evaluate near-shore area groundwater contaminant fate and transport.	The near-shore area is directly affected by river stage. Limited data are available to adequately understand groundwater flow paths, contaminant migration, and mixing in the near-shore area.	Re-evaluation of groundwater remedial activities provided additional information on the hydrologic rate of exchange between the river and groundwater. It was concluded that no additional data were needed for the RI and FS. Section 2.1.8.1, "Surface Water/Groundwater Interactions" Section 3.7.3, "Groundwater/Surface Water Interactions" Chapter 4, "Nature and Extent of Contamination" Chapter 5, Contaminant Fate and Transport	Yes
10. The mechanism to explain the persistence of the Cr(VI) plume is unknown.	Collect soil and water samples from the following units: vadose zone, deep vadose zone, periodically rewetted zone, unconfined aquifer, above the RUM unit, and within the RUM unit.	Collect groundwater and soil samples from RI borings and wells. Soil and water analyses needed to determine the potential for each unit to contain sufficient Cr(VI) contamination to be a continuing source of groundwater contamination.	Drilled and sampled soil and groundwater to evaluate Cr(VI) from each of the following: • Four groundwater wells drilled into the RUM unit. Three completed in the unconfined aquifer; one completed within the RUM unit. • Nine groundwater wells completed within the unconfined aquifer. • Two boreholes drilled through the 116-K-2 Trench; subsequently converted to groundwater monitoring wells completed within the unconfined aquifer. Locations shown in Figure 2-1. Soil and groundwater samples collected as shown in Tables 2-4 and 2-5. Section 4.3, "Groundwater Contamination" Section 4.4, "Distribution of Groundwater Contaminants" Chapter 5, "Contaminant Fate and Transport"	Yes
11. Potential alternative remedial technologies have not been sufficiently investigated.	Evaluate alternative potential remedial technologies.	Groundwater contamination above aquatic standards and drinking water MCLs has been detected in 100-K. Interim remedial actions are currently in operation. Additional data and information are needed to evaluate potential final remedies as part of the FS.	Collected information on the potential use of additional groundwater treatments at 100-K. This information was gathered through the groundwater RPO activity and through further evaluation of existing technologies as part of the FS (DOE/RL-2018-22). Section 1.2.3.3, Previous Groundwater Investigations and Remediation DOE/RL-2018-22, Chapter 1, "Identification and Screening of Technologies" DOE/RL-2018-22, Chapter 2, "Development and Screening of Alternatives" DOE/RL-2018-22, Appendix A, "Technologies not Retained"	Yes
12. Insufficient data are available to support fate and transport modeling.	Collect additional data to support future fate and transport modeling. Assess the physical and hydraulic properties of soil and estimate contaminant K_d to support modeling.	Estimate soil and hydraulic properties, determine level of contamination, confirm contaminant distribution coefficients (K_ds), and perform batch leach contacting test on selected soil samples.	Collected physical soil properties (Table 2-4) from RI borings including batch leach, soil analytical, and physical property data. Performed batch leach testing on six RI borings (C7684, C7686, C7688, C7695, C7831, and C7832) (locations shown in Figure 2-1). Section 3.5, "Vadose Zone" Chapter 5, "Contaminant Fate and Transport"	Yes

Table 2-2. Data Gaps and 100-K Remedial Investigation Work Conducted

Data Gap	Data Need	Scope of Work	Work Conducted/Section with Discussion	Data Gap Filled?
13. Data are needed to define the spatial and temporal distribution of groundwater contamination.	Collect and analyze groundwater samples from select groundwater monitoring wells.	Collect and analyze groundwater samples from 18 groundwater monitoring wells at three river stages (high, low, and transitional) to characterize the spatial, temporal, and chemical extent of groundwater contamination.	Sampled 18 wells three times in 2009 and 2010. Sample intervals representative of high, low, and transitional river periods. Evaluated these additional data in conjunction with the historical data. Locations are shown in Figure 2-1. Section 4.3, "Groundwater Contamination" Section 4.4, "Distribution of Groundwater Contaminants" Section 4.5, "Columbia River Surface Water and Sediments" Chapter 6, "Human Health Risk Assessment"	Yes

References: DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*.

DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*.

DOE/RL-2018-22, *Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units* (pending).

OSR-2008-0003, *100-K Area Orphan Sites Evaluation Report*.

OSR-2009-0002, *100-F/IU-2/IU-6 Area – Segment 1 Orphan Sites Evaluation Report*.

OSR-2011-0001, *100-F/IU-2/IU-6 Area – Segment 4 Orphan Sites Evaluation Report*.

TPA-CN-384, *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0 (As amended by TPA-CN-257, June 1, 2010).*

CVP = cleanup verification package
FS = feasibility study
MCL = maximum contaminant level
OSE = orphan site evaluation
RI = remedial investigation
RPO = remedial process optimization
RSVP = remaining site verification package
RUM = Ringold Formation upper mud

Table 2-3. Supplemental Investigations and Other Primary Investigations

Scope of Work Identified	Section with Discussion
Evaluating and developing approaches to obtain data that will demonstrate compliance with ambient water quality criteria in the river for RODs. In April 2008, a technical review panel was convened to evaluate groundwater interactions with the Columbia River (SGW-39305). The panel suggested that the current mixing/dilution conceptual model should be re-evaluated. In addition, data may be needed to show representativeness of contaminant concentrations for compliance. Therefore, evaluation will include determination of whether a 1:1 dilution assumption for groundwater entering the river is valid, and may include evaluation of whether data from aquifer tube samples are representative. Data collected as part of the RI for site releases to the Columbia River may be useful in this evaluation.	Section 2.1.8, "Surface Water and Sediment Investigations"
Collecting data and developing River Corridor background values in soil for antimony, boron, molybdenum, and selenium. Site-specific background values for these constituents may be needed to determine final soil RAG values where calculated risk-based concentrations and/or ecological protection concentrations are less than background. Interim remedial actions have used Washington State background values for antimony and selenium; interim soil RAGs for boron and molybdenum are above expected site-specific background values.	Section 2.1.13, "River Corridor Supplemental Investigations"
Re-evaluate soil cleanup level for Cr(VI) to support the ROD. The lowest soil RAG for Cr(VI) under the interim RODs is 2 mg/kg. However, the calculated MTCA [WAC 173-340-747(3)(a)] soil RAG value may be less than the current limits of analytical quantitation in environmental samples, depending on the soil-partitioning value and groundwater to river dilution attenuation factor used, and final soil cleanup values may default to the limits of quantitation. Because there is uncertainty in analytical detection and quantitation of Cr(VI) near the limits of detection, it may be necessary to consider the realistic capabilities of analytical performance in determination of a final soil cleanup value.	
Determining a site-specific soil-partitioning value for antimony. This value is necessary for calculation of MTCA [WAC 173-340-747(3)(a)] soil RAG values for antimony. Antimony is not a significant contaminant in the River Corridor, and determination will include review of scientific literature, which suggests antimony soil partitioning values in the range of 1.4 to 45 mL/g.	
Re-evaluate soil cleanup levels for arsenic to support the ROD. The soil RAG for arsenic under the interim RODs is 20 mg/kg, based on the Tri-Party Agreement (Ecology et al., 1989a) to use the 1996 MTCA [WAC 173-340-740(2)] Method A value (DOE/RL-96-17). The MTCA [WAC 173-340-740(2)]) Method A value is also 20 mg/kg. The MTCA [WAC 173-340-740(3)] Method B and MTCA [WAC 173-340-747(3)(a)] soil values for arsenic are below the site arsenic background of 6.5 mg/kg. Selection of a final soil cleanup level for arsenic in the River Corridor will be accomplished through development of RODs.	

Table 2-3. Supplemental Investigations and Other Primary Investigations

Scope of Work Identified	Section with Discussion
Other Primary Investigations that Potentially Affect Feasibility Study Decisions for Waste Sites and Groundwater Contamination	
River Corridor Baseline Risk Assessment	Chapter 6, "Human Health Risk Assessment" Chapter 7, "Ecological Risk Assessment"
Annual Groundwater Monitoring	Section 2.1.11, "Groundwater Investigations" Section 4.3, "Groundwater Contamination" Section 4.4, "Distribution of Groundwater Contaminants"
Ongoing Aquifer Tube Sampling	Section 2.1.11, "Groundwater Investigations" Section 4.3, "Groundwater Contamination"

References: DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*.

SGW-39305, *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area*.

Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*.

WAC 173-340-740, "Model Toxics Control Act—Cleanup," "Unrestricted Land Use Soil Cleanup Standards."

WAC 173-340-747, "Deriving Soil Concentrations for Groundwater Protection."

Cr(VI) = hexavalent chromium
MTCA = "Model Toxics Control Act—Cleanup"
RAG = remedial action goal
RI = remedial investigation
ROD = record of decision

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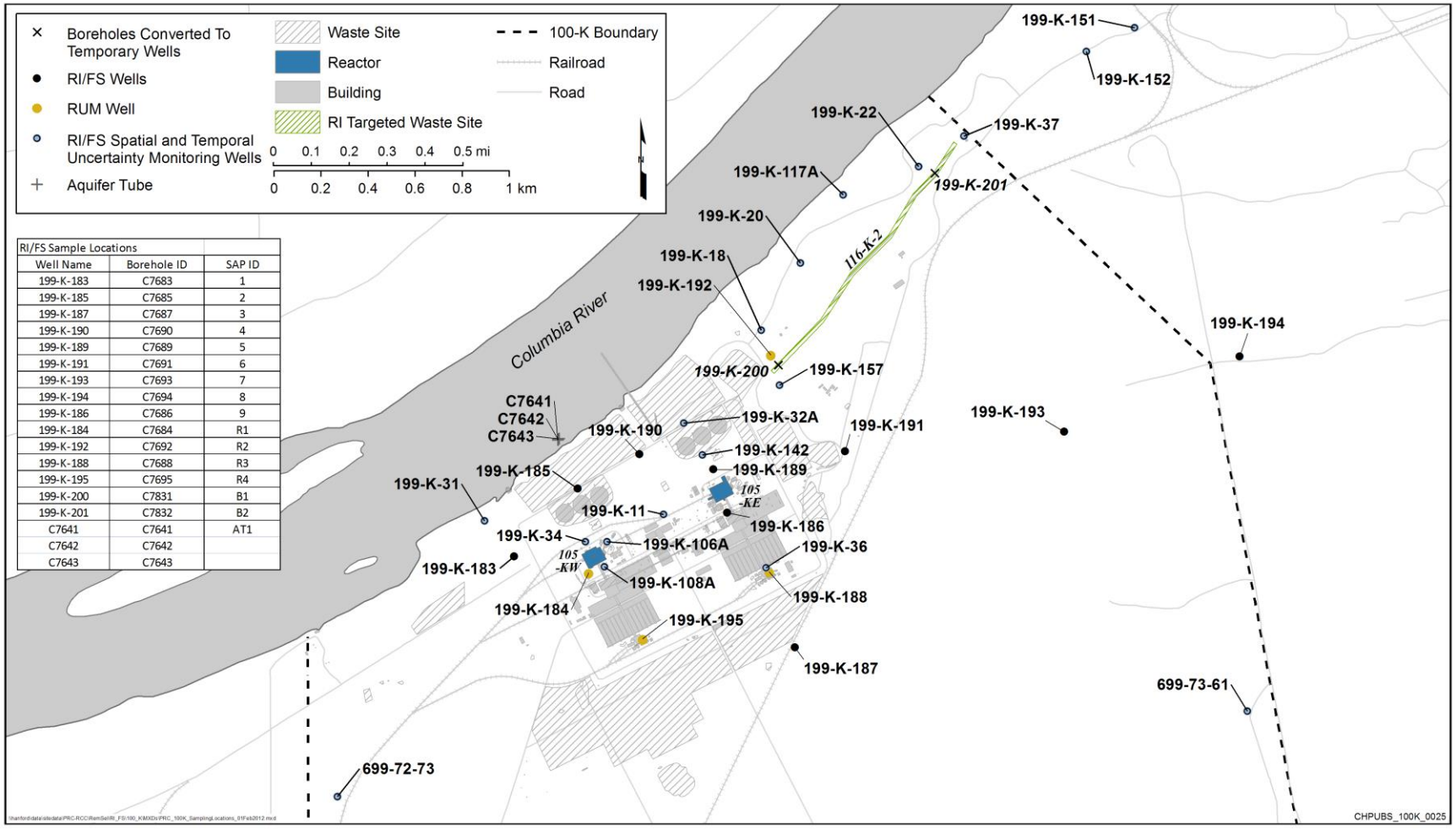


RI/FS Sample Locations		
Well Name	Borehole ID	SAP ID
199-K-183	C7683	1
199-K-185	C7685	2
199-K-187	C7687	3
199-K-190	C7690	4
199-K-189	C7689	5
199-K-191	C7691	6
199-K-193	C7693	7
199-K-194	C7694	8
199-K-186	C7686	9
199-K-184	C7684	R1
199-K-192	C7692	R2
199-K-188	C7688	R3
199-K-195	C7695	R4
199-K-200	C7831	B1
199-K-201	C7832	B2
C7641	C7641	AT1
C7642	C7642	
C7643	C7643	

Figure 2-1. Map Showing RI Sampling Locations per 100-K SAP (DOE/RL-2009-41)

Table 2-4. Summary of Soil Samples Collected for 100-K Remedial Investigation

Well Name	Well Identification	Soil Chemistry		Physical Properties		Changes and Deviations from 100-K SAP (DOE/RL-2009-41)
		Number Planned	Number Collected	Number Planned	Number Collected	
199-K-183	C7683	7	12	6	5	Extra chemistry samples collected at lithology changes and at geologist's discretion. Insufficient sample obtained at one interval for physical properties analysis.
199-K-184	C7684	10	17	6	7	Extra chemistry samples collected at lithology changes and at geologist's discretion. Physical properties samples collected at approximately 7.6 and 15.2 m (25 and 50 ft) into the RUM.
199-K-185	C7685	7	7	6	5	Insufficient sample obtained at one interval for physical properties analysis.
199-K-186	C7686	7	25	6	3	Additional samples collected based on observation of suspected petroleum hydrocarbon contamination between approximately 12.2 and 18.3 m (40 and 60 ft) bgs. Insufficient sample obtained at three intervals for physical properties analysis.
199-K-187	C7687	7	8	6	5	Extra chemistry samples collected at lithology changes and at geologist's discretion. Insufficient sample obtained at one interval for physical properties analysis.
199-K-188	C7688	10	29	6	7	Extra chemistry samples collected at lithology changes and at geologist's discretion. Additional samples collected at approximately 1.5, 7.6, and 15.2 m (5, 25, and 50 ft) into the RUM.
199-K-189	C7689	7	17	6	5	Extra chemistry samples collected at lithology changes and at geologist's discretion. Insufficient sample obtained at one interval for physical properties analysis.
199-K-190	C7690	7	15	6	2	Extra chemistry samples collected at lithology changes and at geologist's discretion. Insufficient sample obtained at four intervals for physical properties analysis.
199-K-191	C7691	7	13	6	8	Contact between the Hanford formation and Ringold Formation unit E was deeper than estimated. Additional samples were collected to meet requirements.

Table 2-4. Summary of Soil Samples Collected for 100-K Remedial Investigation

Well Name	Well Identification	Soil Chemistry		Physical Properties		Changes and Deviations from 100-K SAP (DOE/RL-2009-41)
		Number Planned	Number Collected	Number Planned	Number Collected	
199-K-192	C7692	10	14	6	5	The bottom of the unconfined aquifer was encountered deeper than estimated. Additional samples for chemical analyses were collected to meet requirement for a sample from the bottom of the unconfined aquifer. Insufficient sample obtained at one interval for physical properties analysis. Physical properties samples collected at approximately 7.6 and 15.2 m (25 and 50 ft) into the RUM.
199-K-193	C7693	7	7	6	3	The Hanford formation/Ringold Formation unit E contact was at a depth approximately 4.6 m (15 ft) shallower than estimated. Samples at approximately 3 and 1.5 m (10 and 5 ft) above the Hanford formation/Ringold Formation unit E contact were not collected.
199-K-194	C7694	7	7	6	2	Groundwater encountered approximately 3 m (10 ft) higher than expected. A physical properties sample was collected at approximately 1.5 m (5 ft) into the RUM. Insufficient sample obtained at four intervals for physical properties analysis.
199-K-195	C7695	10	23	6	8	The Hanford formation/Ringold Formation unit E contact was deeper than estimated. Additional physical property samples were collected to meet requirements. Extra chemistry samples collected at lithology changes and at geologist's discretion. Additional physical properties samples collected at approximately 7.6 and 15.2 m (25 and 50 ft) into the RUM.
199-K-200	C7831	4	13	2	0	Extra chemistry samples collected at lithology changes and at geologist's discretion. Insufficient sample obtained at two intervals for physical properties analysis.
199-K-201	C7832	7	17	2	1	Extra chemistry samples collected at lithology changes and at geologist's discretion. Insufficient sample obtained at one interval for physical properties analysis.

Reference: DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*.

Note: Numbers do not include duplicates or other quality assurance/quality control samples.

bgs = below ground surface

RUM = Ringold Formation upper mud

SAP = sampling and analysis plan

Table 2-5. Summary of Water Samples Collected for 100-K Remedial Investigation

Well Name	Well Identification	100-K SAP (DOE/RL-2009-41) Requirement	Depths Sampled	Number of Intervals Sampled	Deviations from 100-K SAP (DOE/RL-2009-41)
199-K-183	C7683	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	22.9 to 44.1 m (75.0 to 144.8 ft)	15	The first sample into the water table was not collected due to a cemented formation, which did not allow for adequate water production.
199-K-184	C7684	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer and from water-bearing intervals of the RUM unit	24.9 to 48.7 m (81.5 to 159.9 ft)	17	None
199-K-185	C7685	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	15.8 to 40.2 m (52 to 132 ft)	17	None
199-K-186	C7686	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	27.1 to 48.8 m (89 to 160 ft)	15	None
199-K-187	C7687	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	35.9 to 59.6 m (117.7 to 195.7 ft)	17	None
199-K-188	C7688	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer and from water-bearing intervals of the RUM unit	32 to 56.1 m (105 to 184 ft)	16	Sample scheduled for approximately 47.2 m (155 ft) bgs (16.8 m [55 ft] into unconfined aquifer) could not be collected due to heaving sand. A sample attempted at 52.7 m (172.9 ft) was not successful.
199-K-189	C7689	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	23.5 to 46.3 m (77 to 152 ft)	16	None
199-K-190	C7690	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	18 to 40.8 m (59 to 133.7 ft)	16	None
199-K-191	C7691	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	23.8 to 47.2 m (78 to 155 ft)	16	None
199-K-192	C7692	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer and from water-bearing intervals of the RUM unit	16.8 to 55.5 m (55 to 182.0 ft)	19	None

Table 2-5. Summary of Water Samples Collected for 100-K Remedial Investigation

Well Name	Well Identification	100-K SAP (DOE/RL-2009-41) Requirement	Depths Sampled	Number of Intervals Sampled	Deviations from 100-K SAP (DOE/RL-2009-41)
199-K-193	C7693	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	25.1 to 48.2 m (82.5 to 158 ft)	16	None
199-K-194	C7694	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer	26.8 to 43.3 m (88 to 142.2 ft)	11	No sample collected at 35.7 m (117 ft).
199-K-195	C7695	Collect sample every 1.5 m (5 ft) throughout unconfined aquifer and from water-bearing intervals of the RUM unit	27.5 to 53.6 m (90.1 to 175.8 ft)	18	None
199-K-200	C7831	Collect one sample at 1.5 m (5 ft) into the unconfined aquifer.	17.86, 18, and 18.07 m (58.6, 59, and 59.3 ft)	3	Additional samples collected.
199-K-201	C7832	Collect one sample at 1.5 m (5 ft) into the unconfined aquifer.	17.9 and 18.4 m (58.7 and 60.4 ft)	2	Additional samples collected.

Reference: DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*.

RUM = Ringold Formation upper mud

SAP = sampling and analysis plan

The following sections present details of investigations conducted under the 100-K Work Plan (DOE/RL-2008-46-ADD2), and activities conducted under other scopes of work that may affect the FS decisions, including the Columbia River RI Work Plan (DOE/RL-2008-11) and the RCBRA (DOE/RL-2007-21).

2.1.2 Data Sets

Historical, RI, and interim RA data are evaluated in this report. Appendix D provides additional details and data summaries. The following data were compiled and evaluated for the RI:

- Waste site RA soil analytical data (CVP and RSVP data). These data sets are used to evaluate the nature and extent of soil contamination and to develop and refine the CSM (Chapter 4), groundwater protection (Chapter 5), human health risk assessment (Chapter 6), and ecological risk assessment (Chapter 7).
- Field investigation soil analytical data (LFI data). These data are used in the evaluation of nature and extent (Chapter 4) and considered in the groundwater protection evaluation (Chapter 5), human health risk assessment (Chapter 6), and ecological risk assessment (Chapter 7).
- RI soil analytical data. Depth specific soil samples collected during RI drilling are used to evaluate contaminant distribution in the vadose zone and refine the CSM (Chapter 4).
- Groundwater analytical data. Various data subsets were used for different purposes. (a) Data from October 2009 to April 2017 were used for statistical summaries in Chapter 4 and the risk assessments in Chapters 6 and 7; (b) data from October 2009 through April 2017 were used to produce plume maps and trend plots in Chapter 4; (c) the maximum contaminant concentrations at each 100-K well in 2016 were used to produce the initial plumes for groundwater modeling (Chapter 5 and Appendix F); (d) groundwater characterization data, collected from boreholes during drilling of RI wells and post-RI wells, were used to construct vertical profiles and cross sections (Chapter 4 and Appendix C).
- Well and borehole drilling and construction information. These data were used to develop the geologic cross sections (Chapter 3) and for groundwater model development (Chapter 5 and Appendix F).
- Fate and transport parameters (e.g., geochemical parameters, hydrogeologic parameters, and soil physical properties). These data are used to develop the groundwater model and in fate and transport evaluations (Chapter 5 and Appendix F).
- Distribution coefficient data for metals. These data are used to evaluate metals fate and transport (Chapter 5).
- Geologic information. These data are used to develop the geologic cross sections (Chapter 3 and Appendix C) and groundwater model (Chapter 5 and Appendix F).
- Groundwater levels and river stage. These data are used to develop groundwater flow maps (Chapter 3) and the groundwater model (Chapter 5 and Appendix F).

Most sample data used in the RI were analyzed in a fixed laboratory using approved methods with specific quality assurance (QA)/quality control (QC) requirements. Additional parameters were measured in the field (e.g., specific conductance, pH, DO, oxidation-reduction potential, temperature, and turbidity). A soil sample data usability assessment (DUA) (WCH-489, *100-K Remedial Investigation/Feasibility Study Data Quality Assessment Report*), and water sample DUA, *Data Quality Assessment for 100-KR-4*

Remedial Investigation Data, are provided in Appendix D for the RI data. Data validation qualifiers are included in Appendix D. Detection limits, precision, accuracy, and completeness were assessed to determine whether the chemical and radiochemical data obtained were the right type, quality, and quantity to support regulatory decision-making. Data validation for the RI is provided in Appendix D.

2.1.3 Historical Information Review

Historical information for 100-K was researched and reviewed during the work plan preparation. This information was considered during the work plan development and preparation of this report. Reports containing relevant or significant information are summarized in Section 1.2.3 and in the Annotated Bibliography in Appendix B.

2.1.4 Surface Features

Surface feature mapping, such as high-resolution topography, was conducted using Light Detection and Ranging (LIDAR) mapping technology in 2008. LIDAR is an optical remote sensing technology that measures properties of scattered light to find range and/or other information for a distant target. The accuracy of the LIDAR topography is estimated at 11 cm (4.3 in.). LIDAR data were used to create a topographic map of 100-K for defining surface relief/elevation differences (Section 3.1). Surface topography establishes part of the framework needed to evaluate fate and transport.

2.1.5 Contaminant Source Investigations

The OSE process in 100-K was completed in February 2008. The discovery site process, described in Section 1.2.3.2, continued during remedial action activities (e.g., waste site RTD). Site discovery activities will continue during future remedial action.

2.1.6 Meteorological Investigations

The Hanford Meteorological Station (HMS) (http://www.hanford.gov/hms/) provides a range of Hanford Site weather forecast products and real-time meteorological data, and an extensive historical database of meteorological and climatological data. Metrological measurements have been recorded at HMS since late 1944. Information specific to precipitation and wind speed have the potential to affect remedial actions, as discussed in Section 3.2. No additional meteorological data were collected as part of this RI.

2.1.7 Air Investigations

The Hanford Site Environmental Monitoring Program is described in DOE/RL-91-50. Monitoring of radionuclide airborne emissions from site facilities is performed through several programs. Near-facility environmental monitoring is performed by the Effluent Monitoring Program and measures radionuclide concentrations in the ambient air on the Hanford Site in or near facilities and operations.

Nonradioactive air pollutants are emitted from a variety of sources at the Hanford Site. Sections 2.1.7.1 and 2.1.7.2 summarize the most recent information regarding Hanford Site air monitoring activities as reported in DOE/RL-2017-24.

2.1.7.1 Air Monitoring Near Facilities and Operations

Ambient air is monitored at locations on the Hanford Site near facilities and operations. Samplers are located primarily within approximately 500 m (1,640 ft) of projects or facilities having a known potential for, or history of, airborne releases of radioactive contamination. This ambient monitoring is termed near-facility environmental monitoring. Monitoring locations are associated largely with major nuclear facilities and waste storage, disposal, or cleanup activities. Occasional adjustments are made in the number or location of the monitoring stations as changes in the sources of emissions may occur. There were 60 continuously operating air samplers near site facilities and operations areas across the

Hanford Site in 2016 (DOE/RL-2017-24). Table 6-3 in DOE/RL-2017-24 lists the six locations in the 100-K Area where ambient air was monitored in 2016. Analytical results showed radionuclide concentrations at or below typical Hanford Site levels.

2.1.7.2 Air Monitoring at Hanford Sitewide and Offsite Locations

As part of the Hanford Site Environmental Surveillance Project, 40 continuously operating air samplers on or near the Hanford Site collected radionuclide samples in 2016 (DOE/RL-2017-24). The sampling stations were grouped into four location categories: Hanford Site (21 stations), perimeter (11 stations), nearby communities (7 stations), and distant community (1 station).

Samples are collected from known or expected air transport pathways, which are generally downwind from potential or actual airborne releases and downgradient of liquid discharges. Airborne particle samples are collected at each station biweekly and monitored for gross alpha and gross beta concentrations. Biweekly samples are combined into semiannual composite samples and analyzed for gamma emitting radionuclides. Atmospheric water vapor samples are collected every 4 weeks and analyzed for tritium at approximately 20 locations. A detailed discussion of the air sampling and results at the Hanford Site is presented in in Section 6.2 of the 2016 Sitewide Environmental Report (DOE/RL-2017-24). Table 6-4 of the same report provides sample locations and a list of analyses for each location.

No additional air monitoring, with the exception of in-process monitoring at the immediate work site during select borehole, well, and test pit activities, was conducted as part of this RI. The Washington State Department of Health also conducts independent sampling and analysis of various media, including ambient air, soil, and biota, both on and off the Hanford Site. This independent sampling and analysis routinely confirms little or no environmental impacts outside of the most closely controlled work areas on the Hanford Site.

2.1.8 Surface Water and Sediment Investigations

An investigation of pore water, surface water, and sediment was conducted to identify the nature and extent of contaminants entering the Columbia River, specifically by groundwater upwelling. The effort was performed per the Columbia River RI Work Plan (DOE/RL-2008-11) through activities planned prior to the 100-K RI, as outlined in the 100-K Work Plan (DOE/RL-2008-46-ADD2). Data Gaps 6 and 9 (Table 2-2) identify the importance of addressing groundwater discharge and surface water/groundwater mixing to support decision making in a ROD. The following sections provide details on these investigations. Results are described in Section 3.7.3.

Investigation data collected during the RI to evaluate groundwater discharge to the Columbia River have been integrated with data sets collected as part of the Columbia River RI Work Plan (DOE/RL-2008-11), presented in the CRC (DOE/RL-2010-117), and with data collected as part of the RCBRA (DOE/RL-2007-21). Appendix L provides the conceptual model evaluation for potential fate, transport, and exposure pathways in riparian and nearshore areas in 100-K.

2.1.8.1 Surface Water/Groundwater Interaction

Uncertainty in the nature and extent of contamination entering the Columbia River was identified during the work plan process (Data Gap 6). Water samples were collected from the rocky bed of the Columbia River (pore water) and from aquifer tubes adjacent to the river to address this uncertainty.

100-K groundwater discharges to the Columbia River via seeps and upwelling to the riverbed. This groundwater flow provides a pathway for contaminant transport to the Columbia River. Rapid, periodic, or cyclic river elevation fluctuations occur in controlled response to flood conditions, hydroelectric

production, and salmon spawning programs at upriver dams and reservoirs. These river elevation changes influence flow conditions within the aquifer. Daily fluctuations of more than 2 m (6 ft) are common. Even greater changes (more than 4.5 m [15 ft]) are observed seasonally, with high river stage in the spring or early summer and low river stage in the fall. Periods of high or low river flow affect groundwater flow.

The nearshore groundwater conditions are directly affected by river stage. A wide range of mixing ratios between groundwater and river water has been observed at the river bed and in groundwater at nearshore locations (SGW-39305, *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area*). This mixing ranges from pure groundwater to pure river water, depending on where the measurement is taken.

Scenarios for contaminant plume discharge to the river vary widely because of dynamic seasonal conditions in the zone of interaction. The greatest contaminant flux and highest concentrations at potential exposure locations occur during periods of low river stage. During this period, the hydraulic gradient toward the river is steepest, and mixing between river water and groundwater is at its lowest stage.

2.1.8.2 Pore Water, Surface Water, and Sediment Sampling

Groundwater beneath the Hanford Site discharges to the Columbia River via seeps and upwelling to the riverbed. This groundwater flow path provides a means to transport Hanford Site contaminants, which have leached into the groundwater from the past waste disposal practices to the Columbia River.

Nearshore groundwater conditions, including flow rates and direction, and contaminant flux, are directly affected by river stage changes. Limited historical data are available to provide understanding of groundwater flow paths, contaminant migration, and mixing in the nearshore area. A 2008 evaluation (SGW-39305) observed a range of mixing ratios between upwelling water and river water at the bottom of the river and between river water and groundwater at nearshore locations. The mixing ratios represented a continuum from pure groundwater to pure river water, depending on when and where the measurement was taken. The 100-D/H OU attempted to determine a mixing ratio or dilution factor along the river and identified none that were useable, based on literature review of available tools. No data collection strategies were identified that would support determination of a dilution ratio (DOE/RL-2010-95, *Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units*, Section 2.1.7.1). The interim action ROD for 100-HR-3 and 100-KR-4 (EPA/ROD/R10-96/134) assumed a 1:1 dilution for compliance monitoring. A definitive dilution factor would not affect P&T performance evaluations (e.g., DOE/RL-2016-68), which compare reported concentrations directly to cleanup levels.

Scenarios for plume discharge to the river vary widely because of seasonality and dynamic conditions in the zone of interaction. The greatest contaminant flux and highest concentrations at exposure locations are postulated at low river stage. During this period, the hydraulic gradient toward the river is steepest, and mixing between river water and groundwater within the hyporheic zone is minimal.

To address the uncertainty related to the nature and extent of contamination entering the Columbia River, including the contaminant transport mechanisms, data were collected near 100-K in 2009 and 2010. Groundwater Cr(VI) plume locations in 100-K were used to guide river pore water sample locations. Pore water sampling in the Columbia River was conducted during three phases, as outlined in the Columbia River RI Work Plan (DOE/RL-2008-11).

The first phase of the Columbia River RI pore water sampling, termed Phase II(a), focused on identifying riverbed areas where groundwater was entering the Columbia River. The second phase, termed Phase II(b), returned to a subset of the Phase II(a) sample locations to collect pore water samples for indicator contaminant analysis. For 100-K, the indicator contaminant was Cr(VI). The third phase identified a

subset of the previous sample locations for sampling and analysis of pore water, surface water, and sediment for a wide range of potential contaminants.

The objective of Phase II(a) sampling was to identify and delineate groundwater plumes upwelling in the Columbia River adjacent to Hanford Site operations areas. In situ pore water conductivity and temperature data were collected in Phase IIa using a multisensor water sampling probe capable of being inserted approximately 30 cm (12 in.) into the riverbed. Six cross-river transects were conducted near 100-K; each transect had five sample locations. Up to 10 locations surrounding each transect were also sampled. Measurements were made at 90 stations near 100-K in early 2009. Chapter 3 summarizes results of this portion of the study.

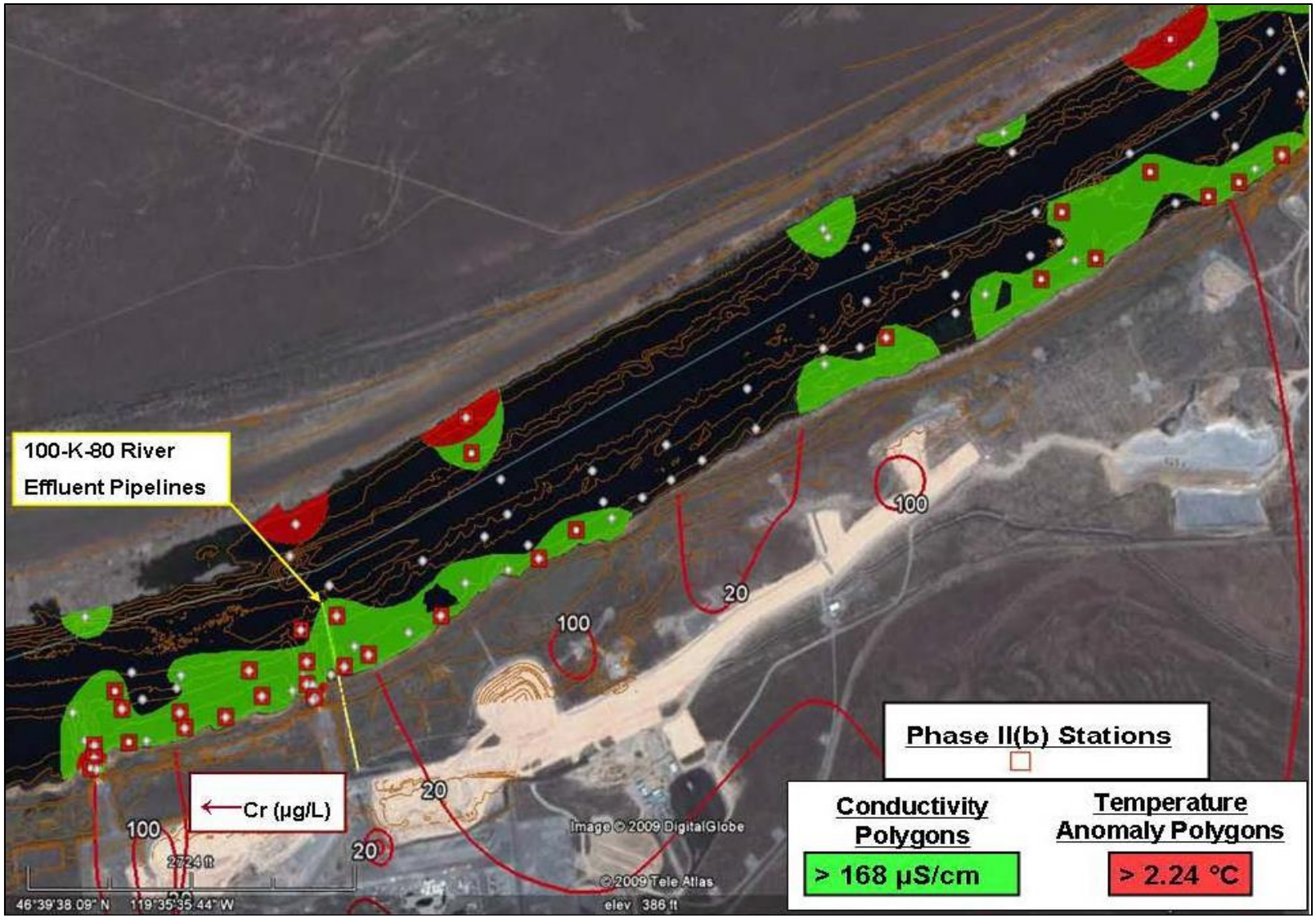
Pore water sampling for Phase IIb was conducted at a subset of the Phase IIa locations (32 locations) that clearly showed groundwater upwelling based on conductivity and temperature variances between the river and pore water, and were deemed most likely to have contamination. Figure 2-2 shows these sample locations, which were approved by the Tri-Parties. The Phase IIb pore water samples were analyzed for Cr(VI).

During Phase III, the contaminant influence on surface water quality immediately above groundwater upwelling locations was assessed by collecting water column samples. Pore water samples for Phase III were collected from established upwelling locations, with the focus on sites where Cr(VI) was detected in Phase IIb pore water samples. The Tri-Parties selected six locations (Figures 2-3 and 2-4) near 100-K for Phase III sampling, consisting of five primary sites and one secondary site (to be sampled after primary sites had been sampled). Pore water, surface water, and sediment samples were collected at each of the six locations. River water and pore water samples were collected concurrently at approximately 0.3 m (12 in.) above the riverbed. Sediment samples were obtained as close to the pore water sample locations as reasonably possible, with a preference given to locations with sediment deposits.

Phase III samples were analyzed for a range of radiological and nonradiological analytes as shown in Table 2-6. While samples were successfully collected at each specified location, not all media and/or analyses could be collected and/or conducted for each sample location due to site-specific sampling or sample volume constraints. Table 2-7 provides the numbers of samples collected during each sampling phase and the collection period. Chapter 4 summarizes results of Phases IIb and III.

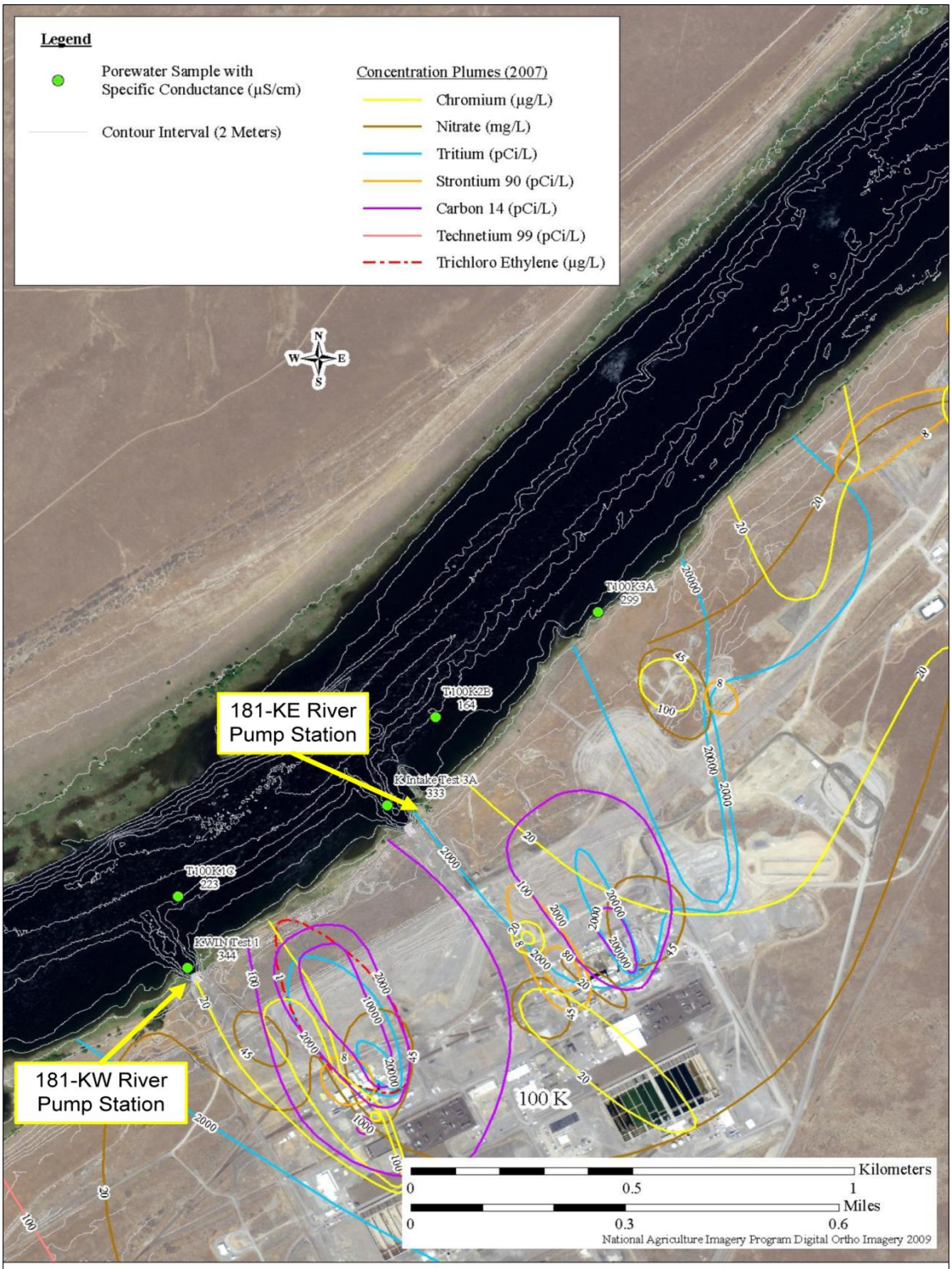
Aquifer Tube Installation and Monitoring. Initial characterization of site contamination near the river relied on data from a limited number of near-river wells, contaminant plume migration predictions, and riverbank seep sampling to predict shoreline conditions. To resolve the uncertainty, aquifer tubes were installed along the River Corridor, including 100-K, to assist with characterizing nearshore contaminants. The aquifer tubes are small diameter polyethylene tubes with a screen (sampling port) at the lower end (Figure 2-5), and were placed into the aquifer by driving temporary steel casings into the ground and inserting tubes into the casings. The temporary steel casing was driven by a hydraulic ram attached to a vehicle or by a hand-carried pneumatic hammer. The steel casing was then pulled out, leaving the tube and the stainless steel drive point in place. Water samples were collected from the tubes using a peristaltic pump. The tubing exposed at the ground surface is minimal length (several feet) and protected from wildlife and the elements by PVC conduit. Figure 2-5 shows the main components of aquifer sampling tube installation.

As part of this RI, aquifer tubes C7641, C7642, and C7643 were installed at 100-K (Figure 2-1). These tubes were sampled for the first time in August 2010. A larger set of 100-K aquifer tubes was sampled annually between 2010 and 2017. Results of aquifer tube sampling are discussed in Section 4.4.



Reference: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*, Figure 3-5.

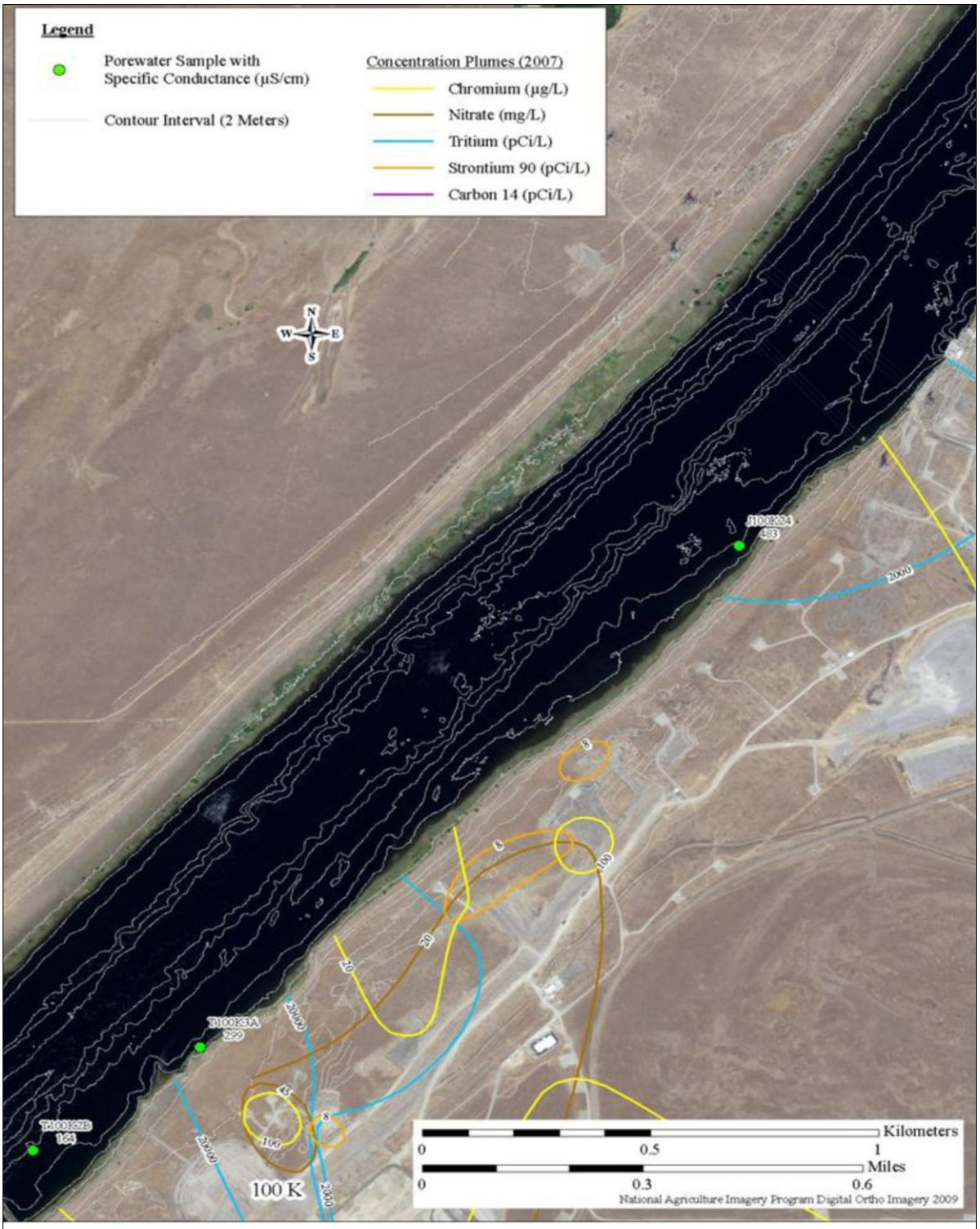
Figure 2-2. Columbia River Pore Water Sampling Locations at 100-K – Columbia River Remedial Investigation Phase IIb



Source: Figure 3-61, Sheet 1, WCH-380

Reference: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*.

Figure 2-3. Columbia River Pore Water Sampling Locations at 100-K – Columbia River Remedial Investigation Phase III



Source: Figure 3-61, Sheet 2, WCH-380

Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling.*

Figure 2-4. Columbia River Pore Water Sampling Locations at 100-K – Columbia River Remedial Investigation Phase III

Table 2-6. Analytes for Columbia River Remedial Investigation (Phase III) Sampling

Media	Analytes															
	Metals (Filtered)[a]	Metals (Unfiltered)[a]	Metals (Solid) [a]	Hexavalent Chromium	Nitrate and Anions	AVS/SEM	Hardness/DOC/Alkalinity	TOC/TIC	TOC/Grain Size	Isotopic Thorium	Isotopic Plutonium	Tritium	Strontium-89/90	Isotopic Uranium	Radionuclides, GEA [b]	Field Parameters [c]
Pore Water	X	X		X	X			X				X	X			X
Surface Water	X	X		X	X		X			X	X		X	X	X	X
Sediment			X	X	X	X			X	X	X		X	X	X	

Reference: WCH-286, *Sampling and Analysis Instructions for the Remedial Investigation of Hanford Site Releases to the Columbia River*.

a. Inductively coupled plasma metals including uranium (Method 6010TR) and mercury (Methods 7470/7471).

b. Radionuclides include americium-241, antimony-125, beryllium-7, cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, potassium-40, radium-226, radium-228, and ruthenium-106.

c. Field parameters for pore and surface water include temperature, specific conductivity, dissolved oxygen, and pH.

AVS/SEM = acid volatile sulfides/simultaneously extracted metals
DOC = dissolved organic carbon
GEA = gamma energy analysis
TIC = total inorganic carbon
TOC = total organic carbon

Table 2-7. Sample Collection at 100-K during Columbia River Remedial Investigation

Sample Phase	Sample Dates	Parameters of Interest	Number of Samples/ Stations
Phase IIa	January to March 2009	Temperature and conductivity	90
Phase IIb	September to November 2009	Cr(VI)	32
Phase III	January to February 2010	See Table 2-6	6

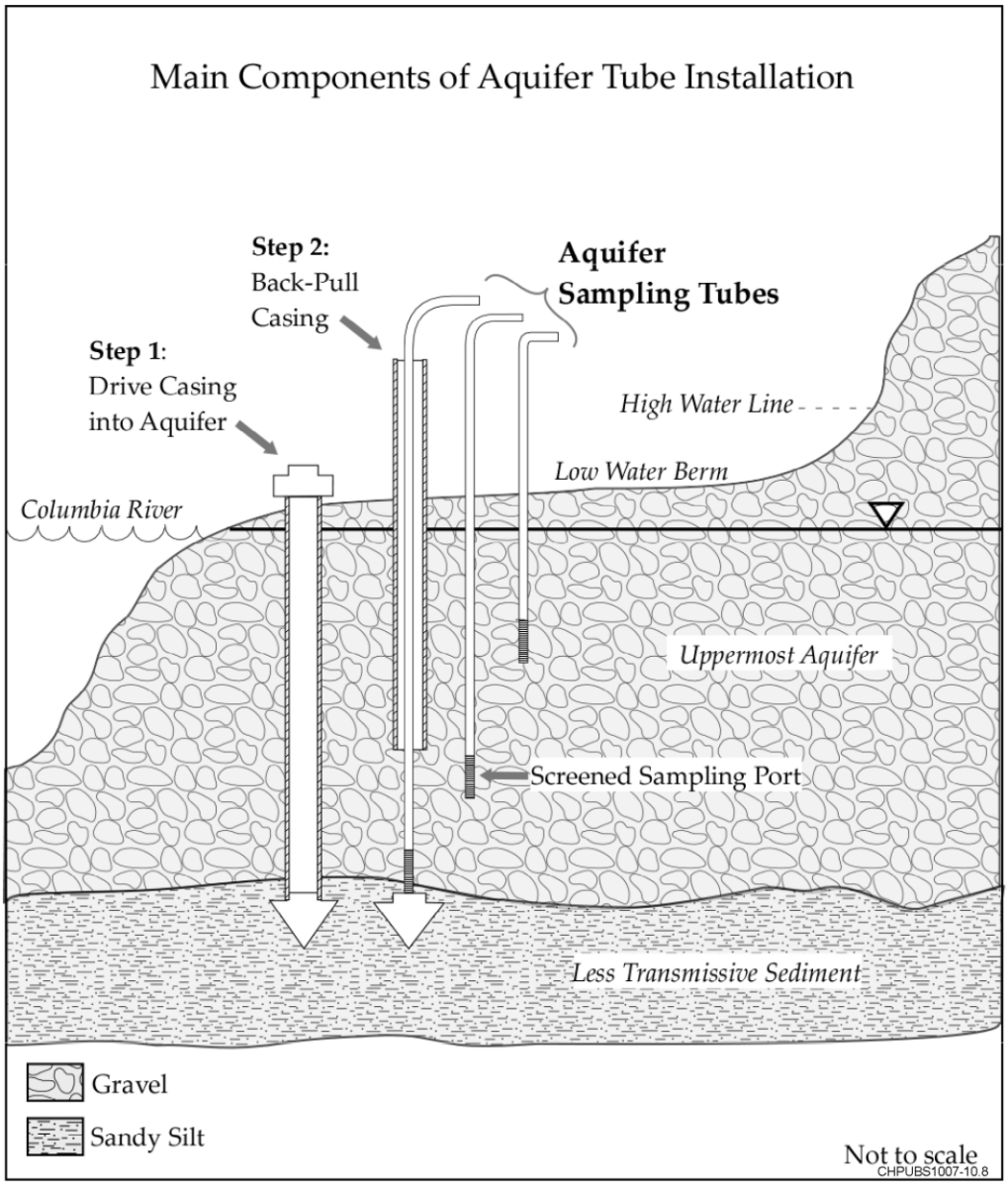


Figure 2-5. Main Components of Aquifer Tube Installation

2.1.8.3 Additional Surface Water and Sediment Sampling

In addition to the sampling described in Section 2.1.8.1, supplemental samples of surface water, sediment, and island soil were taken during the RI at locations described in WCH-352, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, River Sediments, and Island Soils*, and WCH-398, *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (hereinafter called the Hanford Site Releases Data Summary), to identify the nature and extent of potential contaminant releases associated with Hanford Site operations. Figure A-5 in Hanford Site Releases Data Summary (WCH-398) shows the sample locations near 100-K. Additional samples collected for the Columbia River RI included one surface water and 13 shoreline, shallow, and core sediment samples.

2.1.8.4 Routine Monitoring of Surface Water

DOE conducts routine monitoring of Columbia River surface water on the Hanford Site (DOE/RL-2017-24). Samples are collected upstream of the Hanford Site at Priest Rapids Dam, downstream of the site at the City of Richland, and at several locations on the site. A cross-river transect is sampled at the Hanford town site. River water is not sampled at 100-K. Constituents of interest in Columbia River water samples collected at Priest Rapids Dam and the City of Richland include gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium isotopes, and plutonium isotopes. Section 4.5 discusses the results of surface water sampling.

2.1.9 Geologic Investigations

Geologic characterization data needs were identified to support modeling and analysis. Geologic investigations included characterization while installing and sampling RI wells and boreholes, evaluating bathymetric data, and conducting geophysical logging.

Geological investigations were conducted to address Data Needs 2, 5, 7, 10, and 12 listed in Table 2-2. In addition, geologic data were needed to enhance understanding of the hydrogeologic conditions, aquifer interactions, and contaminant mobility through the vadose zone and in the unconfined and confined aquifers.

Additional wells were installed since the RI for characterization, as replacements for wells removed during waste site remediation, and as extraction, injection, and monitoring wells for groundwater remediation. These data provided additional geologic characterization information to meet data needs.

2.1.9.1 Geologic Characterization

To address the RI data needs, nine wells were installed in the unconfined aquifer. Four borings were drilled into the RUM unit, with one well installed in the uppermost confined aquifer in the RUM. The other three borings did not encounter a water-bearing unit in the RUM, so the wells were installed in the unconfined aquifer in the Ringold Formation unit E. Boreholes were drilled at the east and west ends of the 116-K-2 Trench. Water samples were not collected during drilling because of silty aquifer conditions and low water production. The boreholes were converted to 10 cm (4 in.) temporary wells to obtain water samples from below the 116-K-2 Trench.

Geologic samples were collected at approximately 1.5 m (5 ft) depth intervals, and at discernible changes in lithology from ground surface to total depth. In general, the major stratigraphic units encountered during this project included backfill, Holocene eolian deposits, cataclysmic Hanford formation flood deposits, and fluvially derived Ringold Formation unit E deposits. Drilling was terminated below the RUM contact, with the exception of the four borings drilled into the RUM unit. The four borings drilled into the RUM did not advance to the underlying Columbia River Basalt Group. Table 2-4 identifies soil samples collected for the RI.

To support modeling efforts, split spoon samples were collected from each well at major formations and lithology changes to provide site-specific physical property data (grain size, porosity, moisture content, bulk density and, in the case of saturated samples, saturated hydraulic conductivity). In Table 2-4, the number of soil samples collected per boring is listed under the column entitled “Physical Soil Samples.” One physical sample analysis, such as sieve analysis, was not collected in each of boreholes C7683, C7685, C7686, C7687, C7689, C7690, C7693, C7831, and C7832, as there was an insufficient sample volume remaining after the geochemical sample was removed.

Table 2-8 lists the RI wells, boreholes, aquifer tubes, and hydrogeologic units monitored. Table 2-9 identifies post-RI borehole drilling and well installations completed between February 2011 and April 2017. Appendix C includes additional information about the wells, such as screen depths and elevations of geologic contacts. Geologic data from these wells were combined with data from older wells to support 100-K geology interpretations. Geologists used the data to construct geologic cross sections and maps. Section 3.4 (Chapter 3) and Appendix C present the 100-K geologic investigation results. The following reports contain geologist's logs, geophysical logs, and well completion details for the RI wells and post-RI wells:

- SGW-48760, *Borehole Summary Report for Two Characterization Boreholes in the K2 Trench in the 100-KR-4 Operable Unit to Support WCH in FY 2010* (hereinafter called K-2 Trench Borehole Summary Report)
- SGW-49459, *Borehole Summary Report for the Drilling and Installation of RI/FS Wells in the 100-KR-4 Operable Unit* (hereinafter called Borehole Summary Report for KR-4 RI/FS Wells)
- SGW-58157, *Borehole Summary Report for the Installation of Three Wells in the 100-KR-4 Operable Unit, FY2013*
- SGW-59027, *Borehole Summary Report for the Installation of Two Wells in the 100-KR-4 Operable Unit, with and option of Three Wells, FY2014*
- SGW-59494, *Borehole Summary Report for the Installation of Two Characterization, Monitoring, and Extraction Wells in the 100-KR-4 Operable Unit, FY2015*
- SGW-60149, *Report for Soil Borings and Well Installations in the UPR-100-K-1 and 116-K-3 Waste Sites*
- SGW-60241, *Borehole Summary Report for the Installation of Four 100-KR-4 Operable Unit Extraction Wells, FY16*

Table 2-8. 100-K RI Well, Borehole, and Aquifer Tube Construction Summary

Well Name	Well Identification	Dates Drilled	Location Objective (100-K Work Plan [DOE/RL-2008-46-ADD2])	Hydrogeologic Unit Monitored
199-K-183	C7683	May to Jun. 2010	Determine the extent of Cr(VI) in groundwater	Unconfined aquifer
199-K-185	C7685	Jun. to Jul. 2010	Determine the extent of Cr(VI), Sr-90, C-14, trichloroethene, and tritium downgradient of the KE Reactor	Unconfined aquifer
199-K-186	C7686	Dec. 2010 to Feb. 2011	Characterize deep vadose zone and unconfined aquifer	Unconfined aquifer
199-K-187	C7687	May 2010 to Jun. 2010	Determine the extent of Cr(VI) in groundwater	Unconfined aquifer
199-K-189	C7689	Jul. to Sep. 2010	Characterize deep vadose zone and unconfined aquifer	Unconfined aquifer
199-K-190	C7690	Jul. to Aug. 2010	Determine the extent of Cr(VI) in groundwater at a hot spot downgradient of the KE Reactor	Unconfined aquifer

Table 2-8. 100-K RI Well, Borehole, and Aquifer Tube Construction Summary

Well Name	Well Identification	Dates Drilled	Location Objective (100-K Work Plan [DOE/RL-2008-46-ADD2])	Hydrogeologic Unit Monitored
199-K-191	C7691	Jun. to Jul. 2010	Determine the extent of Cr(VI) and tritium in groundwater near the 116-K-2 Trench	Unconfined aquifer
199-K-193	C7693	Sep. to Nov. 2010	Determine the extent of Cr(VI) in groundwater	
199-K-194	C7694	Dec. 2010 to Jan. 2011		
199-K-184 [a]	C7684	Dec. 2010 to Jan. 2011	Characterize the deep vadose zone, unconfined aquifer, and RUM	
199-K-188 [a]	C7688	Dec. 2010 to Feb. 2011	Characterize the deep vadose zone, unconfined aquifer, and RUM	
199-K-192	C7692	Aug. to Nov. 2010	Characterize the deep vadose zone, unconfined aquifer, and RUM	Uppermost confined aquifer
199-K-195 [a]	C7695	Nov. to Dec. 2010	Characterize the deep vadose zone, unconfined aquifer, and RUM	Unconfined aquifer
199-K-200	C7831	Aug. to Sep. 2010	Characterize contamination beneath the 116-K-2 Trench	
199-K-201	C7832	Aug. to Sep. 2010	Characterize contamination beneath the 116-K-2 Trench	
199-K-221	C8796	Mar. to Jun. 2015	Monitoring well to characterize 116-KE-3 waste site [b]	
199-K-222	C8797	Jul. to Sep. 2015	Monitoring well to characterize UPR-100-K-1 waste site [b]	
RI Aquifer Tubes				
--	C7641	Mar. 2010	Determine the extent of Cr(VI), Sr-90, C-14, trichloroethene, and tritium downgradient of the KE Reactor	Unconfined aquifer
--	C7642	Mar. 2010		
--	C7643	Apr. 2010		

Reference: DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units.*

a. Drilled into the RUM but completed and screened in the Ringold Formation unit E.

b. Characterization borehole to evaluate surface barrier protectiveness and evaluate groundwater contamination.

C-14 = carbon-14
Cr(VI) = hexavalent chromium
RI = remedial investigation
RUM = Ringold Formation upper mud
Sr-90 = strontium-90

Table 2-9. 100-K Post-RI Groundwater Interim Remedial Action Wells Construction Information Summary

Well Name	Well Identification	Dates Drilled	Well Location and Purpose
199-K-196	C7696	Jul. to Aug. 2011	Extraction well for river Protection downgradient of KW Reactor
199-K-197	C7697	May to Jul. 2011	Plume delineation near southwest end of 116-K-2 Trench
199-K-198	C7698	Mar. to May 2011	River protection downgradient of 116-K-2 Trench
199-K-199	C7699	Feb. to Mar. 2011	River protection downgradient of 116-K-2 Trench
199-K-202	C8289	Aug. to Sep. 2013	Plume delineation and river protection
199-K-203	C8290	Aug. 2014 to Feb. 2015	Plume delineation and river protection downgradient of KE Reactor
199-K-204	C8291	Aug. to Oct 2014	Monitoring well for plume delineation downgradient of KW Reactor
199-K-205	C8292	Sep. 2013 to Feb. 2014	Extraction well near 183-KW Headhouse to increase mass removal
199-K-206	C8293	Oct. 2013 to Mar. 2014	Injection well near 183-KW Headhouse to increase KW system capacity
199-K-207	C8294	Dec. 2014 to Feb. 2015	Monitoring well for plume delineation, northeast of KE Reactor at 118-K-1 waste site
199-K-208	C8295	Dec. 2014 to Feb. 2015	Extraction well northeast of KE Reactor
199-K-209	C8296	Jan. to Mar. 2015	Monitoring well for plume delineation east of 100-K
199-K-210	C8297	Mar. to Jun. 2014	Extraction well for river protection downgradient of KE Reactor
199-K-212	C8299	Mar. to May 2014	Extraction well for river protection downgradient of 116-K-2 Trench
199-K-220	C8795	Mar. to Jun. 2014	Extraction well to increase mass removal near 183-KW Headhouse
199-K-223	C9595	Jun. to Sep. 2016	Monitoring well for plume delineation near KW Reactor
199-K-224	C9596	Jun. to Aug. 2016	Monitoring well for plume delineation near KW Reactor
199-K-225	C9597	Jun. to Oct. 2016	Extraction well near 183-KE Headhouse for source area remediation
199-K-226	C9598	Jul. to Oct. 2016	Extraction well northeast of KE Reactor for source area remediation

RI = remedial investigation

2.1.9.2 Bathymetric Evaluation

Contaminant flow paths from 100-K to the Columbia River are related to the locations of geologic units both on shore and exposed at the bed of the Columbia River. To evaluate contaminant flow paths to aquatic receptors, updated and accurate river bathymetric data were needed (Data Gap 8). An evaluation of the RUM unit surface using near river wells indicated that the top of the RUM intersects the Columbia River. No additional data were proposed for the area as part of the RI; however, the existing data were further evaluated to better define the river bathymetry. Figure 2-6 shows the Columbia River bathymetry near 100-K. Coyote Rapids (Figure 2-6) is a feature resulting from resistant Ringold Formation unit E cemented units in the riverbed.

The development of a high-resolution bathymetry dataset for the Columbia River through the Hanford Reach was a continuation of fiscal year (FY) 2009 work that focused on retrieving, assembling, and processing 66 km (41 mi) of existing bathymetry and terrestrial topographic data (PNNL-19878, *Development of a High-Resolution Bathymetry Dataset for the Columbia River through the Hanford Reach*). At the conclusion of the FY 2009 work, it was determined that additional data were needed. The data would be collected over a 30 km (19 mi) section to supplement existing bathymetric and topographic data and would fill data gaps in the central portion of the Hanford Reach. In FY 2010, hydrographic surveys were conducted, and the resulting data were incorporated into a multisource data fusion process to produce a single high-resolution (1 m [3.3 ft]) dataset for the Hanford Reach. To complete the interpretations, key hydrogeologic unit surfaces (e.g., structure maps of the Ringold Formation unit E and RUM, based on data from wells and boreholes) were projected beneath the footprint of the river. The river bathymetry (river bottom elevation) was then overlain onto the hydrogeologic unit structure maps. Ringold Formation unit E sediments are in contact with the river along the 100-K shoreline.

2.1.9.3 Geophysical Logging

To better understand the area geology, geophysical logging was completed at each of the soil borings drilled for the RI. Logging was conducted using a Spectral Gamma Logging System and a Neutron-Moisture Logging System to identify natural and manmade gamma-emitting radionuclides near the boreholes. Soil moisture was determined using a neutron logging tool. The starting point for logging, either the ground surface or top of the casing, was recorded for each well or borehole. Borehole logging was performed through the temporary casings to produce a geophysical log of the entire borehole. Geophysical logs for RI boreholes are available in Appendix C and in the borehole summary reports listed in Section 2.1.9.1.

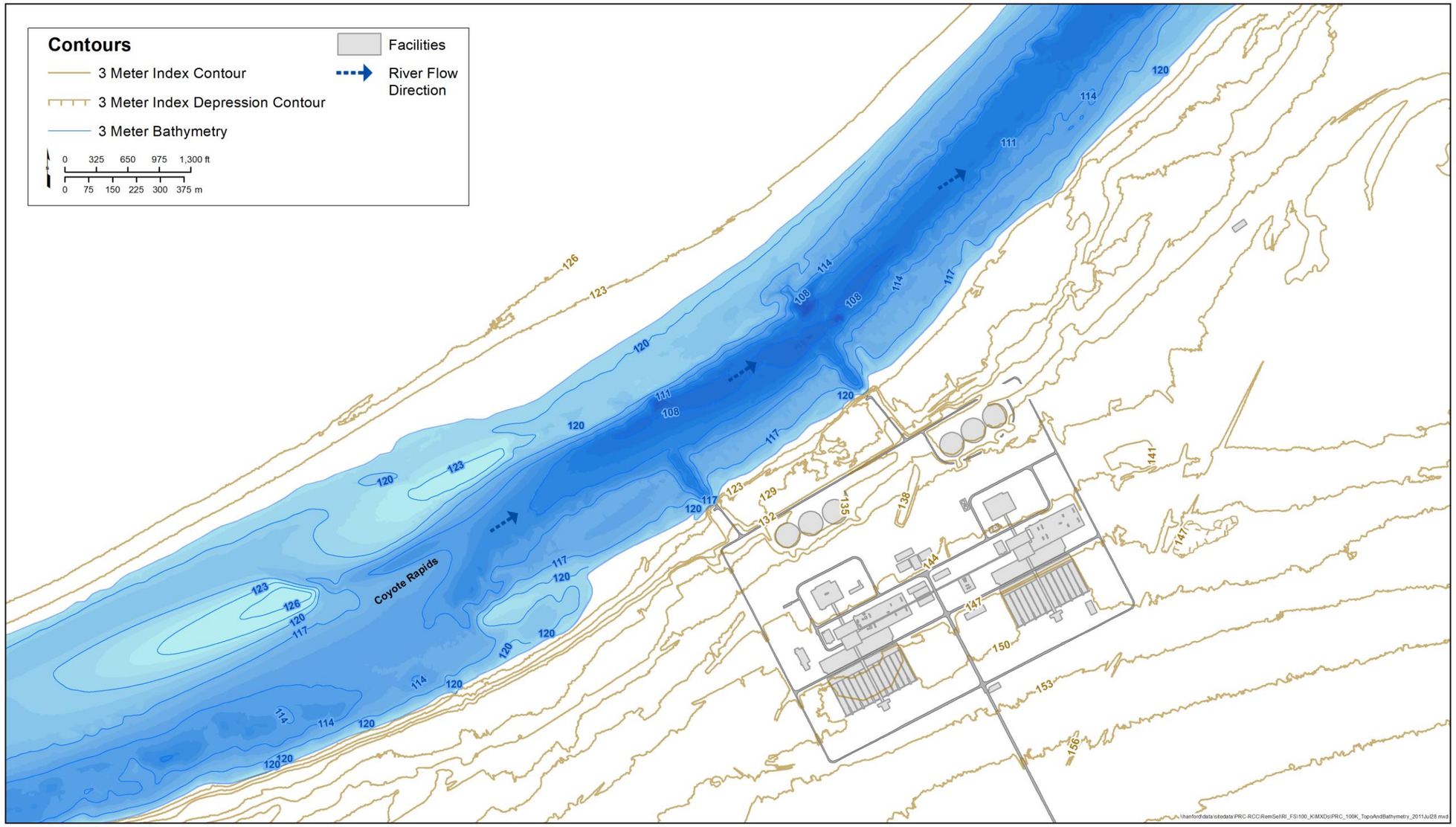


Figure 2-6. Bathymetry of the Columbia River near 100-K

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2.1.10 Vadose Zone Investigations

Historical soil borings and interim action waste site remediation activities provide information on the nature and extent of contaminants and the overall vadose zone characteristics within 100-K. These data were supplemented with RI data collected to address uncertainties identified in the 100-K Work Plan (DOE/RL-2008-46-ADD2) related to the nature and extent of contamination beneath unremediated waste sites, select interim closed out waste sites, and potential contamination around reactor structures (Data Gaps 1, 2, and 3), provide better information on subsurface conditions beneath the unconfined aquifer (Data Gap 7), identify potential Cr(VI) sources (Data Gap 10), and further characterize soil properties (Data Gap 12). For purposes of this discussion, waste sites referred to here are the sites identified in the WIDS database, as described in Chapter 1.

All waste sites were re-evaluated in the RI as follows:

- Rejected, not accepted, or closed out sites were reviewed to confirm that their status was appropriate. Sites whose status was confirmed were documented in Chapter 1 as requiring no additional RI or FS evaluation. Rejected, not accepted, or closed out sites whose status was not confirmed were further evaluated in this RI and will not be carried forward into the FS.
- Interim closed out and no action sites were evaluated in the RI (Chapters 4, 5, 6, and 7) to determine whether they should be evaluated through the FS process.
- Waste sites requiring remediation that were not completed by April 1, 2017, were evaluated in the FS.

Data needs specific to sources are identified and described in this section. Data needs were addressed relative to unremediated and remediated waste sites and reactor areas.

2.1.10.1 Characterize below Unremediated Waste Sites to Assess Nature and Extent of Contamination in the Vadose Zone

Characterization beneath unremediated waste sites was identified as Data Gap 1 in the 100-K Work Plan (DOE/RL-2008-46-ADD2). Interim RAs have been effective in documenting residual contamination following the completion of RTD activities. Waste site interim RA data are used in the CSM and to identify the potential nature and extent of contamination for analogous waste sites. The data are discussed in Chapter 4.

Sequencing of waste site cleanup is based on the Tri-Party Agreement (Ecology et al., 1989a) milestone framework. Within this framework, knowledge of operational processes (such as sodium dichromate use) and past releases was used to target and prioritize specific waste sites or areas with groundwater contaminant sources or potential sources. Effective waste site cleanup implementation prevents human and environmental exposure to soil contamination and further groundwater degradation, thereby increasing the likelihood for success of groundwater cleanup actions.

There are 197 waste sites in 100-K; 77 remain to be addressed under the interim action RODs. Data needs associated with soil remedial actions in 100-K were met by planning and scheduling the remedial actions, collecting data to verify interim cleanup of waste sites, and obtaining concurrence from regulators on the achievement of interim action ROD RAGs for direct exposure, protection of groundwater, and Columbia River protection. Interim remediation data for 54 waste sites were incorporated into this RI.

Accepted waste sites applicable to Data Gap 1 are identified in Chapter 4. Section 3.4.3 and Appendix C present information for the RI boreholes (wells 199-K-189 [C7689], 199-K-186 [C7686], and 199-K-184 [C7684]).

2.1.10.2 Characterize beneath Remediated Waste Sites

The need to characterize beneath remediated waste sites to assess the extent of residual contamination in the vadose zone was identified in Data Gap 2. The 100-K Work Plan (DOE/RL-2008-46-ADD2) addressed this data need by installing two boreholes beneath the 116-K-2 Trench. Additional post-RI boreholes provide data to assess residual vadose zone and aquifer sediment contamination. The characterization data are summarized in Chapter 4. These data were used to supplement and validate the CSM, including modeling input parameters and assumptions addressed in Chapter 5, and were used in the human health and ecological risk assessments (Chapters 6 and 7).

The RI boreholes were drilled and sampled, and 10-cm (4-in.) temporary PVC wells were installed in the 116-K-2 Trench (wells 199-K-200 [C7831] and 199-K-201 [C7832]). Table 2-8 and Appendix C present RI soil boring and well information. Samples were screened for radiological contamination using field instruments and visually inspected for staining as an indicator of Cr(VI). In addition, to meet the Data Gap 12 requirements, batch leach testing was performed on samples collected at 0.76 m (2.5 ft) intervals from the bottom of the waste site excavation (or the maximum depth of remedial action) to the water table.

At the 116-K-2 Trench, continuous sampling was performed using a split spoon sampler to the top of the unconfined water table, and an aquifer sediment sample and filtered water sample were collected 1.5 m (5 ft) into the unconfined aquifer. Additional samples (Tables 2-4 and 2-5) were collected at the geologist or sampler's discretion, based on media characteristics, visual inspection, and field screening result. These samples were analyzed for physical properties, including grain size, porosity, moisture content, bulk density and, in the case of saturated samples, saturated hydraulic conductivity.

Boreholes C7831 and C7832 within the 116-K-2 Trench were converted to temporary groundwater monitoring wells with concurrence from DOE and EPA. Copies of the borehole logs, detailed sampling summary, well construction summaries, well summary sheets, geophysical logs, and final surveys are located in K-2 Trench Borehole Summary Report (SGW-48760).

Each waste site characterization effort had a specific list of constituents to be sampled and analyzed, as specified in the 100-K SAP (DOE/RL-2009-41). Table 2-10 presents a list of those constituents.

The UPR-100-K-1 and 116-KE-3 waste sites are associated with the KE FSB. Interim remediation at these two sites was limited in depth due to proximity to the KE Reactor. Two borings were drilled and monitoring wells were installed in 2015 (wells 199-K-221 [C8796] and 199-K-222 [C8797]) to characterize beneath these sites as reported in SGW-60149. Section 4.2.2 presents information for post-RI boreholes (wells 199-K-221 [C8796] and 199-K-222 [C8797]) that were completed as monitoring wells near the KE and KW Reactors to characterize the 116-KE-3 and UPR-100-K-1 waste sites.

2.1.10.3 Characterize beneath and around Reactor Structures

Activities associated with D4 and ISS of the KE and KW Reactors are still under way. Portions of the reactor structures and facilities near them remain in place. Although access to the area has been limited due to safety concerns, characterization has included field screening and periodic analysis of soil and building debris during D4 and source area removal actions. Additional information regarding the characterization is described in Section 4.2.1.

Table 2-10. Master List of Soil/Aquifer Sediment Target Analytes for 100-K

Radionuclides	Nonradionuclides		
Americium-241	1,1-Dichloroethene	Benzo(ghi)perylene	Lead
Carbon-14	1,4-Dichlorobenzene	Benzo(k)fluoranthene	Manganese
Cesium-137	Acenaphthene	Beryllium	Mercury
Cobalt-60	Aluminum	Bis (2-ethylhexyl) phthalate	Methylene chloride
Europium-152	Anthracene	Cadmium	Nickel
Europium-154	Antimony	Carbazole	Nitrate (as N)
Europium-155	Aroclor 1016 (PCB)	Carbon tetrachloride	Nitrite (as N)
Nickel-63	Aroclor 1221 (PCB)	Chloroform	Pentachlorophenol
Plutonium-238	Aroclor 1232 (PCB)	Cr(VI)	Phenanthrene
Plutonium-239/240	Aroclor 1242 (PCB)	Chromium (total)	Pyrene
Strontium-90	Aroclor 1248 (PCB)	Chrysene	Selenium
Technetium-99	Aroclor 1254 (PCB)	Cobalt	Silver
Tritium	Aroclor 1260 (PCB)	Copper	Tetrachloroethene
Uranium-233/234	Arsenic	Dibenz(a,h)anthracene	Thallium
Uranium-235	Barium	Di-n-butylphthalate	Toluene
Uranium-238	Benzene	Ethylene glycol	Total petroleum hydrocarbon
	Benzo(a)anthracene	Fluoranthene	Trichloroethene
	Benzo(a)pyrene	Fluoride	Vanadium
	Benzo(b)fluoranthene	Indeno(1,2,3-c,d)pyrene	Zinc

Additional characterization was needed for areas near the KE and KW Reactors to support the ROD (Data Gap 3). To fill the data gap, RI boreholes were drilled and groundwater monitoring wells 199-K-184, 199-K-189, and 199-K-186 were installed within 100 m (330 ft) of the KE and KW Reactors. Wells 199-K-221 and 199-K-222 were drilled and installed to provide additional waste site soil and groundwater characterization near the KE Reactor, including potential tritium and strontium-90 plumes associated with the KE FSB. Well 199-K-186 was relocated from the original location proposed in 100-K SAP (DOE/RL-2009-41) and 100-K Work Plan (DOE/RL-2008-46-ADD2) because the proposed location was in a culturally sensitive area. During RI drilling, well 199-K-186 was located approximately 80 m (262 ft) southeast of the former KE Reactor building (Figure 2-1). Well 199-K-189, a replacement well for 199-K-109A, was moved approximately 67 m (220 ft) to the north because the planned location interfered with access roads for demolition and waste site remediation activities. Soil samples were collected at each borehole before monitoring well construction and groundwater sample collection to characterize the deep vadose zone. Chapter 4 includes discussion of the soil and groundwater results.

Borehole logs, detailed sampling summaries, well construction summaries, well summary sheets, geophysical logs, and final surveys are available in K-2 Trench Borehole Summary Report (SGW-48760) and Borehole Summary Report for KR-4 RI/FS Wells (SGW-49459). Appendix C of this RI/FS report summarizes the slug tests.

2.1.10.4 Evaluate Reasons for the Persistence of Cr(VI)

Data were needed to determine the potential for the vadose zone, deep vadose zone, periodically rewetted zone (PRZ), unconfined aquifer, and RUM to contain sufficient mass of leachable contamination to be continuing sources of Cr(VI) groundwater contamination (Data Gap 10). Soil and groundwater samples were collected and analyzed for contaminants and physical properties (Tables 2-4 and 2-5). Borehole drilling is described in Section 2.1.9.1. The data developed by the sampling and analysis activities were evaluated in an effort to determine if these units contain sources of Cr(VI) that may account for the

persistence of the groundwater Cr(VI) plumes. High leachable Cr(VI) concentrations indicate potential sources. Results of Cr(VI) leaching are discussed in Chapter 5.

Groundwater monitoring data provide indicators of continuing sources. A rebound study was conducted at the KW area in 2016 to identify whether a continuing source exists at the 183-KW Headhouse area. Continuing source evaluations based on the RI and post-RI soil sampling and groundwater monitoring are presented in Chapters 4 and 5.

2.1.10.5 Characterize beneath the Unconfined Aquifer

The unconfined aquifer in 100-K is in the Ringold Formation unit E, and the RUM is considered the base of the unconfined aquifer. Additional data were collected during the RI to further define the extent of contamination in the RUM unit and support an evaluation of contaminant fate and transport. Data needs (Data Gap 7) included physical and hydrogeologic soil parameters, and groundwater COPCs.

Four boreholes (shown in Figure 2-1) were drilled and wells were installed to address the need for characterization data from the RUM unit (below the unconfined aquifer) and to evaluate the reasons for Cr(VI) persistence. Well 199-K-184 was drilled near the southwest corner of the KW Reactor building; well 199-K-192 was drilled downgradient of the head (west) end of the 116-K-2 Trench; well 199-K-188 was drilled near the 183.1-KE Headhouse, and former 120-KE-6 Sodium Dichromate Storage Tank and 100-K-98 drain; and well 199-K-195 was drilled near the 183.1-KW Headhouse, through the former 120-KW-5 Sodium Dichromate Storage Tank drain (100-K-97). Borehole C7688 was initially planned near 100-K-98, but was moved several meters downgradient because of utility interference. Methods for collecting soil and groundwater samples during RUM unit drilling are described in Section 2.1.9.1. Information on soil and groundwater sampling is summarized in Tables 2-4 and 2-5.

Split spoon samples were collected from the deep unconfined aquifer at the base of the Ringold Formation unit E, immediately on drilling into the RUM unit, at additional locations within the RUM unit, and within a shallow RUM sand layer. The samples were field screened for radiological contamination and analyzed for location-specific analytes (199-K-184 and 199-K-192) or for radiological constituents along with Cr(VI) and other metals (199-K-188 and 199-K-195). Batch leach testing for Cr(VI) and select metals analyses were conducted on samples from each well.

Additional split spoon samples were collected at major formation and lithology changes for analysis of physical properties (grain size, porosity, moisture content, bulk density and, in the case of saturated samples, saturated hydraulic conductivity). Table 2-4 lists the number of soil samples collected per boring under the column entitled “Physical Soil Samples.” In addition, samples were collected at 1.5 m (5 ft) intervals throughout the borehole for field screening and potential placement in geologic archives.

During deep borehole drilling, unfiltered and filtered groundwater samples were collected from the unconfined aquifer and water-producing portions of the RUM unit, for field screening and COPC analysis, as specified in the 100-K SAP (DOE/RL-2009-41, Table 1-3). Table 2-5 presents a sample summary.

Following construction, each well was developed by pumping at a rate ranging from 7.6 to 379 L/min (2 to 100 gal/min). Development continued until clear water with low turbidity (less than or equal to 5 nephelometric turbidity units) and stable (at least three consecutive measurements within 10% of each other) temperature, pH, and specific conductivity measurements were achieved. Water level drawdown and recovery was monitored with pressure transducer and datalogger equipment.

The 100-K SAP (DOE/RL-2009-41) required slug testing at wells screened in the RUM (199-K-192) to determine flow properties. Slug testing was conducted at all the RI wells, except temporary wells 199-K-200 and 199-K-201 installed in the 116-K-2 Trench, to provide additional information for groundwater modeling. Following well development, slug testing was conducted in accordance with general guidelines listed in the 100-K SAP (DOE/RL-2009-41). The slug testing provided a near-well hydraulic conductivity estimate. Hydraulic conductivity values are reported in Chapter 3, while the slug test and pump test data are summarized in Appendix C. A pump test was conducted at well 199-K-192 because it was the only well screened in the RUM.

2.1.10.6 Develop Additional Data Needed for Modeling

Insufficient data to support fate and transport modeling were identified as Data Gap 12. The fate and transport of site contaminants in the environment depends on the source mass and volume discharged and contaminant specific distribution coefficient (K_d), which quantifies the contaminant partitioning between solid and aqueous phases.

The data needed to develop a K_d estimate and conduct accurate fate and transport modeling include: physical properties, hydraulic conductivity, batch leach test results, contaminant concentrations, and field screening parameters. Supporting data were collected during the RI (e.g., PNNL-20234, *Report for Batch Leach Analyses on Sediments at 100-KR-4 Operable Unit, Boreholes C7684, C7688, and C7695*) and during post-RI sampling (e.g., ECF-100KR2-16-0127, *Evaluation of Strontium-90 Leaching Characteristics from Borehole Sediment Samples Collected at UPR-100-K-1 and 116-KE-3 Crib within the 100-K Area of the Hanford Site*). Details on RI sampling are provided in the 100-K SAP (DOE/RL-2009-41).

Fate and transport modeling selected K_d values for all COPCs (both radionuclides and non-radionuclides except uranium) from ECF-HANFORD-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*.

2.1.11 Groundwater Investigations

Investigations undertaken within and beneath the unconfined aquifer evaluated the Cr(VI) and other COPCs concentrations. These efforts fill the data need to define the extent of groundwater contamination in select areas of the unconfined aquifer (Data Gap 5) and in the uppermost confined aquifer in the RUM (Data Gap 7). Results from groundwater samples collected in the PRZ, unconfined aquifer, and above and within the RUM unit were evaluated with soil results to identify mechanisms for Cr(VI) persistence (Data Gap 10). Soil sampling is described in Section 2.1.9.1.

Groundwater data were collected during the RI from 18 wells to define the spatial and temporal distribution of groundwater contamination (Data Gap 13). Additional data collected from October 2009 through April 2017, which were considered representative of current groundwater conditions, were used to evaluate the nature and extent of contamination. These groundwater monitoring data are from the interim RA and Hanford Site programs and are discussed in Section 2.1.11 sections.

2.1.11.1 Define the Nature and Extent of Groundwater Contamination in the Unconfined Aquifer

Prior to the RI, the nature and extent of groundwater contamination across 100-K was limited because of existing monitoring well depths and locations. Not all groundwater COPCs were routinely monitored, and the contaminant distribution through the unconfined aquifer, deep vadose zone, PRZ, unconfined aquifer, above the RUM unit, and within the RUM unit was not well defined. Data from previous investigations were generally limited in the contaminants analyzed and the sampling frequency, leading to uncertainty in the extent of groundwater contamination.

To address these uncertainties (Data Gap 5), nine boreholes were drilled to the RUM contact and wells installed with screens across the entire aquifer thickness. Three aquifer tubes were installed downgradient from the KE Reactor (Figure 2-1). During field activities, groundwater and soil were sampled and analyzed as described in the 100-K SAP (DOE/RL-2009-41). Samples were collected to characterize the extent of select contaminants (Cr(VI), strontium-90, carbon-14, trichloroethene, and tritium) in the unconfined aquifer. Information about borehole drilling is in Section 2.1.9.1 and well construction details are in borehole summary reports SGW-48760 and SGW-49459, and Appendix C. Table 2-8 summarizes information about the RI wells, and Tables 2-4 and 2-5 summarize the samples collected during drilling. Table 2-11 lists the groundwater COPCs included in RI field investigation.

Table 2-11. 100-K RI Groundwater COPCs

Radionuclides	Nonradionuclides		
Carbon-14	1,1,2-Trichloroethane	Chromium	Nitrite (as N)
Tritium	1,1-Dichloroethene	Cobalt	Selenium
Strontium-90	Antimony	Copper	Sulfate
	Arsenic	Fluoride	Tetrachloroethene
	Barium	Cr(VI)	Thallium
	Benzene	Lead	Trichloroethene
	Beryllium	Manganese	Uranium
	Cadmium	Mercury	Vanadium
	Carbon tetrachloride	Nickel	Vinyl chloride
	Chloride	Nitrate (as N)	Zinc
	Chloroform		

Groundwater samples were collected at 1.5 m (5 ft) intervals throughout the unconfined aquifer while drilling each RI borehole. Four borings were advanced up to 15 m (50 ft) into the RUM before drilling was discontinued. Of the four deep boreholes drilled into the RUM, only 199-K-192 encountered a water-bearing unit. These groundwater samples were generally collected using a pump. Before sampling, the well was purged until indicator parameters stabilized, but not necessarily three casing volumes. If insufficient water was available alternative sampling means, such as a bailer, were used. Laboratory filtered water samples were analyzed for Cr(VI) and other metals to support K_d determinations and determine analyte distribution in the unconfined aquifer (either in suspended sediments or dissolved in the groundwater) and refine the nature and extent of Cr(VI) contamination.

Figure 2-7 illustrates general well construction. All wells, except for 199-K-186, 199-K-188, and 199-K-195, were constructed with 15.2 cm (6 in.) diameter, Schedule 10, Type 316L stainless steel, V-slot continuous wire wrap screen atop a 1.5 m (5 ft) long stainless steel sump with end cap. The screen lengths vary but, generally, are across the saturated zone in 3.05 m (10 ft) sections. The sump, end cap, and riser casing were the same schedule and grade stainless steel as the screen. Centralizers were used above and below the screen and every 12 m (40 ft) to ground surface.

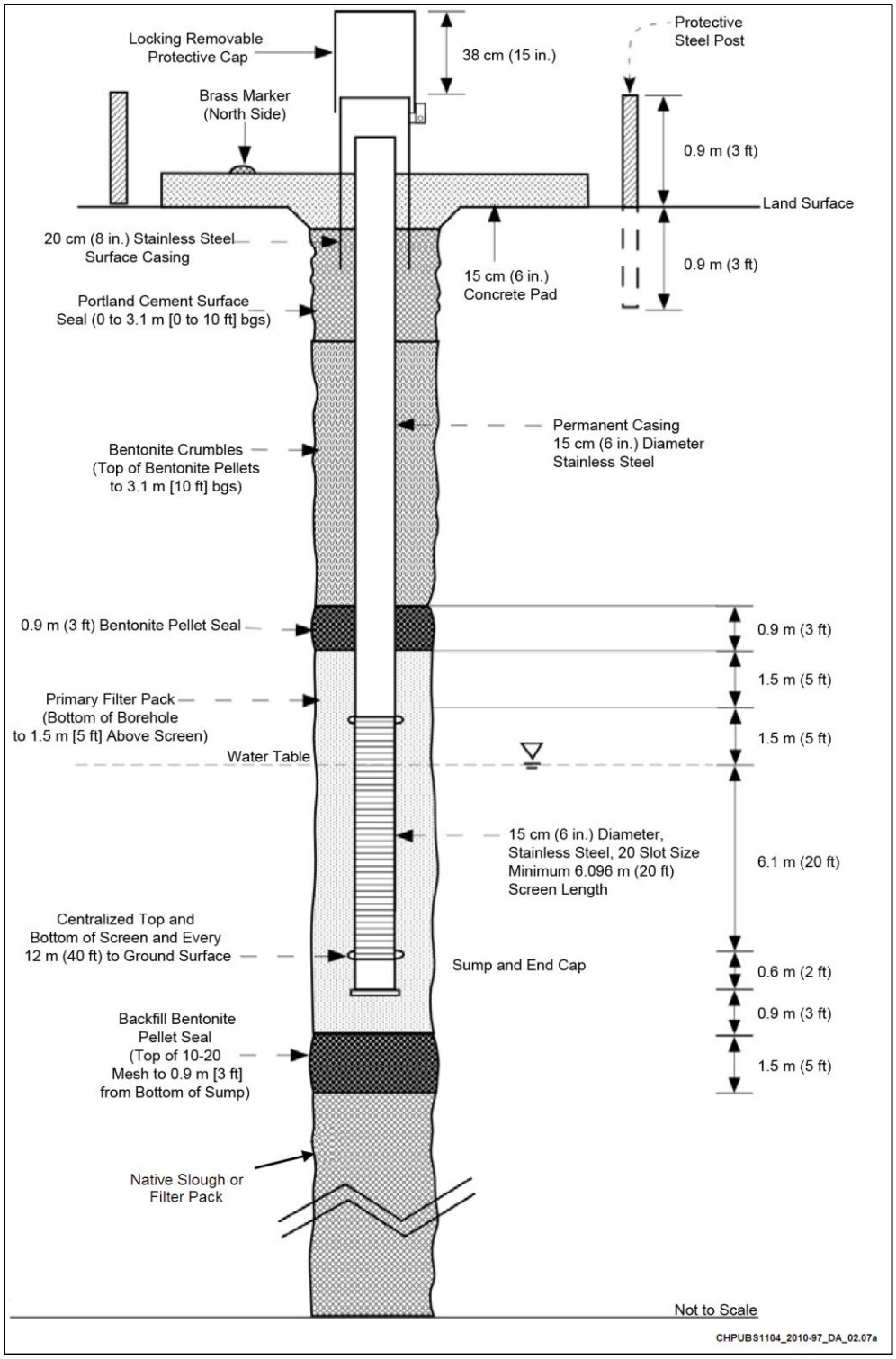

Figure 2-7. General Well Design

Wells 199-K-186, 199-K-188, and 199-K-195 were constructed with 0.01 m (4 in.) Schedule 40 PVC and 0.01 m (4 in.) 20 Slot 0.00051 m (0.020-in.) PVC screen. Temporary wells were installed at boreholes C7831 (199-K-200) and C7832 (199-K-201) using PVC materials. Boreholes extending below the well design depth were decommissioned from total depth using 10-20 mesh Colorado silica sand (CSS) fill material allowing for a 1.5 m (5 ft) bentonite pellet seal below the well sump. The filter pack was placed from approximately 1.5 m (5 ft) below to 1.5 m (5 ft) above the screened interval. The filter pack consisted of 10-20 mesh CSS. The typical annular seal included a 0.9 m (3 ft) layer of bentonite pellets placed immediately above the filter pack, bentonite crumbles above the pellets to approximately 3 m (10 ft) bgs, and a cement grout seal above the crumbles to ground surface. Annular seals varied on some of the wells; details are included in the borehole summary reports.

Each well was protected with a Type 304 or higher grade (e.g., 304L, 316, or 316L) stainless steel casing. This casing is at least 5 cm (2 in.) larger in diameter than the permanent casing, and extends 1 m (3.3 ft) above ground surface with a 38 cm (15 in.) diameter lockable cap. Wells are identified with a brass survey marker located on the well pad.

Post-RI wells provide information on the nature and extent of groundwater contaminants. Table 2-9 provides a summary of the post-RI wells installed between 2011 and April 2017. Figure 2-8 shows 100-K well locations as of December 2017. Details are included in Appendix C and borehole summary reports (SGW-58157, SGW-59027, SGW-59494, SGW-60149, and SGW-60241).

The 100-K shoreline includes 28 aquifer tube locations and 70 aquifer tubes. The RI field investigation installed three aquifer tubes in a cluster downgradient from the KE Reactor. The aquifer tubes were installed and sampled consistent with the DOE/RL-2000-59 to ensure consistency with existing aquifer tubes. Table 2-8 summarizes information on the aquifer tube cluster installed as part of the RI. Aquifer sampling tubes are 0.64 cm (0.25 in.) diameter polyethylene tubes with 15.2 cm (6 in.) long stainless steel screens at the lower end. Figure 2-5 shows the main components of aquifer tube installation.

Aquifer tube sampling for COPC analyses was conducted during August, November, and December 2010 during periods of “transition,” “low,” and “high” river stages, respectively. The sampling concurred with the aquifer tube-sampling program requirements established for the Hanford Site. The aquifer tube data are located in Appendix D.

Groundwater monitoring data are available from other 100-K wells and through interim RA and the sitewide surveillance (e.g., *Atomic Energy Act of 1954* [AEA]) groundwater monitoring programs. Groundwater monitoring under the AEA is implemented primarily through DOE O 435.1 Chg 1, *Radioactive Waste Management*. CERCLA monitoring was controlled through DOE/RL-96-90 from 1997 through 2016. Changes to this monitoring plan are summarized in Table 2-4 of DOE/RL-2013-33, *Remedial Design/Remedial Action Work Plan for the 100-KR-4 Groundwater Operable Unit Interim Action.* CERCLA monitoring since June 2016 has been directed by DOE/RL-2013-29.

The CERCLA groundwater monitoring data includes additional information on the distribution of groundwater contaminants. Summaries are provided in Hanford Site annual groundwater monitoring reports (e.g., DOE/RL-2016-67) and performance summary reports for groundwater interim RAs (e.g., DOE/RL-2016-68).

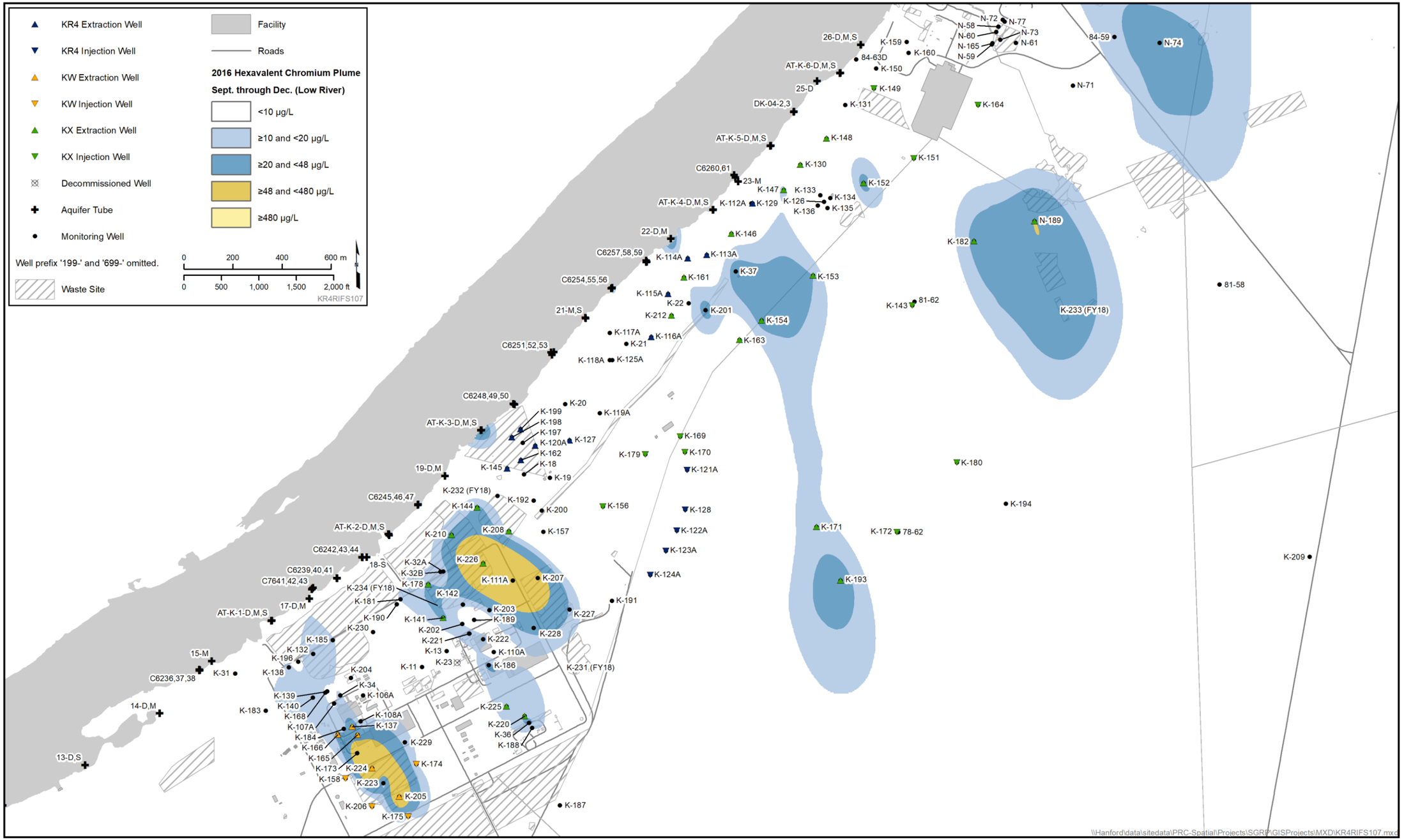

Figure 2-8. 100-K Well Locations

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2.1.11.2 Characterize beneath the Unconfined Aquifer

Data were collected during the RI to further define the extent of contamination in the RUM unit and evaluate contaminant fate and transport. Data needs (Data Gap 7) included physical and hydrogeologic soil parameters, and groundwater COPCs. Section 2.1.10.5 discusses the borehole drilling and soil sampling for four boreholes advanced to characterize the RUM unit.

Unfiltered and filtered groundwater samples were collected from the unconfined aquifer and water-producing portions of the RUM unit during drilling of deep borings. The groundwater samples were field screened and analyzed for COPCs as identified in the 100-K SAP (DOE/RL-2009-41, Table 1-3). Table 2-5 presents a summary of the water samples collected during RI for the 199-K-184, 199-K-188, 199-K-192, and 199-K-195 well drilling and installations.

2.1.11.3 Evaluate Reasons for the Persistence of Cr(VI)

Data were needed to determine if the PRZ, unconfined aquifer, and RUM unit contain sufficient Cr(VI) to be a continuing source of groundwater contamination (Data Gap 10). The data described in Section 2.1.10.4 were evaluated to determine continuing sources of Cr(VI).

2.1.11.4 Define the Spatial and Temporal Distribution of Groundwater Contaminants in the Unconfined Aquifer

Additional groundwater data were needed to characterize the distribution of contamination in the unconfined aquifer and to address uncertainties associated with the HHRA of the RCBRA (DOE/RL-2007-21) groundwater pathway (Data Gap 13).

Monitoring well locations were identified to represent conditions at 100-K. To provide the number of sampling points for a monitoring well network, the average groundwater yields were used to determine the number of residences supported on one supply well. Thus, the grid size specific to each area was determined. Use of a random grid generator provided approximate locations for sampling points based on the final number of sampling points and the total area. Groundwater samples were collected so that they chemically, radiologically, spatially, and temporally represented the area groundwater. Eighteen monitoring wells (Figure 2-1) were sampled and analyzed for this purpose. Groundwater elevation data were collected to evaluate groundwater and plume flow direction.

The selected wells were sampled to obtain temporal representation of groundwater conditions. This sampling was planned and conducted at high, low, and transitional river stages. Three rounds of groundwater samples (three samples total per well) were collected for COPCs analysis (Table 2-11) to support the RI for each contaminant. Each round of monitoring met the goal for completion within 30 consecutive calendar days to minimize statistical variability in water levels. Table 2-12 summarizes sampling dates.

2.1.11.5 Ongoing Groundwater Monitoring

The 100-K RI groundwater data were evaluated with groundwater data from ongoing monitoring well and aquifer tube sampling as described in Section 2.1.11.1. Monitoring wells and aquifer tubes in 100-K are sampled according to an established schedule and analyzed for specified constituents. Sampling was conducted per DOE/RL-96-90 from 1997 through 2016, and per DOE/RL-2013-29 from June 2016 through April 2017.

Table 2-12. Dates of 100-K Spatial/Temporal Groundwater Sampling

Sampling Round*	Start	End	Duration (Days)
Round 1 (Low River)	October 22, 2009	October 29, 2009	9
Round 2 (Transitional River)	March 5, 2010	March 25, 2010	21
Round 3 (High River)	June 11, 2010	June 30, 2010	19

*Spatial/temporal groundwater sampling was performed at the following wells: 199-K-11, 199-K-18, 199-K-20, 199-K-22, 199-K-31, 199-K-32A, 199-K-34, 199-K-36, 199-K-37, 199-K-106A, 199-K-108A, 199-K-117A, 199-K-142, 199-K-151, 199-K-152, 199-K-157, 699-72-73, and 699-73-61.

2.1.12 Ecological Investigations

DOE monitors and surveys plant and animal resources on the Hanford Site to establish potential radiological exposures resulting from site activities; assess the condition of endangered, threatened, or sensitive species; and evaluate breeding locations, habitat use, and distribution of key wildlife species. Ecological investigations have been conducted at 100-K. These investigations included work completed in support of the RCBRA Volume I (DOE/RL-2007-21), the CRC Volume I (DOE/RL-2010-117), and the annual environmental surveillance program. The 100-K Work Plan (DOE/RL-2008-46-ADD2) did not identify a need for additional ecological investigations. Section 3.10 summarizes the ecology of the Hanford Site, and Section 4.6 summarizes the results of DOE biota monitoring.

Annual ecological monitoring activities at the Hanford Site are summarized in the annual environmental report (e.g., 2016 Sitewide Environmental Report [DOE/RL-2017-24]). Activities include monitoring vegetation, fish, and wildlife for Hanford Site contaminants and plant and wildlife population surveys. Plant population surveys on the Hanford Site include species listed by Washington State as endangered, threatened, or sensitive and species with insufficient data to evaluate their status. Annual wildlife population surveys have historically included fall Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), bald eagles (*Haliaeetus leucocephalus*), and mule deer (*Odocoileus hemionus*), although other species have been periodically monitored.

The number of fall Chinook salmon spawning nests (redds) in the Hanford Reach is estimated by aerial surveys. Four aerial surveys for Chinook spawning redds were conducted in 2016, with no redds identified in the 100-K sub-area (DOE/RL-2017-24). Aerial and follow-up boat surveys for steelhead redds are conducted in the Hanford Reach in the spring of each year to identify potential spawning areas and timing, and an annual index of relative abundance among spawning areas. Three aerial surveys and one boat survey in 2015 did not identify any steelhead redds in either of two sub-areas at 100-K (HNF-59116, *Hanford Site Steelhead Redd Monitoring Report for Calendar Year 2015*).

Ecological monitoring on the Hanford Site includes characterizing breeding locations, habitat use, and key wildlife species distribution. Characterization studies have focused on the Woodhouse's toad (*Anaxyrus woodhousii*), a Washington State monitored species, and the burrowing owl, a Washington State candidate species.

Radiological surveys are conducted around active and inactive waste sites at the Hanford Site to detect surface radiological contamination, including biointrusion, from plants and animals (including insects).

2.1.13 River Corridor Supplemental Investigations

To support information needs for the entire River Corridor, the following supplemental activities from the Integrated Work Plan (DOE/RL-2008-46) were carried out separately from RI field investigation activities described in the 100-K SAP (DOE/RL-2009-41):

- **Evaluated groundwater and surface water interactions for the River Corridor.** Flow paths in the groundwater/river zone of interaction vary with daily and seasonal fluctuations in river stage. River water infiltrates the banks during high river stages, moves inland, and then reverses flow as the river stage subsides and moves back through the hyporheic zone and discharges to the riverbed. Monitoring and modeling studies suggest that this back-and-forth motion of groundwater and the river is cyclical in response to the diurnal river stage cycles, which typically include two high stages and two low stages in response to upstream hydroelectric dam power peaking demands. Review of modeling suggests there is a significant back-and-forth motion in the groundwater near the river that results in a substantial reduction in groundwater velocity in the aquifer. It will experience numerous changes in flow direction before it eventually reaches the water column in the river.

- **Analyzed samples to determine River Corridor background concentration values for antimony, boron, cadmium, lithium, mercury, molybdenum, selenium, silver, and thallium.** Site-specific background values for these constituents were needed to determine soil RAG values, because calculated risk-based concentrations and/or ecological protection concentrations were less than Washington State or expected site-specific background values. Provisional data have been calculated and are presented in ECF-HANFORD-11-0038, *Soil Background Data for Interim Use at the Hanford Site* (Appendix G). Background values are discussed further in Section 4.1.

- **Reevaluated the soil cleanup level for Cr(VI) to support the ROD.** The lowest soil RAG for Cr(VI) under the Interim Action RODs is 2 mg/kg. Based on the evaluation of soil cleanup levels and analytical methods, the accepted modeling approach was used to establish PRGs for this RI. The development of PRGs for groundwater and surface water protection is presented in Chapter 5.

- **Determined a site-specific contaminant distribution coefficient (K_d) for antimony.** Over the past several years, different K_d values have been identified at the Hanford Site for antimony; a site-specific value is needed to calculate soil RAG values (MTCA [WAC 173-340-747(3)(a)]). The following scientific literature review was conducted for this task:

  - The 1.4 mL/g K_d value is based on testing of Rainier Mesa tuff and does not appear to be comparable to Hanford Site soil types.

  - The 0 to 40 mL/g K_d range appears based largely on experience and general knowledge rather than on specific test results. A document (PNL-SA-6957, *Laboratory Measurements of Radionuclide Distribution Between Selected Ground Water and Geologic Media*) that was considered in establishing this range presents a K_d of approximately 65 mL/g antimony desorption from soil. This appears to be one of the few references available that presents actual K_d desorption data; the value supports the conclusion that desorption values are much greater than sorption values.

- The 45 mL/g K_d value is calculated based on a theoretical correlation between K_d and the soil to plant concentration factor; it does not represent a value from experimental determination. This value used by EPA is identified in Ecology, 2015, "Cleanup Levels and Risk Calculations" database.

- The 3.76 mL/g K_d value is actual static batch equilibrium testing on sand/clay soil at a pH of 7.6 and appears a reasonable approximation of Hanford Site soil types. This value is based on sorption, not desorption.

Based on this review, a K_d value of 3.76 mL/g was used in the modeling presented in Chapter 5. This is considered a conservative value since it assumes a higher level of mobility than suggested by the technical review of the literature. The K_d value used, while conservative, results in the maximum analyte concentration reaching groundwater at a peak year much greater than 1,000 years, and eliminating antimony as a COPC. A higher K_d value would have no effect on that result.

- **Re-evaluated soil cleanup levels for arsenic to support the ROD.** The soil RAG for arsenic under the Interim Action RODs is 20 mg/kg, based on the Tri-Party Agreement (Ecology et al., 1989a) stipulation to use the 1996 MTCA (WAC 173-340-740(2), "Unrestricted Land Use Soil Cleanup Standards") Method A value (100 Area RDR/RAWP [DOE/RL-96-17]). The MTCA [WAC 173-340-740(2)] Method A value is also 20 mg/kg. However, this 20 mg/kg value for arsenic exceeds the 1×10^{-6} individual cancer risk based on the MTCA [WAC 173-340-740(3)] Method B value (0.67 mg/kg), and the MTCA [WAC 173-340-747(3)(a)] groundwater protection value (0.00737 mg/kg). Both values are less than the Hanford Site arsenic background concentration of 6.5 mg/kg.

  Arsenic is a statewide concern because of historic smelter operations and pesticide use in agricultural areas (e.g., orchards). The State of Washington programs established to evaluate arsenic contamination continue to consider the Method A soil cleanup level of 20 mg/kg as a trigger for action. The Hanford Site cleanup value for arsenic is 20 mg/kg based on a letter published by the Ecology Toxics Cleanup Program on June 11, 2013 (Ecology, 2013, "Issues Associated with Establishing Soil Cleanup Levels for Arsenic"). This letter indicates that the Method A soil cleanup level of 20 mg/kg can be used to define natural background levels.

2.2 Field Activity Documentation

As discussed in previous sections, field investigations have been conducted in 100-K to address data needs identified in the work plan. These data are supplemented with interim RA data. The field investigation results are summarized in a variety of documents and tables, as listed in Table 2-13. Appendix D includes soil, groundwater, and water level data collected for 100-K.

Table 2-13. Field Activity Documentation

Field Activity	Documentation
Monitoring well installation	SGW-48760, *Borehole Summary Report for Two Characterization Boreholes in the K2 Trench in the 100-KR-4 Operable Unit to Support WCH in FY 2010* SGW-49459, *Borehole Summary Report for the Drilling and Installation of RI/FS Wells in the 100-KR-4 Operable Unit* SGW-58157, *Borehole Summary Report for the Installation of Three Wells in the 100-KR-4 Operable Unit, FY2013* SGW-59027, *Borehole Summary Report for the Installation of Two Wells in the 100-KR-4 Operable Unit, with and option of Three Wells, FY2014* SGW-59494, *Borehole Summary Report for the Installation of Two Characterization, Monitoring, and Extraction Wells in the 100-KR-4 Operable Unit, FY2015* SGW-60149, *Report for Soil Borings and Well Installations in the UPR-11-K-1 and 116-K-3 Waste Sites* SGW-60241, *Borehole Summary Report for the Installation of Four 100-KR-4 Operable Unit Extraction Wells, FY16* Well database (https://ehs.hanford.gov/eda/)
Characterization sampling during drilling (soil and groundwater)	Sampling paperwork in project files Data in HEIS (https://ehs.hanford.gov/eda/)
Aquifer tube installation and sampling	Project controlled notebook Data in HEIS (https://ehs.hanford.gov/eda/)
Aquifer testing	SGW-40781 PNNL-21845
Collection of automated hydraulic head data	Virtual Library (automated water level network)
Groundwater sampling of spatial and temporal monitoring network Ongoing Groundwater Monitoring	Groundwater sample records in the Integrated Document Management System; groundwater data in HEIS (https://ehs.hanford.gov/eda/) Annual Reports (http://www.hanford.gov/page.cfm/SoilGroundwaterAnnualReports)

HEIS = Hanford Environmental Information System

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3 Physical Characteristics of the Study Area

This chapter describes the physical and environmental characteristics of 100-K, including the information obtained during the RI and ongoing monitoring activities. This information and the nature and extent of contamination described in Chapter 4 are key components of the CSM. Topics of this chapter include surface features, meteorology, hydrology, geology, soil, hydrogeology, artificial water systems, demography, and cultural resources.

The 100-K Area is located on the south bank of the Columbia River, downstream from 100-BC and upstream from the other Hanford Site reactor areas. The following physical features summarize the 100-K Area:

- The Columbia River flows to the northeast past 100-K. Flow volume is controlled by Priest Rapids Dam, located 23 km (14 mi) upstream. Flow volumes typically peak from April through early July during spring runoff and are lowest from September through October.
- The topography in 100-K is relatively flat inland from the Columbia River, and changes are greatest near the Columbia River where the riverbank slopes steeply.
- The vadose zone comprises primarily Hanford formation unconsolidated gravel and sand and underlying Ringold Formation unit E. The Hanford formation is characterized by pebble-to-cobble and boulder size clasts with some silt and fine-to-coarse sands. Ringold Formation unit E is primarily fine-to-coarse sandy gravel. The vadose zone is up to 32 m (105 ft) thick in elevated inland areas and thins to 4.6 m (15 ft) near the Columbia River. Percent moisture in Hanford formation samples from RI wells and boreholes ranged from <2% to 7%.
- The uppermost aquifer at 100-K is unconfined and composed primarily of the sands and gravels of the Ringold Formation unit E. A low-permeability geologic unit in the Ringold Formation, informally designated the RUM, forms the bottom of the unconfined aquifer. This unit is continuous beneath 100-K and generally slopes downward toward the north. Aquifer thickness ranges from 5.2 m (17 ft) to 32 m (105 ft) thick. The changing river stage influences groundwater elevations several hundred meters inland. Groundwater flow is toward the river, but when river stage is high, groundwater can flow away from or parallel to the river.
- Horizontal hydraulic conductivity was determined from slug and tracer tests. The wells screened in Ringold Formation unit E had hydraulic conductivity ranging from 0.69 m/d (2.3 ft/d) to 44 m/d (145 ft/d). Slug test results for the RUM well had a hydraulic conductivity of 0.2 m/d (0.7 ft/d).
- Vertical hydraulic conductivity of the aquifer, estimated from laboratory tests of sediment samples, was highly variable. Estimates are 13 m/d (43 ft/d) for the Hanford formation, 2.4 m/d (7.9 ft/d) for Ringold Formation unit E, 0.0014 m/d (0.0046 ft/d) for RUM silt, and 1.5 m/d (4.9 ft/d) for RUM sandy gravel.
- With the exception of the Columbia River influence, natural recharge to the aquifer beneath the 100-K Area is low because there are no natural water bodies within the area, and the Hanford Site has a hot, arid climate. Artificial recharge may include leakage from facilities associated with water supply. Leaks from piping are a potential source of artificial recharge to groundwater. Water applied to control dust during waste site remediation also provides localized recharge.
- The water table depth ranges from 0 m (0 ft) adjacent to the river to 37 m (120 ft) inland. The water table is mostly flat, but varies through P&T system operations. Gradients steepen towards the river during low river stage and flatten near the river during high river stage. Water level data and

contaminant migration indicate the groundwater flow direction through the Ringold Formation unit E is primarily to the northwest. On average, flow is toward the northwest, discharging to the Columbia River. Flow rates range from about 0.013 m/d (0.045 ft/d) to 0.9 m/d (2.8 ft/d) in the unconfined aquifer within Ringold Formation unit E. The average vertical hydraulic gradient is upward in 100-K.

- The Hanford Site River Corridor, including 100-K, is reserved for the management, protection, and preservation of archaeological, cultural, ecological, and natural resources. Limited public access is consistent with resource preservation.

- The HRNM extends inland a quarter mile from the Columbia River along the entire length of the 100-K Area adjacent to the river. The monument was created, in part, from the security buffer zone surrounding the Hanford Site, which has been untouched by development or agriculture since 1943. The shoreline at 100-K has numerous culturally sensitive areas that need to be considered during any remediation activities.

- The predominant plant community at 100-K is sagebrush, Sandberg's bluegrass, and cheatgrass. A relatively narrow riparian zone along the Columbia River supports grasses, sedges, and scattered deciduous shrubs and trees. Two species of federal listed threatened plants (Umtanum desert buckwheat and White Bluffs bladderpod) occur on the Hanford Site. Neither of these plants is known to occur on or near any 100-K waste sites.

- Two species of federal listed fish (Upper Columbia River spring run Chinook salmon, listed as endangered, and steelhead, listed as threatened) occur in the Hanford Reach. The spring run Chinook salmon do not spawn in the Hanford Reach but use it as a migration corridor. No steelhead redds have been observed in the Columbia River offshore of 100-K in recent surveys.

3.1 Surface Features

The topography in 100-K is relatively flat inland from the Columbia River. The area has been disturbed and graded extensively by human activity from reactor construction in the 1950s through recent waste site remediation activities Topographic changes are greatest near the Columbia River. Surface elevations range from approximately 160 m (525 ft) above mean sea level (amsl) near the southern boundary of 100-K to 119 m (390 ft) along the river. The mean elevation in 100-K is 145 m (476 ft). Figure 3-1 shows 100-K topography.

The land surface in and around the 100-K Reactor area has been extensively modified from its original pre-Hanford configuration (Figure 3-2) to a degree much greater than at other single-pass reactor sites. During construction in the early 1950s, the ground surface was designed to slope toward the river to facilitate flow of cooling water and other waste streams in constructed systems. The 100-K Reactor area was stripped of existing vegetation, which was gradually replaced by shallow-rooted grasses in areas away from operations and traffic. Areas to the south, west, and east of the reactor area were also stripped of vegetation and used for laydown yards, construction shops, and other activities. Reactor and water treatment structural foundations extended to depths exceeding 7 m (23 ft), resulting in significant volumes of soil excavation.

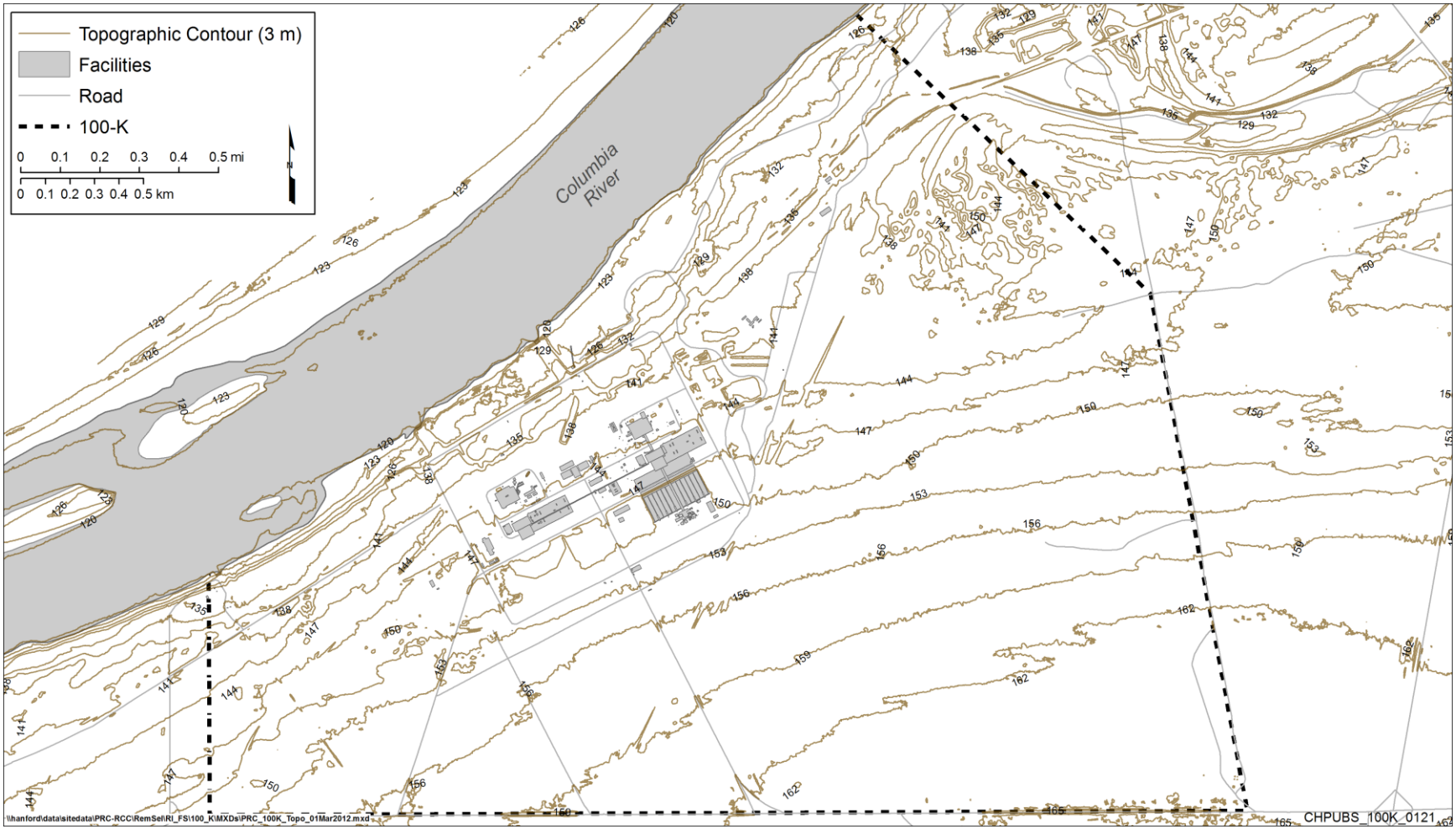

Figure 3-1. 100-K Topography

Figure 3-2. 100-K (1951)

In areas near the river and the northern 100-K Reactor security fence, fill was added to a depth of up to 4.6 m (15 ft) (Figure 3-3). It is likely that excavated material was used with borrow pit material to build up the ground surface in areas nearer the river. The excavated material would most likely have been the coarse granular sediments of the Hanford formation (Section 3.4.2.3). The fill material was generally placed on top of existing Hanford formation sediments.

Since 2002, demolition and waste site remediation activities have typically resulted in excavations to depths of 4.6 to 14 m (15 to 45 ft) bgs. Excavations were completed to remove facilities and associated waste sites around these structures (Figure 3-4). The excavations are backfilled and recontoured when work is completed.

Figure 3-3. 100-K (1953)

3.2 Meteorology

The Hanford Site is characterized by a semiarid climate and is the driest and warmest portion of the Columbia Basin. The Cascade Range, to the west, creates a rain shadow effect on the Hanford Site climate, while the Rocky Mountains and mountain ranges in southern British Columbia protect it from the more severe polar air masses from the north (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*, hereinafter called 2004 Hanford Climatological Summary).

The Hanford Meteorological Station (http://www.hanford.gov/page.cfm/HMS) and 30 monitoring locations throughout the Hanford Site and local area provide climate data. From 1945 through 2016, the recorded maximum temperature was 45°C (113°F) in July 2006, July 2002, and August 1961 (http://www.hanford.gov/page.cfm/hms/products/maxmonth). The recorded minimum temperature was -30.6°C (-23°F) in February 1950 (http://www.hanford.gov/page.cfm/hms/products/minmonth). The normal annual relative humidity is 55.3% (2016 Sitewide Environmental Report [DOE/RL-2017-24]).

Figure 3-4. 100-K (2004)

Annual precipitation historically recorded at the Hanford Site has varied from 7.6 to 31.3 cm/yr (3.0 to 12.3 in./yr) from 1947 to 2016, with an average of 17.2 cm/yr (6.8 in./yr) (https://www.hanford.gov/files.cfm/Monthly_and_Annual_Precipitation.pdf). Most precipitation occurs during winter, with more than half of the annual amount occurring from November through February (2016 Sitewide Environmental Report [DOE/RL-2017-24]). Between 1946 and 2016, the average annual snowfall was 36.1 cm (14.2 in.) (https://www.hanford.gov/files.cfm/Monthly_and_Seasonal_Snowfall1.pdf). Winter monthly average snowfall ranged from 5.8 cm (2.3 in.) in February to 13.0 cm (5.1 in.) in January.

Surface winds blow predominantly from the northwest during winter and summer and from the southwest during spring and fall. Along the Columbia River, local winds are strongly influenced by the topography near the river (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization* [hereinafter called the NEPA Characterization Report]). In 100-K, winds blow predominantly from the west and west-northwest. Wind speeds and directions at 15 m (50 ft) above the ground from 1945 through 2004 are reported in PNNL-15160. Wind speed averages have not been published for years 2005 to present. However, speeds are not expected to vary considerably during this time range. The prevailing wind direction at the Hanford Site is from the west-northwest or northwest, and the peak gusts are from the south-southwest, southwest, or west-southwest (PNNL-15160). The highest monthly peak gust was reported at 129 km/hr (80 mph) in January 1972. The highest monthly average wind speeds occur in June and range from a high of 14.6 km/hr (9.1 mph) to a low of 11.7 km/hr (7.3 mph). The lowest monthly average wind speeds occur in December and range from a high of 9.7 km/hr (6.0 mph) to a low of 5.3 km/hr (3.3 mph). The variability in monthly average wind speeds is much greater in the winter than during the remainder of the year.

The wind speed class with the highest frequency of occurrence is 6 to 11 km/hr (4 to 7 mph). Winds in that category occur 37% of the time. The speed class with the second highest frequency is 13 to 19 km/hr (8 to 12 mph), at 25%. Winds averaging more than 40 km/hr (25 mph) only occur 1% of the time, annually, with the highest frequency in March (1.6%) (PNNL-15160). High speed surface winds can generate regional dust storms and work conditions that sometimes lead to onsite work delays.

3.3 Surface Water Hydrology

This section describes the Columbia River and water use at 100-K. The Columbia River influences site hydrogeology and contaminant migration, and is used as an onsite water supply.

3.3.1 Columbia River

The Columbia River has played a major role in the depositional and erosional processes that helped produce the sedimentary and geologic features across the Hanford Site. The stretch of the Columbia River that extends from Priest Rapids Dam, 21 km (15 mi) upstream of 100-K, to the headwaters of Lake Wallula, is known as the Hanford Reach. In May 2000, the Hanford Reach was incorporated into the 70,820 ha (175,000 ac) HRNM.

Figure 2-6 illustrates river bottom bathymetry at 100-K. The deepest portion of the river adjacent to 100-K has an elevation of approximately 108 m (354 ft). At an average river stage of 120 m (394 ft), the river is up to 12 m (39 ft) deep. Through Coyote Rapids west of the 100-K reactors, the river bottom elevation drops about 9 m (30 ft) from around 117 m (384 ft) to 108 m (354 ft) over a distance of around 400 m (1,300 ft).

Columbia River flow at 100-K is to the east and is controlled mainly by Priest Rapids Dam. The flow rate at Priest Rapids from CY 2008 through 2016 averaged 3,285 m^3/sec (116,000 ft^3/sec). The highest average flow during this period (4,148 m^3/sec [146,500 ft^3/sec]) occurred in 2011 and 2012; the lowest

flow was in 2010. Flow volumes are usually highest from April through early July because of runoff from regional and high elevation snowmelt. Flows are lowest from September through October. The width of the Columbia River through the Hanford Site can vary from 300 to 1,000 m (1,000 to 3,300 ft), depending on the flow rate. The elevation of the river also changes with the flow rate, resulting in wetting and drying of the shoreline area (NEPA Characterization Report [PNNL-6415]).

River stage at 100-K can vary seasonally more than 5 m (13 ft) (Figure 3-5). Daily variations of more than 2 m (6 ft) are common as a result of dam operation for power needs and fish management. High river stage can be >122 m (400 ft) and generally occurs in May or June. Low river stage, generally about 117 m (384 ft), typically occurs in September or October. Figure 3-5 illustrates these annual patterns for recent years of low, average, and high river stage. The 100-K river stage was estimated from Priest Rapids Dam gauge heights using the procedure described in ECF-Hanford-13-0028, *Columbia River Stage Correlation for the Hanford Area*.

The suspended sediment load in the Columbia River is typically very low. The bed load consists mainly of fine and medium sand. The river also has a low nutrient content and an absence of microbial contaminants (DOE/RW-0164, *Site Characterization Plan: Reference Repository Location, Hanford Site, Washington*). Typical flow rates in the study area suggest that little deposition is occurring along the Hanford Reach, except along the shoreline portion of islands (Columbia River RI Work Plan [DOE/RL-2008-11]).

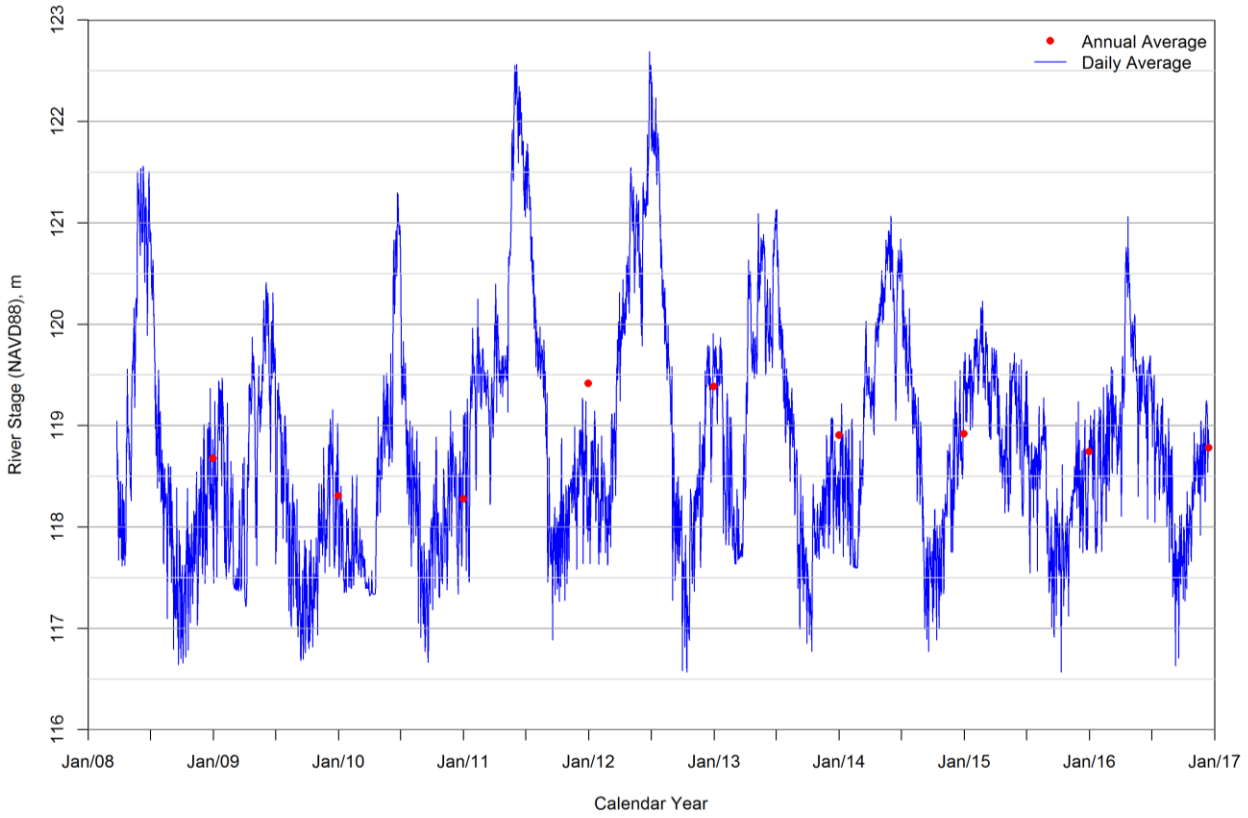

Figure 3-5. Daily Average and Annual Average River Stage at 100-K (2008–2017)

3.3.2 Surface Water Use

Water is withdrawn from the Columbia River at 100-BC for Hanford Site water use. Columbia River water is pumped at the 181-B Pump House as the primary water supply for Hanford Site workers and facilities. Section 3.8 includes additional information about the water system.

Other users withdraw water in the Hanford Reach for offsite irrigation and for use at the Energy Northwest nuclear power plant and Hanford Site. The Columbia River provides extensive recreation opportunities, including fishing, hunting, boating, sailing, waterskiing, diving, and swimming. The Columbia River also supplies water for public and domestic use, irrigation, barge transportation, industry, and wildlife habitat (DOE/RL-2005-40, *100-B/C Pilot Project Risk Assessment Report*, Draft B).

3.4 Geology

The Hanford Site and Pasco Basin lie within the Columbia Plateau of southeastern Washington State. This broad plain, situated between the Cascade Mountains to the west and the Rocky Mountains to the east, is underlain by a thick sequence of volcanic Columbia River basalt, which forms the basement rock for the region (PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*). Tectonic folding and faulting, which began with extrusion of the Columbia River Basalt Group (CRBG) basalts, continues to the present. The last basalt flows to reach the Pasco Basin occurred between 8.5 and 10.5 million years ago (Reidel, 1984, "The Saddle Mountains: The Evolution of an Anticline in the Yakima Fold Belt"; DOE/RW-0164). Unconsolidated sediments of the late Miocene, Pliocene, and Pleistocene ages (suprabasalt sediments) have accumulated up to 520 m (1,700 ft) thick in the Pasco Basin, the result of ancestral Columbia and possibly Snake/Clearwater River deposition (WHC-SD-EN-TI-155, *Geology of the 100-K Area, Hanford Site, South-Central Washington*).

During the Ice Age (Pleistocene epoch), massive cataclysmic floods repeatedly occurred, interrupted by interglacial periods of several tens of thousands of years. Three episodes of cataclysmic flooding are recognized in the Pasco Basin. The oldest ice age floods were at least 770,000 years ago (±20,000 years); however, the first floods may have occurred closer to the beginning of the Ice Age, 2.6 million years ago. Gravels associated with the last (most recent) episode of flooding are found throughout the Pasco Basin. Fine-grained deposits associated with that flood event contain volcanic material dating between 13,000 and 15,000 years ago (WHC-SD-ER-TI-003, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*).

3.4.1 Geologic Setting

100-K lies on the northern flank of the Wahluke Syncline and is located adjacent to the Columbia River to the west and north; to the east and south are portions of the Hanford Site. The suprabasalt sedimentary sequence is up to 229 m (750 ft) thick at Hanford, depending on location. At 100-K, the basalt was encountered in one location (well 699-81-62), at a depth of 161 m (527 ft) bgs.

Numerous investigations have contributed to understanding 100-K geology and hydrogeology. Data from the RI wells and boreholes, and interim RAs were evaluated and combined with historical information. The information was integrated to form an updated interpretation of 100-K geology. The general stratigraphic relationships of the units remain unchanged, but the local geometry and thickness relationships are more detailed

Major geologic units from shallowest to deepest are Holocene sediments, the Hanford formation, the Ringold Formation, and the Columbia River Basalt Group. ECF-100NPL-11-0070, *100 Area*

Stratigraphic Database Development, describes the process used to create geologic maps and cross sections presented in Appendix C.

A partial listing of previous reports used to supplement the geologic data collected during the RI include the following:

- DOE/RL-93-79, *Limited Field Investigation Report for the 100-KR-4 Operable Unit*
- DOE/RL-2002-39, *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin*
- WHC-SD-EN-TI-011, *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas*
- BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*
- USGS Professional Paper 717, Newcomb et al., 1972, *Geology and Ground-Water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington*
- WHC-SA-0740-FP, *Sedimentology and Stratigraphy of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington*
- WHC-SD-EN-DP-090, *Borehole Data Package for the 100-K Area Groundwater Wells, CY 1994*
- WHC-SD-EN-TI-155, *Geology of the 100-K Area, Hanford Site, South-Central Washington*
- WHC-SD-ER-TI-003, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*
- DOE/RW-0164, *Site Characterization Plan: Reference Repository Location, Hanford Site, Washington*

Appendix B provides a bibliography of additional documents related to 100-K.

3.4.2 Stratigraphy

Figure 3-6 shows the generalized geologic/hydrostratigraphic column for the 100-K Area. Specific stratigraphic units are listed from youngest to oldest and described in more detail in the subsections that follow, which consists of the following major units from shallowest to deepest:

- Recent eolian or anthropogenic deposits (sand or sand and gravel)
- Hanford formation (sand and gravel)
- Ringold Formation unit E (sand and gravel)
- RUM (silt, fine sand, and clay—includes water-bearing gravely to sandy layers)
- Ringold Formation unit C (sand and gravel)
- Ringold Formation lower mud (RLM) unit (silt and clay)
- Ringold Formation unit B (sand within RLM)
- CRBG (CRBG basalt flows interlayered with Ellensburg Formation sediments)

- Ellensburg Formation (sedimentary interbeds [tuff, paleosols, and sand] between CRBG basalt flows, including the Rattlesnake Ridge Interbed)

The sediments that overlie the basalts are divided into two primary units. The Ringold Formation is of late Miocene to middle Pliocene age (approximately 10.5 to 3 million years before present [B.P.]) (WHC-SA-0740-FP). The Ringold Formation is overlain by a sequence of Pleistocene age (approximately 1 million to 12,000 B.P.) cataclysmic flood deposits (Newcomb et al., 1972). These sediments that form a major portion of the Pasco Basin are not formally named in the stratigraphic nomenclature. This unit is informally referred to as the "Hanford formation." Holocene surficial deposits of silt, sand, and gravel form a relatively thin veneer at the surface (WHC-SD-ER-TI-003; Bjornstad et al., 2001, "Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State").

The sedimentary deposits at 100-K are underlain by Miocene-aged (approximately 17 to 8.5 million years B.P.) basalt of the CRBG that is interbedded with the Ellensburg Formation (WHC-SD-EN-TI-155). The CRBG may exceed 3,050 m (10,000 ft) in thickness locally including the interbedded sediments of the Ellensburg Formation. The Ellensburg Formation consists of a series of sedimentary units (epiclastic and volcaniclastic) that are interbedded with many of the basalt flows of the CRBG (USGS Bulletin 1457-G, *Revisions in Stratigraphic Nomenclature of the Columbia River Basalt Group*).

The physical properties of these geologic units and sublayers influence the distribution of contaminants in the subsurface. The most important to understanding groundwater contaminant behavior are the Hanford formation, Ringold Formation unit E, and the RUM. The connectivity of transmissive units within the RUM has not been determined.

The Ringold Formation at 100-K includes several formational sub-units (lithofacies) including the Ringold Formation unit E, the RUM, the Ringold Formation unit C (potentially), Ringold Formation unit B, and the RLM. Ringold Formation unit C is usually indistinguishable from unit E. The Hanford formation comprises most of the vadose zone throughout 100-K. The Ringold Formation unit E comprises most of the unconfined aquifer and part of the vadose zone. Aquifer testing and slug testing data indicate that the horizontal hydraulic conductivity of the Hanford formation is generally three times greater than the Ringold Formation unit E; although a variable degree of cementation can influence the transmissivity in both units (Section 3.7, Appendix C). The RUM is present throughout 100-K, forming the base of the unconfined aquifer. The RUM includes interbedded sandy zones that form confined water-bearing units. Figure 3-6 shows these relationships.

3.4.2.1 Surface Deposits

Recent deposits include eolian sands and river alluvium, which were placed over the past 10,000 years, and backfill materials deposited by humans. Construction backfill varies in depth, depending on the excavated depth of waste sites and building foundations, and backfill material may cover larger graded areas to depths of 0.3 m (1 ft) or more. Backfill deposits may be up to 8 m (26 ft) thick near reactors and clearwells, but are generally <5 m (16 ft) thick in other areas. Holocene deposits were likely removed or altered due to extensive grading in the 1950s because of anthropogenic activities associated with construction of the reactors and supporting facilities. Outside of those areas, the Holocene deposits are relatively thin (0.3 m [1 ft]) (WHC-SD-EN-TI-155).

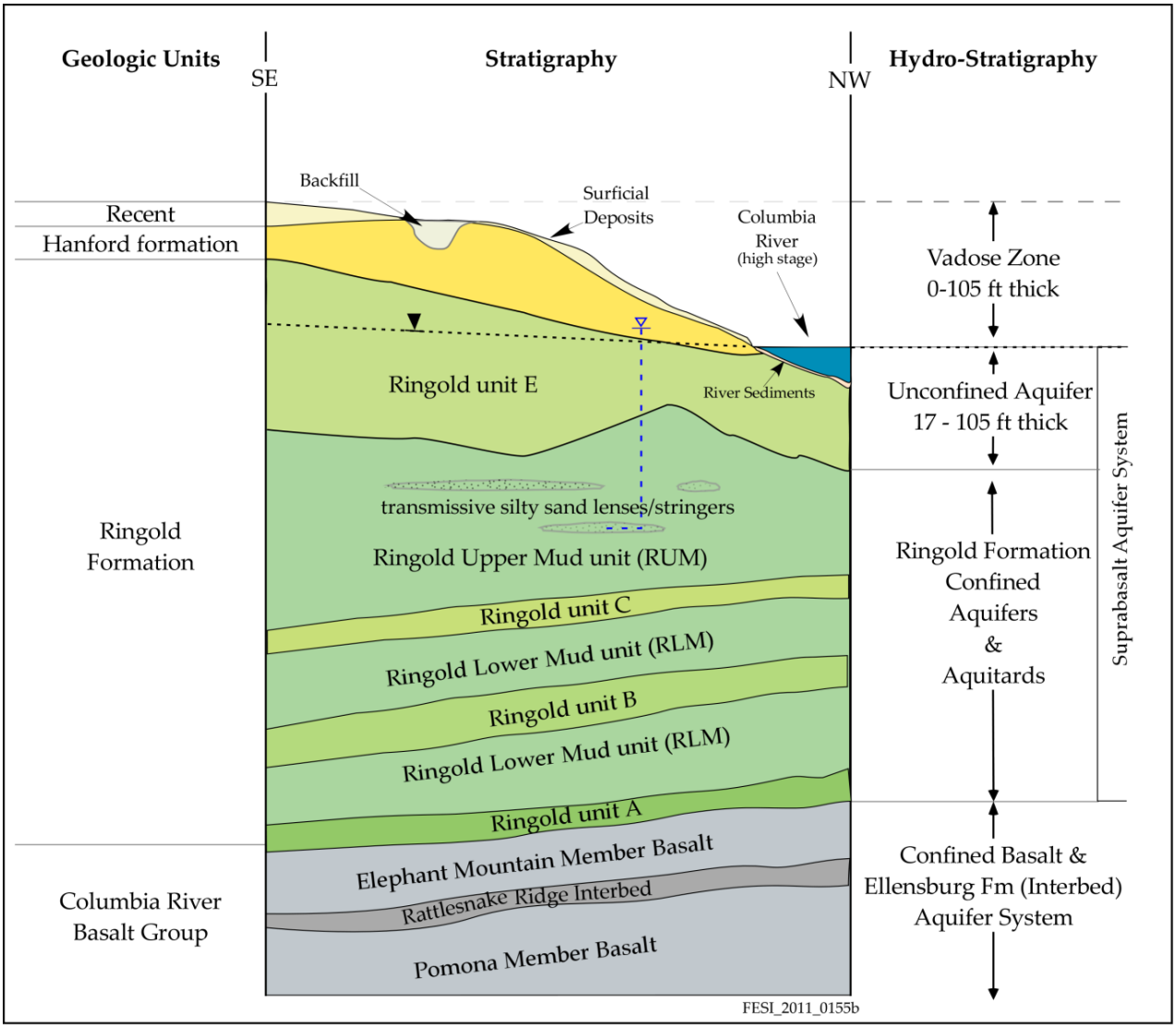

Figure 3-6. Generalized Geology and Hydrostratigraphy of 100-K

3.4.2.2 Hanford Formation

The Hanford formation consists predominantly of unconsolidated sediments that cover a wide range of grain sizes, from boulder-sized gravel to sand, silty sand, and silt. The Hanford formation is an informal name used to describe these Pleistocene-age cataclysmic flood deposits. The Hanford formation facies consists of moderately to very poorly sorted, large to very large, cobble- to boulder-sized clasts in open framework gravels that include discrete sand lenses, with little, or no, silt and clay-sized material. The gravel-dominated Hanford formation is highly basaltic, ranging from approximately 50 to 80% basalt (WHC-SD-EN-TI-011). The sand fractions are also high in basalt content, with the remaining portion composed of feldspar, quartz, and traces of mica. The grains typically are sub-round to round gravel and subangular to sub-round in the sand grain fraction. The gravel-dominated facies typically are well stratified and contain little to no cementation (WHC-SD-EN-TI-132, *Geologic Setting of the 100-HR-3 Operable Unit, Hanford Site, South-Central Washington*).

The Hanford formation has traditionally been classified into three separate lithofacies: gravel-dominated, sand-dominated, and interbedded sand and silt-dominated (DOE/RL-2002-39). Within 100-K, the gravel facies is dominant; the sand- and silt-sand facies are found to the south in the Cold Creek Basin.

The gravel-dominated unit consists of loose, massive to large-scale cross-beds built of pebble-to-cobble and boulder size clasts and is dark gray in color. In general, cross-bedding indicates a water- or wind-driven depositional environment in which the steeper slope of cross-beds point to the downstream direction of movement. Silts and fine-to-coarse sands are also present, as are minor local deposits of fluvial, colluvial, and aeolian material, which occur interbedded with the flood gravels. Suspected flood-driven rip-up clasts of RUM clays and silts have been observed on occasion in excavations around the KW Headhouse. Figure 3-7 shows a rip-up clast in situ at a 2011 excavation. In overall composition, gravel clasts are 50 to 75% or more basaltic, with lesser amounts of light-colored silicic igneous and metamorphic rock types. The Hanford sand fraction is also commonly >50% basaltic material. Hanford gravels are typically more basalt-rich than Ringold gravels, which are composed of a wider variety of regional rock types. In addition, the Hanford gravel clasts are more angular and less rounded than Ringold gravels, as they have not been transported as far from outcrops.

The Hanford formation was deposited by cataclysmic Ice Age floodwaters that drained from glacial Lake Missoula during the Pleistocene Epoch (DOE/RW-0017, *Draft Environmental Assessment: Reference Repository Location Hanford Site, Washington*). The Hanford formation ranges in thickness from <1 m (3.3 ft) near the river shoreline to approximately 30 m (100 ft) near the south boundary of 100-K (WHC-SD-EN-TI-011). Within the 100-K Reactor area, the Hanford formation is no more than 20 m (65 ft) thick. The Hanford formation comprises most of the vadose zone throughout the area.

3.4.2.3 Hanford-Ringold Contact

The erosional unconformity surface between the Hanford formation sediments and the underlying Ringold Formation unit E sediment is referred to as the “Hanford formation/Ringold Formation contact” (Figure 3-8). Hydrologic property differences exist across the contact between these two formations due to differences in the physical nature of the two units and due to paleofloods scouring actions. Ringold Formation unit E sediments are generally a denser, more consolidated, and well-graded formation versus the looser, coarser-grained Hanford formation flood deposits. The contact was observed to be well defined in some boreholes but gradational in others, suggesting a mixing of materials near the end of a flood cycle in some areas. The pattern and flow path of these paleoflood channels are preserved in the topographic expression of the contact. Paleochannels filled with more permeable flood deposits may create preferential flow paths for groundwater.

The sediment texture change at the contact may retard the vertical migration of wastewater and precipitation down toward the aquifer and may contribute to lateral migration. Vertical hydraulic conductivity data, presented in detail in Appendix C, indicate that the saturated hydraulic conductivity of the Hanford formation is approximately an order of magnitude greater than that of Ringold Formation unit E. The water table is below this contact in most of 100-K. However, where the Hanford formation/Ringold Formation contact occurs below the water table, groundwater flows will tend to have a greater velocity within the Hanford formation portion with less water migrating downward through Ringold Formation unit E.

Figure 3-7. Rip-Up Clast, 120-KW-1 Excavation, 17.6 m (58 ft) bgs (2011)

3.4.2.4 Ringold Formation

The Miocene- to Pliocene-age (8.5 to 3.4 million years B.P.) Ringold Formation is a combination of alluvial and lacustrine deposits produced by the ancestral Columbia River and other regional river systems. Across the Hanford Site, the Ringold Formation is as much as 185 m (606 ft) thick. At well 699-81-62, which is located east of the 116-K-2 Trench in 100-K, the Ringold Formation is 159 m (520 ft) thick. The formation is divided into three informal units: the Wooded Island, Taylor Flats, and Savage Island members (BHI-00184; Lindsey, 1996, *The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral Columbia River System, South-central Washington and North-central Oregon*). The Wooded Island member is a fluvial to lacustrine (lake) derived unit, while the Taylor Flats and Savage Island members are primarily lake deposits. The latter two members have been eroded within 100-K through by preglacial and cataclysmic Lake Missoula floods.

The typical stratigraphic units within the Ringold Formation are generally identified, from shallowest to deepest, as unit E, RUM (confining layer), units B and C, RLM, and Ringold Formation gravel unit A. Beneath 100-K, the Ringold Formation does not contain all the commonly encountered stratigraphic units found elsewhere across the Hanford Site.

Ringold Formation units A to E gravels consist of clast- and matrix-supported pebble-to-cobble gravels with a fine- to coarse-grained sand matrix (Lindsey, 1996). Clasts are typically composed of a variety of source material including quartzite, intermediate-to-silicic volcanic basalt, gneiss, greenstone, and granite. The degree of carbonate, iron oxide, and silica cementation within these units varies from none to well developed. Cementation may extend laterally for several hundred meters and may be up to several meters thick. The cemented units produce little to no water. The sand and gravel units may be massively bedded or cross-bedded, indicating fluvial to aeolian deposition. The RUM units are typically plastic silts and clays, with fine sand laminations. Indications of paleosol conditions include biologic action within the sediments. The fine-grained materials occur in thick (>5 m [16 ft]) deposits as well as thin interbeds. Silty sand to fine gravely sand lenses 1 to 3 m (3 to 10 ft) thick are encountered in the RUM and may locally bear water. Individual gravel clasts tend to be more rounded to discoidal in shape. The RUM is typically about 30 m (100 ft) thick and displays a number of paleosol features. Figure 3-9 present a structural contour map of the top of the RUM unit.

Ringold Formation unit A is reported to be approximately 23 m (75 ft) thick at 100-K. It is composed of fine-to-coarse sands and gravels across most of the eastern Hanford Site. The RLM is approximately 32 m (105 ft) thick and consists of overlapping lacustrine and paleosol deposits. The coarse-grained Ringold Formation unit B is an approximately 28 m (75 ft) thick sand- and gravel-dominated units. Ringold Formation unit C gravel is separated from Ringold Formation unit B by a thick overbank-paleosol unit, considered part of the RLM. Ringold Formation unit C locally is 4.6 m (15 ft) thick but thickens to the west and is another sand and gravel-dominated sequence (WHC-SD-EN-TI-155).

The uppermost unit of the Wooded Island member is Ringold Formation unit E, which forms the unconfined aquifer in 100-K. It is a gravel-dominated sequence comprised mainly of fine-to-coarse gravels and fine-to-coarse sands. Locally, sand-dominated units interbed with the sandy gravels. Silt and fine sand may be present as a minor constituent (10% to 15%) but, occasionally, may rise to become the dominant grain-size fraction. Rip-up clasts of RUM clays and silts are reported on rare occasions in 100-K wells. Cementing is known within Ringold Formation unit E, and it is the resistant unit forming the Columbia River's Coyote Rapids, located just upriver from the 181-KW Pump House. The relative straightness of the Columbia River between 100-K and 100-N is attributed to the river's erosion into the cemented bedrock sediments of Ringold Formation unit E. Ringold Formation unit E unconformably rests on the RUM aquitard. In turn, the Hanford formation was deposited on the eroded top of Ringold Formation unit E. *The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral*

Columbia River System, South-central Washington and North-central Oregon (Lindsey, 1996) depicts Ringold Formation unit E as absent 3.2 km (2 mi) to the southeast of 100-K and south of 100-N, beyond well 699-77-54 in cross section L-L' (Figure C-L in Appendix C).

Interpretations of the borehole log for well 699-81-62 have identified Ringold Formation units A, B, C, and E gravels and three RUM units (Lindsey, 1996). Except for the uppermost Ringold Formation unit E gravels, the gravels are confined aquifers interbedded with aquitard muds. For this report, the uppermost mud unit is termed the RUM unit and is considered a separate unit from the RLM. Overlying the basalts, a 2.1 m (7 ft) thick coarse, cemented conglomerate is found at well 699-81-62. Elsewhere, this unit has been given the name Snipes Mountain Conglomerate and is frequently grouped within the basal Ringold Formation unit A. Ringold Formation unit A is 6 m (20 ft) thick at well 699-81-62, where basalt bedrock was encountered. The RLM at well 699-81-62 is 38 m (125 ft) thick and consists of overlapping lacustrine and paleosols, and Ringold Formation unit B is 23 m (75 ft) thick and consists of sand- and gravel-dominated units. In turn, a 46 m (150 ft) thick overbank-paleosol mud unit caps Ringold Formation unit B. Ringold Formation unit C gravel is separated from Ringold Formation unit B by a thick overbank-paleosol unit, considered part of the RLM. Ringold Formation unit C locally is 4.6 m (15 ft) thick but thickens to the west and is another sand and gravel-dominated sequence. The RUM is 30 m (100 ft) thick and displays several paleosol features.

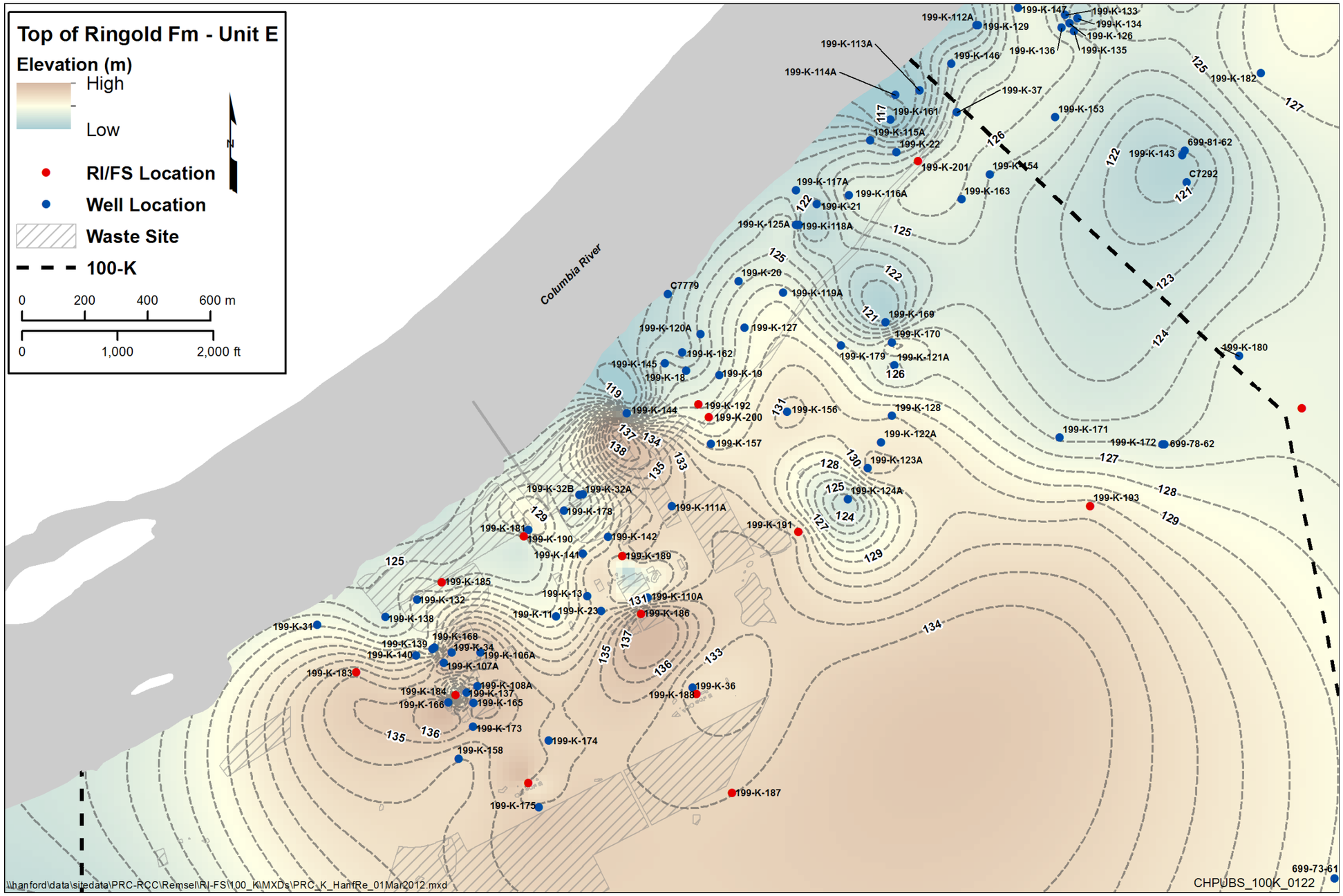

Figure 3-8. Structural Contour Map of the Hanford/Ringold Contact (Unconformity)

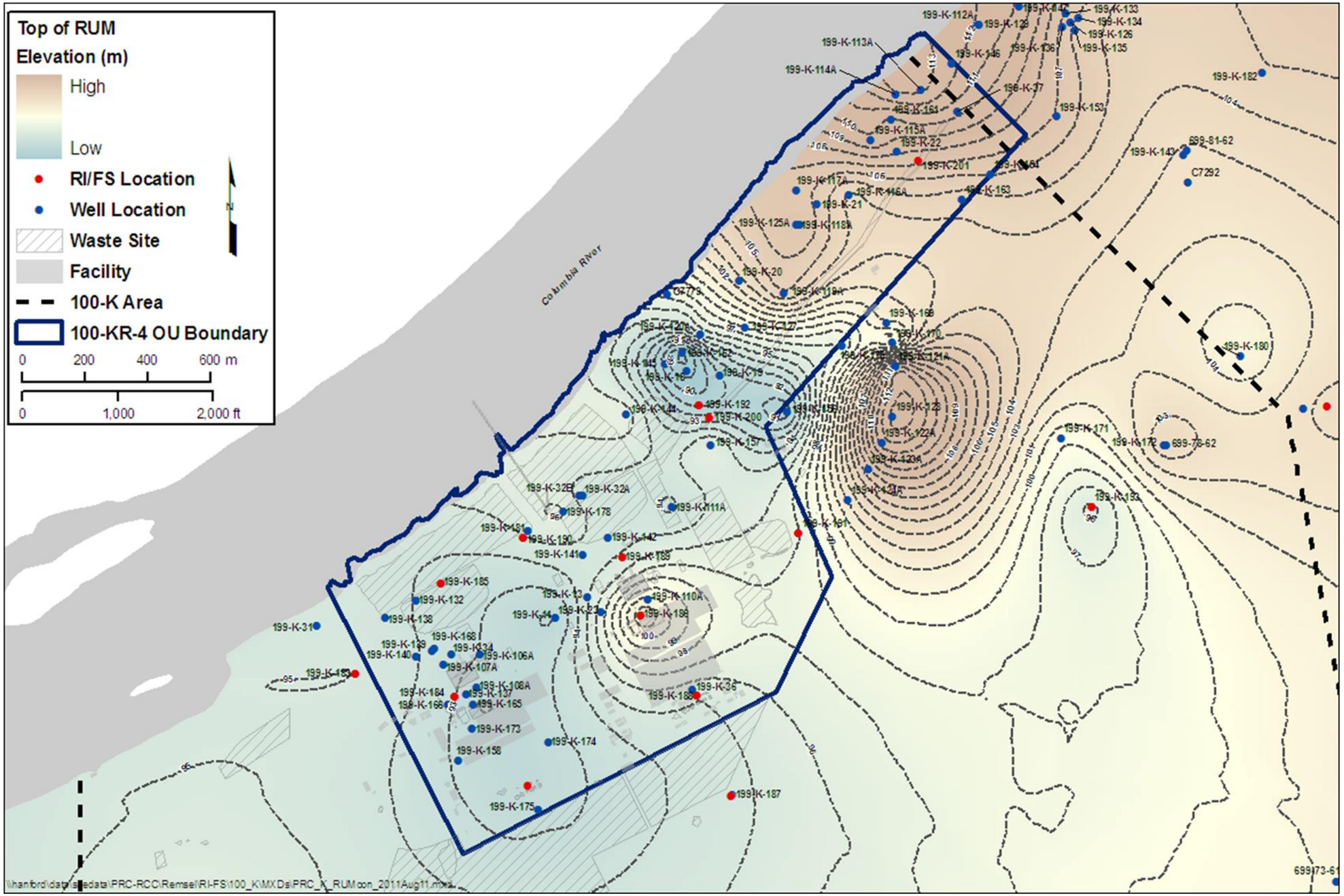

Figure 3-9. 100-K Structural Contour Map of the Top of the RUM Unit

3.4.2.5 Columbia River Basalt Group and Ellensburg Formation

There were approximately 300 CRBG basalt flows, and the maximum total thickness in the Pasco Basin is approximately 4,600 m (15,000 ft). The CRBG erupted in the Miocene Epoch (17 to 8.5 million years ago) and has been divided into four formations from youngest to oldest: Saddle Mountain Basalt, Wanapum Basalt, Grand Ronde Basalt, and Imnaha Basalt (WHC-SD-ER-TI-003).

Sedimentary interbeds of the Ellensburg Formation occur between basalt flows. These interbed sediments (tuffaceous sands, silts, and clays) and the porous/fractured basalt flow tops and flow bottoms form confined "interflow" aquifer zones that may extend across the Pasco Basin (DOE/RW-0164).

3.4.2.6 Hydrogeologic Cross Sections

Geological characterization and physical and hydraulic property data needs were identified to support development and refinement of the CSM and modeling for 100-K. Soil and groundwater data obtained from the RI boreholes and post-RI wells were incorporated with existing data to further the understanding of the stratigraphy, hydrogeology, and contaminant mobility through the vadose zone and within the unconfined and semiconfined aquifers. Characterization data collected for the RI and subsequent investigations are described in Chapter 2.

Hydrogeologic cross sections, surface contour maps, and isopach maps of underlying 100-K stratigraphy were created for this RI report to present detailed representations of 100-K geology (Figures 3-8, 3-9, 3-10, Appendix C). Sufficient information exists to define the unconfined aquifer system in 100-K, as the majority of boreholes were drilled to confirm the depth to the RUM that forms the base of the unconfined aquifer. Hydrogeologic information about the Ringold Formation units below the RUM is limited in comparison to the Hanford formation and Ringold Formation unit E. The RI characterization and RA well installations, described in Chapter 2, improved understanding of the relationships and properties of these units.

Figure 3-10 presents the trend lines used to construct hydrogeologic cross sections, which are summarized in this section and presented and described in detail in Appendix C. Appendix C also includes composite geological, geophysical, well completion and contaminant data for the RI wells.

The map also includes locations for the RI wells and interim RA extraction, injection, and monitoring wells. The hydrogeologic cross sections show hydrogeologic information as well as the locations of selected site features. Cross sections A-A' to F-F' are oriented perpendicular to the river, while cross sections G-G' to J-J' parallel the Columbia River.

Hydrogeologic cross section A-A' (Figure C-2) focuses on the Cr(VI) plume around the KW Reactor. RI wells 199-K-184 and 199-K-195 were drilled into the RUM, but a water-bearing unit was not encountered in that depth. The unconfined aquifer surface is relatively flat and about 29 m (95 ft) thick within Ringold Formation unit E. The RUM surface is basically flat. The Ringold Formation unit E thickens up toward the ground surface near wells 199-K-165, 199-K-137, 199-K-108A, 199-K-106A, and 199-K-204, and thins at 199-K-185. This corresponds roughly with the area near the KW Reactor and 116-KW-1 Crib.

Figure C-3 depicts hydrogeologic cross section B-B', which passes through the KE Reactor area. Well 199-K-188 was intended to be screened in the RUM. This borehole was drilled over 15.2 m (50 ft) into the RUM (a depth of 72 m [235 ft] bgs) without encountering a water-bearing unit. Some undulations in the RUM surface are shown, roughly between the 183.1 KE Headhouse and well 199-K-178. The water table is relatively flat and the unconfined aquifer thickness is about 24 m (80 ft) thick. The Ringold Formation unit E surface shows a channel like depression, about 4.6 to 6.1 m (15-20 ft) in depth, at wells 199-K-220, 199-K-225, and 199-K-196.

Hydrogeologic cross section C-C' (Figure C-4) starts near the Columbia River and extends east beneath the 116-K-1 Crib and the southwest end of the 116-K-2 Trench, then continues southeast past the 118-K-1 Burial Ground. The water table slopes relatively steeply relative to cross section to the west, and the unconfined aquifer is about 24 m (80 ft) thick. The RUM surface slopes generally down toward the river, with small elevation increases at wells 199-K-157 and 199-K-144. The Ringold Formation unit E surface maintains a relatively constant elevation from the south end of the cross section through the north end of the 118-K-1 Burial Ground and then steepens down, roughly paralleling the surface topography to the river.

Cross section D-D' (Figure C-5) trends perpendicular to the river through the southwest end of the 116-K-2 Trench at well 199-K-200 and then diverges to the southeast to show the southeast portion of 100-K. Description of this cross section considers the change in orientation from 199-K-194 to 199-K-158 (southeast–northwest) versus 199-K-158 through 199-K-198 (roughly south to north). The Hanford formation and Ringold Formation unit E thickness are consistent from 199-K-194 to 199-K-172, with the water table indicating flow generally east. Between 199-K-171 and 199-K-156, the Ringold Formation unit E thickens from about 29 m (95 ft) to about 37 m (120 ft), with a concurrent thinning in the Hanford formation. The Ringold Formation unit E retains this thickness to well 199-K-145, and then thins toward the river.

Cross section E-E' (Figure C-6) extends perpendicular from the river past the northeast end of the 116-K-2 Trench. The cross section shows a steady rise in the ground surface and Ringold Formation unit E to well 199-K-201, with a thickening of Ringold Formation unit E. The water table slopes down toward extraction wells 199-K-115A and 199-K-163.

The northernmost cross section perpendicular to the river is F-F' (Figure C-7). Well 199-K-189 is the upgradient terminus for this cross section. The Hanford formation and Ringold Formation unit E thickness are relatively consistent across this cross-section. The RUM surface slopes slightly downward, away from the river before rising between wells 199-K-182 and 199-N-189. The water table is relatively flat.

Cross sections G-G' (Figure C-8) parallels the river through the north 100-K area, through the 116-K-1 Crib, and to the mid-point of the 116-K-2 Trench. The topography shows moderate though variable downward relief from well 199-K-183 to 199-K-178, and then shows the steep slope down to well 199-K-210. The topography remains relatively flat toward the northeast until sloping steeply up near well 199-K-120A. Most of the relief results from Hanford formation thinning, while the RUM shows two troughs, one at well 199-K-210 and the other at well 199-K-145. The water table is relatively flat, with a slight rise to the northeast.

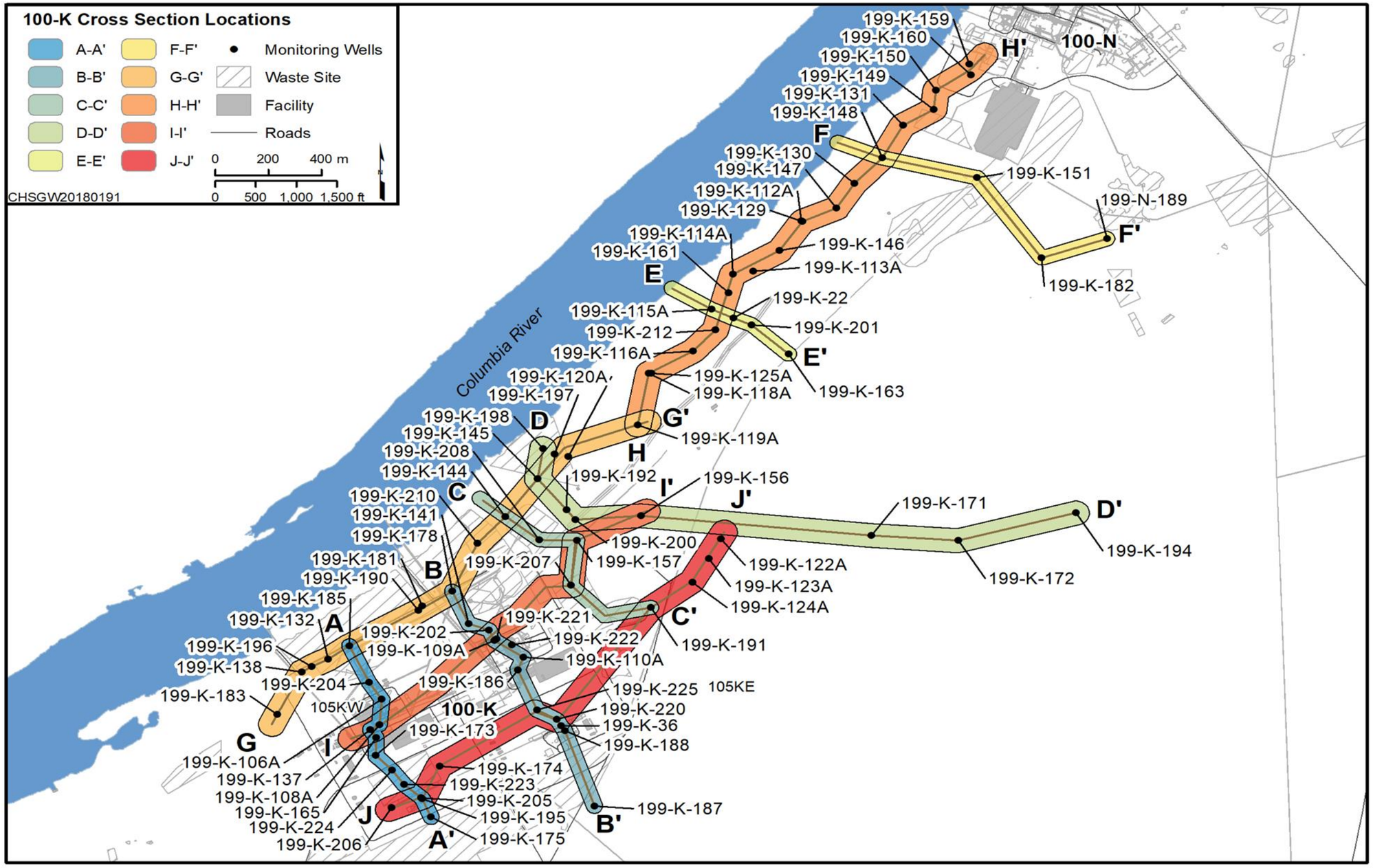

Figure 3-10. Trendline Location Map for 100-K Hydrogeologic Cross Sections

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Cross-section H-H' (Figure C-9) extends parallel and near to the Columbia River to the north from G-G'. Cross section H-H' profiles the area downgradient of the 116-K-2 Trench and into the 100-N area, beginning at well 199-K-119A to well 199-K-159. The Hanford formation variable topography is roughly paralleled by the Ringold Formation unit E surface between wells 199-K-119A and 199-K-116A. The aquifer thins from 199-K-212 to 199-K-114A with an upward slope in the RUM surface. Ringold Formation unit E thickens from well 199-K-129 to 199-K-149 as the surface slopes upward and the RUM surface slopes downward. North of 199-K-150, the RUM surface remains relatively flat while Ringold Formation unit E thins with downward sloping. The water table surface slopes generally down to the north through the southern third of the cross-section area and then slopes upward.

Figure C-10 shows the I-I' cross-section, which parallels the river through the middle of 100-K below the reactors' footprints. The surface topography shows moderate undulations through a slope down to the northeast. The surface of Ringold Formation unit E rises sharply west of the KW Reactor and well 199-K-108A, then an inferred slope down before rising again at 199-K-109A and remaining relatively flat to the northeast from 199-K-202. The RUM surface is generally flat, with a short rise between 199-K-109A and 199-K-203 before a downward slope from 199-K-207 to the northeast. The water table is flat before sloping up from the boundary of the 118-K-1 Burial Ground to the northeast.

Cross-section J-J" (Figure C-11) parallels the river roughly through the 183.1-KE and 183.1-KW Headhouses before trending more northerly to well 199-K-122A. The ground surface slopes to the northeast, and the surface of Ringold Formation unit E is flat. The RUM surface is also relatively flat from the southeast to well 199-K-191, at which point the surface rises and Ringold Formation unit E thins. The water table is flat, with a rise to the northeast.

3.5 Vadose Zone

This section describes the general characteristics of the vadose zone underlying 100-K. The vadose zone (unsaturated zone) extends from ground surface to the water table of the uppermost aquifer. The hydraulic and chemical properties of this region influence the downward movement of liquids and contaminants released near ground surface. The vadose zone includes the soil at the surface, the capillary fringe zone above the principal water-bearing zone, the periodically rewetted zone, and the combined rock, soil, air, and moisture interface linking the two. As the water table fluctuates in response to river stage and recharge rate changes, the periodically rewetted zone experiences either wet or drying conditions. The capillary fringe is the edge of that wetted surface where water seeps into the vadose zone material because of tension saturation. The thickness of the capillary fringe is typically small in sand and gravel formations (e.g., a centimeter or two), whereas the periodically rewetted zone in areas near the river at 100-K may be as much as 2 m (6 ft) thick.

Vadose zone thickness, which also represents the depth to groundwater, ranges from 0 m (0 ft) at the Columbia River shoreline to 32 m (105 ft) in elevated areas away from the river. The vadose zone is typically thinner near the Columbia River and varies with the topography. The vadose zone at 100-K includes surficial soil, Hanford formation sediments, and Ringold Formation unit E sediments. An investigation of the physical and geochemical properties of the vadose zone in the 100 Area is presented in PNNL-17674.

The dominant stratigraphic unit in the vadose zone at 100-K is the Hanford formation. In 100-K, the upper part of the vadose zone to depths from 0 to 13.7 m (0 to 45 ft), has been disturbed in a nonuniform fashion by site grading and construction activities in the mid to late 1950s, by site operations between 1955 and 1971, and by waste site remediation and facilities decommissioning activities since reactor shutdown. The KE and KW Reactor areas were cleared of vegetation and regraded. Select areas away

from the reactors were stripped and graded to support specific facilities, but outside the construction areas the existing plant community and soil profiles were not disrupted.

Water that infiltrates the ground surface is either retained by capillary forces or flows downward toward the water table as gravitational flow. Movement of moisture in the vadose zone is influenced by overall soil moisture content, vegetation cover, soil hydraulic properties, and timing of precipitation events.

3.5.1 Soil Types

Holocene deposits of eolian loess, silt, sand, and gravel form surficial deposits across 100-K. These deposits overlie the Hanford formation in a relatively thin (<1 m [3 ft] thick) veneer in most locations. During the past 10,000 years, a mix of eolian and alluvial processes deposited this soil. In some portions of 100-K, the surface is reworked construction backfill. This backfill material typically consisted of Hanford formation gravel, sometimes mixed with construction debris. Debris pits and piles created during construction have generally been addressed as waste sites. Recent (1995 to present) backfill practices rely almost exclusively on excavated Hanford formation gravel or fill imported from local or offsite borrow pits. This backfill is generally located near existing or former manmade structures and varies in depth, depending on the excavation depth of waste sites and building foundations. Additionally, backfill may cover larger graded areas to a depth up to 0.3 m (1 ft). Holocene deposits may have been removed or altered during activities associated with construction of the reactors and supporting facilities.

The 15 soil types on the Hanford Site are described in BNWL-243, *Soil Survey Hanford Project in Benton County Washington.* The soil types consist of sand, sandy loams, and silty loams. Only three soil types are present within 100-K, as shown in Figure 3-11, and described as follows:

- **Burbank Loamy Sand.** Burbank loamy sand is a dark-colored, coarse-textured soil underlain by gravel. Its surface soil is usually about 40 cm (16 in.) thick but may be up to 75 cm (30 in.) thick. The gravel content of its subsoil is from 20% to 80%.

- **Ephrata Sandy Loam.** Ephrata sandy loam is found on level topography on the Hanford Site. Its surface is darkly colored, and its subsoil is dark grayish-brown, medium-textured soil underlain by gravelly material that may continue for many meters.

- **Ephrata Stony Loam.** Ephrata stony loam is similar to Ephrata sandy loam. It differs by the presence of many large hummocky ridges that are made up of debris from melting glaciers. Areas between hummocks may contain many boulders several meters in diameter.

Soil types in 100-K are dominated by the Ephrata stony and sandy loams. These soil types cover over 80% of the area. The Burbank loamy sand is only present in the south-central region of 100-K. Tables 3-1 and 3-2 present the variation in recharge rates for the soil types in 100-K. There are also many small areas of backfill associated with construction and interim source remedial actions.

Each of these soil types has different characteristics. The characteristics of the soil, such as permeability, are critical to modeling and understanding the effects of infiltration and subsequent recharge to the aquifer. Tables 3-1 and 3-2 present recharge estimates applicable to different conditions for 100-K surface soil. A range from nearly zero to 100 mm/yr is identified in Gee et. al., 2007, *Hanford Site Vadose Zone Studies: An Overview*, depending on the soil type and vegetation cover.

3.5.2 Soil Moisture Variations

Unsaturated flow of liquid in the vadose zone is highly complex and influenced by the hydraulic properties of soil, volumes and rates of applied liquid, and vegetation cover. Movement of moisture in the vadose zone is mainly vertically downward under gravity drainage, controlled by the unsaturated hydraulic conductivity and the difference in hydraulic head between two points (that is, hydraulic gradient). In 100-K, the moisture content in the Hanford formation or Ringold Formation unit E vadose zone ranges from <2% to 10%, with one sample >10%. Samples collected from near the water table generally had higher moisture than those higher in the vadose zone. The exception being those samples near the surface, which occasionally exhibit higher moisture because of precipitation. The moisture content in the vadose zone is largely dependent on the grain size distribution, with finer grained zones able to retain more moisture because of their smaller pore size and greater number of available pores.

Much of the operational area in 100-K has been disturbed by construction, operations, and waste site remediation. This has denuded these areas of the native plant and soil cover, optimizing conditions for deep percolation of precipitation through the vadose zone. During historical operations, water was intentionally discharged to the ground surface, and under both historical and ongoing remedial actions, water may be applied to the ground surface for dust control. Under current conditions, low-moisture conditions dominate the vadose zone, with the majority of moisture resulting from infiltration of natural precipitation. However, periodic elevation of the water table because of fluctuations in river stage, leaks from site infrastructure, and local application of dust suppression water during remedial actions can also contribute to increased soil moisture. The effects of these activities are accounted for when modeling movement of contaminants in the vadose zone (Section 5.6). Native vegetation has been planted on backfilled remediated waste sites, which reduces natural recharge to groundwater as it matures. Recharge rates in groundwater models vary according to vegetative cover (Section 5.3).

Unsaturated flow through the Hanford formation may be influenced by the depositional environment. The flood deposits that constitute the Hanford formation tend to fine upward within each depositional sequence, resulting in alternating coarser and finer grains vertically. Cross beds found in the Hanford formation may also locally influence vertical migration of water, though the magnitude and extent of influence is unknown.

Within 100-K, vadose zone thickness varies because of natural and anthropogenic influences, such as changes in Columbia River stage as well as changes in topography. If groundwater is contaminated, mobile contaminants may be introduced into the basal vadose zone over large areas with the rising water table. With reduction in artificial recharge, precipitation is the main source of recharge; however, fluctuations in river stage and the flux from artificial recharge may affect the fate of contaminants. In the vadose zone, the pressure head is negative under unsaturated conditions (DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program*). This reflects the fact that water in the unsaturated zone is held in soil pores under negative pressure by surface tension forces (DOE/RL-98-28). If the volume of water in the vadose zone is less than the volume that can be retained by surface tension forces (field capacity), no water is available to migrate. Typically, this is the condition in the vadose zone under the native shrub-steppe vegetation on a fully developed soil profile. When this vegetation/soil cover is disturbed, transpiration is essentially zero and a higher percentage of precipitation and any anthropogenic water can infiltrate into the vadose zone. If a sufficient volume infiltrates it may migrate to the water table. Physically, as additional water is added to the vadose zone, it will migrate vertically under the force of gravity when the moisture content exceeds that which can be retained by the soil capillary forces.

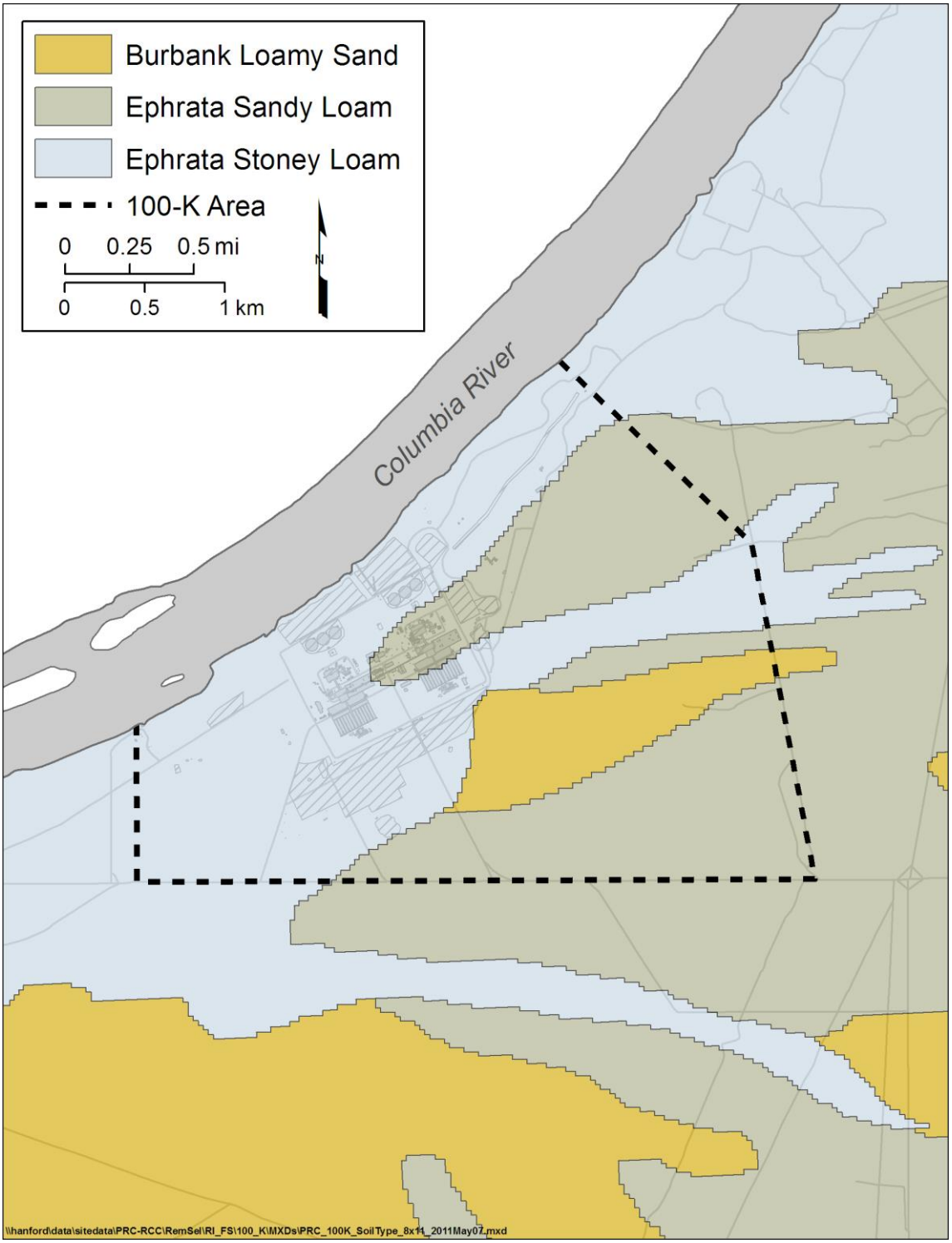


Figure 3-11. Soil Types at 100-K

Table 3-1. Estimated Recharge Rates

Major Soil Type	Estimated Recharge Rate (mm/yr)			
	No Vegetation	Cheatgrass	Young Shrub-Steppe	Mature Shrub-Steppe
Burbank Loamy Sand	52	26	6	3.0
Ephrata Sandy Loam	17	8.5	3.0	1.5
Ephrata Stony Loam	17	8.5	3.0	1.5

Source: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*, Table 4.15.

Table 3-2. Estimated Recharge Rates and Variation—Disturbed Conditions

Condition	Best Estimate (mm/yr)	Estimated Standard Deviation (mm/yr)	Minimum (mm/yr)	Maximum (mm/yr)
Burbank Loamy Sand	52	26	26	101
Ephrata Sandy Loam	17	8.5	8.5	34
Ephrata Stony Loam	17	8.5	8.5	34

Source: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*.

3.5.3 Physical Soil Properties

During the RI field investigations and interim RAs, soil samples were collected within the Hanford formation, Ringold Formation unit E, RUM, and first water-bearing unit in the RUM for evaluation of physical properties such as particle size, percent moisture, bulk density, and calculated porosity. Sample details are included in Appendix C. The samples were collected from the vadose zone, aquifer matrices, and aquitard(s), with stratigraphic formations clearly identified.

Particle size analysis was performed in accordance with ASTM D422-63, *Standard Test Method for Particle-Size Analysis of Soils*. The results of physical testing of the vadose zone samples showed that for grain size the majority of the vadose zone consists of sandy gravels.

Moisture content was determined in accordance with ASTM D2216-05, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*. As noted above, soil moisture in the vadose zone ranged from <2 to 10%.

Density was determined in accordance with ASTM D2937-04, *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method*, and is reported both as wet density and as dry density. Bulk density results ranged from 1,669 to 2,632 kg/m^3 (104.2 to 164.3 lb/ft^3).

Porosity is a calculated value determined by the following equation and reported as a percent.

$$Porosity = 1 - \frac{Bulk\ Density}{Particle\ Density}$$

For purposes of calculating porosity, normal particle density was assumed to be 2.65 g/cm^3 (165.434 lb/ft^3), the approximate particle density of quartz. Porosity ranged from 7.9% to 37%, except for well 199-K-192 sample interval I-002, which had a high bulk density leading to a porosity value of 0.6%.

Historical study data (PNNL-14702) on bulk densities in the Hanford formation versus the Ringold Formation unit E were used for comparison to RI physical property data (Table 3-3) to confirm data were comparable. Size classifications for the RI were primarily based on the borehole log descriptions. Bulk density is used in vadose zone fate and transport calculations. The sitewide statistical mean values were essentially identical for the Hanford formation and the Ringold Formation unit E, with the RI data also comparable within the data set.

3.6 Hydrogeology

The understanding of the 100-K hydrogeologic framework is based on past subsurface investigations and findings from the RI investigation. The three main hydrogeologic units include the vadose zone (discussed in Section 3.5), the suprabasalt aquifer system, and the confined basalt aquifer system.

This section describes the saturated hydrogeology of 100-K, beginning with descriptions of the main aquifer and aquitard units of the suprabasalt aquifer system. This system includes all sediments between the water table and the top surface of the basalt. These units are illustrated conceptually in the hydrostratigraphic column presented in Figure 3-6. The structure of the aquifer system is one of the controlling factors for groundwater flow between the various aquifers, aquitards, and the Columbia River, which forms a regional discharge boundary for shallow groundwater beneath the Hanford Site.

The unconfined aquifer at 100-K is the zone between the water table and the surface of the RUM, and is in the Ringold Formation unit E. Within the RUM, there are zones of sand and gravel that are water-bearing units. These RUM water-bearing units may be connected to each other, to the unconfined aquifer, or to the Columbia River. The extent of this aquifer interconnection varies spatially across 100-K and may have been temporally dependent on the overlying hydrologic conditions, such as elevated head pressures that existed during operations because of high-volume cooling water discharges.

The suprabasalt aquifer system includes an unconfined aquifer consisting of relatively coarse-grained sediments with highly variable permeability, three sand-dominated confined aquifer zones, and three low-permeability units (aquitards). Aquifers found below the upper surface of the RUM are typically confined or semiconfined, but leakage between the units may also occur. In addition, these various units may not be continuous in all locations, making them difficult to differentiate during drilling activities. Table 3-4 presents van Genuchten parameters and hydraulic conductivity data for four sandy gravel samples. Table 3-5 summarizes the general sediment characteristics of the different aquifer and aquitard units. The basalt confined aquifer system includes basalts of the CRBG and interbedded sediments of the Ellensburg Formation.

3.6.1 Unconfined Aquifer

The unconfined aquifer at 100-K is heterogeneous with respect to depth and location. The deposits comprising the unconfined aquifer are primarily Ringold Formation unit E with minor Hanford formation sediments. The thickness of the unconfined aquifer is determined by the difference between the seasonal water table, as affected by P&T system operation, and the topography of the RUM surface, which forms the base of the unconfined aquifer.

Figure 3-9 shows the topography of the top of the RUM surface, which forms the base of the unconfined aquifer. This map shows 23 m (75 ft) of topographic relief on the RUM unit surface in 1 m (3 ft) contour intervals based on borehole data. The RUM surface is the result of erosion and deposition of Ringold Formation unit E sediments. Depressions and highs on the RUM surface are evident across 100-K. The RUM surface slopes to the west, deepens beneath 100-BC, and rises beneath 100-N. One depression is located between and northwest of the two 100-K reactors at well 199-K-11. A second depression is identified by wells 199-K-162 and 199-K-192, near the southwest end of the 116-K-2 Trench. The depression at well 199-K-11 is a broader, shallower feature than the more sharply sculpted depression at wells 199-K-162 and 199-K-192. The latter is 4 to 5 m (13 to 16 ft) lower than adjacent well 199-K-144, which is more representative of the subsurface RUM top to the west and south.

Residual RUM highs are noted in two locations adjacent to the depression at wells 199-K-162 and 199-K-192. Injection wells 199-K-122A and 199-K-128 mark the drilled limits of a RUM high that rises to an elevation of 111 m (364 ft), which is 22 m (72 ft) above the erosional depression at wells 199-K-162 and 199-K-192. Northeast from the well 199-K-121A high point, a second RUM high is apparent at wells 199-K-113A and 199-K-114A. This residual high rises above 112 m (367 ft). Between the two highs, an easterly trending channel appears to cross beneath the 116-K-2 Trench before dissipating further to the east. These depressions may have served as locations in which Cr(VI) settled during operations.

The contact between Ringold Formation unit E and the Hanford formation also displays considerable relief (Figures C-2 through C-10). The highest contact elevation is located near the KW Reactor, and is part of a broader feature beneath and southeast of the reactor. Away from the 100-K Reactor, Ringold Formation unit E sediments thin to the east and south. The deepest point for the contact is at the northeast end of the 116-K-2 Trench, at wells 199-K-161 and 199-K-114A. These and adjacent wells define a localized depression or low in Ringold Formation unit E.

Flow through the unconfined aquifer is controlled, in part, by the geological formation through which the groundwater is passing. The water table is primarily in Ringold Formation unit E at 100-K. The velocity and ease with which water moves through the formation is based on the physical properties (Table 3-3) of the material at any one location. Saturated hydraulic conductivity (K_s) is generally defined as the flow volume over time through a cross-sectional area, presented in centimeters per second, meters per day, or feet per day. The higher the K_s value, the greater the amount of flow. Table 3-6 presents the hydraulic conductivity values at wells within 100-K. Hydraulic conductivity values in Table 3-6 are as high as 0.0512 cm/s (145 ft/d) within Ringold Formation unit E. Data from well 199-K-192 indicate a very low hydraulic conductivity in the RUM.

3.6.2 Confined Aquifer Zones within the Ringold Formation

The RUM contains near-horizontal sandy water-bearing units between the RUM surface and Ringold Formation unit B, a deeper water-bearing unit. These units represent confined or semiconfined units with variable conductivity and interconnectivity. The recognized aquifer units within the RUM are identified as the Ringold Formation unit C, generally the first water-bearing unit, and the lower water-bearing unit, which is presumed to be the Ringold Formation unit B (Figure 3-6). Other water-bearing units may also be present; however, these discontinuous units are not formally recognized in the nomenclature.

Table 3-3. Physical Property Results for Samples Collected in the Vadose Zone

Well ID (Borehole)	Sample Interval	Depth (m bgs)	Depth (ft bgs)	Geologic Unit	Moisture (%)	Calculated Porosity (%)	Bulk Density (kg/m^3)		Grain Size (% Passing Sieve)												Size Classification (%)		
							Wet	Dry	3 in.	1.5 in.	0.75 in.	0.375 in.	#4	#10	#20	#40	#60	#100	#140	#200	Gravel	Sand	Silt/Clay
199-K-183 (C7683)	I-001	4.5	14.75	Hanford	3.12	7.8	2050	1994	100	100	89.9	71.8	47.3	24.7	14.1	9.1	7.2	5.8	5.1	4.5	52.7	42.8	4.5
	I-002	5.9	19.5	Hanford	4.19	8.8	2161	2119	100	89.6	68.5	52.4	43.2	31.4	20.6	13.2	9.5	7.3	6.3	5.4	56.8	37.8	5.4
	I-003	7.6	25	Ringold	2.05	9.8	1764	1724	100	100	100	99.6	99.6	99	93.8	62.2	34.9	22.9	18.4	14.7	0.4	84.9	14.7
	I-004	9.1	30	Ringold	1.15	10.8	2308	2276	100	100	97.1	90.4	83	73.3	62.7	51.7	43.6	36.7	33	29.4	17.0	53.6	29.4
199-K-184 (C7684)	I-004	6.0	19.8	Hanford	19.2	11.8	2335	1999	100	100	100	100	100	100	100	100	99.8	93.5	79.6	64.7	0.0	35.3	64.7
	I-005	7.8	25.7	Hanford	4.29	30.5	1839	1664	100	100	100	100	100	100	99.7	89.3	56.2	34.1	27.9	23.1	0.0	76.9	23.1
	I-006	9.2	30.1	Hanford	3.98	33.9	1749	1677	100	100	100	100	100	98.5	67.2	29.2	12.6	7.5	6.4	5.6	0.0	94.4	5.6
	I-007	10.8	35.4	Hanford	6.10	31.6	1810	1727	100	100	88.5	82.2	78.5	75.9	62.5	43.2	23.3	9	6.6	5.4	21.5	73.1	5.4
199-K-185 (C7685)	I-001	4.6	15	Hanford	6.02	17.0	2198	2092	100	84.8	69.6	56.1	45.7	33.6	25.3	19.8	17.5	15.3	13.6	11.5	54.3	34.2	11.5
	I-002	6.2	20.35	Hanford	3.22	19.5	2132	2095	100	100	54.3	41.9	35.3	30.7	27.4	21.1	13.9	8.5	6.7	5.3	64.7	30.0	5.3
	I-003	7.6	24.9	Ringold	2.39	23.6	2022	1983	100	90.7	81.2	68.6	55.5	45.6	38.1	33.3	27.2	20	17.1	14.7	44.5	40.8	14.7
	I-004	9.2	30.05	Ringold	2.13	17.9	2174	2134	100	100	93.4	87.6	78.6	67.3	57.6	50.6	45.1	38.4	34.7	31.1	21.4	47.5	31.1
199-K-186 (C7686)	I-007	9.8	32.1	Hanford	6.91	7.9	2438	2313	100	100	71.8	53.8	40.2	28.8	15.5	10.3	8.9	7.9	7.4	6.9	59.8	33.3	6.9
	I-009	11.6	38.0	Hanford	6.60	24.2	2006	1913	100	100	77.8	44.4	28.8	15.6	6.5	4.4	3.7	3.2	3	2.8	71.2	26.0	2.8
	I-011	13.0	42.6	Hanford	6.76	23.2	2033	1956	100	100	89	74	58.2	37.8	21.5	15.1	12.7	10.7	9.7	8.7	41.8	49.5	8.7
	I-013	14.6	47.9	Hanford/ Ringold	8.59	19.8	2124	2022	100	89.3	74.9	58	44.5	34.1	25.6	19.8	17.4	15.4	14.1	12.7	55.5	31.8	12.7
199-K-187 (C7687)	I-001	16.6	54.4	Hanford	3.32	26.7	2396	1873	100	92.6	79.3	69.9	59.6	41.3	21.1	11.4	8.6	6.6	5.7	4.9	41.9	51.2	6.8
	I-002	18.2	59.6	Hanford	3.80	20.9	1940	2028	100	92.7	80.9	72.6	62.9	41	18.8	8.7	6.5	5	4.2	3.7	40.4	54.7	4.9
	I-003	19.7	64.6	Hanford	3.68	29.7	2095	1800	100	100	100	100	99.2	90.9	54.9	23.6	14	8.3	6.4	5.1	37.1	59.2	3.7
	I-004	21.3	69.9	Ringold	3.71	9.5	1860	2332	100	100	80.4	67.7	58.1	40.3	24.5	16	11.6	9	7.8	6.8	0.8	94.1	5.1
199-K-188 (C7688)	I-011	16.7	54.7	Hanford	3.88	17.3	2190	2113	100	100	79.6	70.6	60.2	37.5	17.1	9.3	7.1	5.8	5.2	4.7	39.8	55.6	4.7
	I-013	19.0	62.4	Ringold	4.90	9.7	2390	2308	100	88	80.4	70.4	61.7	51.9	43.3	34.4	30.4	26.8	24.7	22.6	38.3	39.1	22.6
	I-015	19.3	63.3	Ringold	3.85	12.2	2324	2244	100	100	91	81.9	71.3	62.2	54.9	47.1	42.4	37.8	35	32.2	28.7	39.1	32.2
	I-017	20.6	67.7	Ringold	5.70	27.5	1919	1882	100	91.3	82.8	68.8	57.4	48.1	34.8	25.6	21.3	17.9	15.9	14	42.6	43.4	14.0
199-K-189 (C7689)	I-006	8.4	27.5	Hanford	4.29	21.1	2089	2025	100	89.6	81.2	69.9	55.8	40.9	26.2	17	13.7	11.1	9.8	8.7	44.2	47.1	8.7
	I-008	10.0	32.9	Hanford	3.64	24.4	2001	1940	100	100	85.8	64.4	46.9	31.6	17.5	9.7	7.5	6	5.3	4.7	53.1	42.1	4.7
	I-010	11.6	37.9	Hanford/ Ringold	4.76	23.3	2030	1981	100	100	70.8	60.3	50.8	41.7	32.4	27	23.3	19.6	17.5	15.3	49.2	35.5	15.3
	I-012	13.0	42.6	Ringold	1.39	27.8	1911	1882	100	100	92.1	86.3	76.8	66.4	56.3	49.6	44.6	37.3	33.1	29.4	23.2	47.4	29.4

Table 3-3. Physical Property Results for Samples Collected in the Vadose Zone

Well ID (Borehole)	Sample Interval	Depth (m bgs)	Depth (ft bgs)	Geologic Unit	Moisture (%)	Calculated Porosity (%)	Bulk Density (kg/m^3)		Grain Size (% Passing Sieve)												Size Classification (%)		
							Wet	Dry	3 in.	1.5 in.	0.75 in.	0.375 in.	#4	#10	#20	#40	#60	#100	#140	#200	Gravel	Sand	Silt/Clay
199-K-190 (C7690)	I-003	7.3	24.0	Hanford	1.73	17.8	2175	2142	100	94.3	80.6	71.7	64	55.4	46.7	41.3	35.4	28.2	24.5	21.4	36.0	42.6	21.4
	I-004	8.8	29.0	Hanford	2.48	31.5	1812	1773	100	80.1	63	56.8	54	52.2	51.2	46.7	29.8	14.7	10.4	7.8	46.0	46.2	7.8
	I-005	10.4	34.0	Hanford	1.40	19.0	2145	2113	100	100	93.4	84.8	78.4	69.6	59.5	52.5	45.9	38.1	34	30.2	21.6	48.1	30.2
	I-006	11.9	39.0	Hanford	1.78	36.9	1669	1520	100	100	94.2	86.8	74.1	59.6	49.5	43.2	36.1	27.5	23.4	20.1	25.9	54.0	20.1
199-K-191 (C7691)	I-001	5.4	17.7	Hanford	4.19	19.3	2135	2073	100	64.9	52.6	42.3	31.6	20.6	11.6	8.5	7.3	6.3	5.8	5.2	68.4	26.4	5.2
	I-002	6.8	22.2	Hanford	2.73	16.7	2206	2150	100	89.9	77.2	64.7	56.6	48.8	32.8	20.7	16.9	14	12.6	11.2	43.4	45.4	11.2
	I-003	8.4	27.6	Hanford	3.35	25.4	1975	1917	100	89	67.5	58.5	51.4	45.6	31.7	21.7	18.1	14.8	13.1	11.5	48.6	39.9	11.5
	I-004	10.1	33.0	Hanford	4.47	14.6	2260	2187	100	94.7	82.7	64	45.6	31.4	12.8	6.3	4	3.2	2.8	2.5	54.4	43.1	2.5
	Add-on 1	11.6	38.2	Hanford	2.38	15.7	2231	2191	100	71	58.2	47.7	42.8	37.1	15.4	7.4	5.6	4.4	3.7	3.2	57.2	39.6	3.2
	Add-on 2	12.9	42.2	Ringold	2.19	19.3	2137	2111	100	73.4	61.4	44.1	34.1	28.3	23.2	18.1	12.4	8.8	7.5	6.4	65.9	27.7	6.4
	Add-on 3	14.2	46.7	Ringold	1.49	17.3	2190	2167	100	92.9	72.1	44.1	27.5	20.1	16.3	14.5	10.9	6.3	4.6	3.5	72.5	24.0	3.5
199-K-192 (C7692)	I-001	0.9	3.0	Hanford	1.74	18.0	2171	2134	100	75.6	51.3	36.8	31.9	27.5	23.9	20.1	17.6	15.1	13.2	10.9	68.1	21.0	10.9
	I-002	2.4	8.0	Hanford	2.47	0.6	2632	2581	100	100	57	36.8	27.5	19.5	12.3	9	7.7	6.4	5.5	4.5	72.5	23.0	4.5
	I-003	4.0	13.1	Hanford	3.25	15.8	2228	2171	100	85.6	78.2	65.6	56.6	49.9	41.7	36.7	32.7	27.6	25.2	22.8	43.4	33.8	22.8
	I-004	5.5	18.1	Hanford	1.53	22.1	2062	2044	100	80.4	63	51.5	43.3	37.2	32.9	29.8	25.9	17.2	14.2	12.1	56.7	31.2	12.1
199-K-193 (C7693)	I-003	14.2	46.7	Ringold	2.45	27.5	1919	1890	100	100	77.7	58.3	45.1	38.4	33.8	29	22.1	15.6	13.1	11	54.9	34.1	11.0
	I-004	15.7	51.5	Ringold	1.40	21.6	2076	2049	100	90.1	82	62.6	52	42	32.2	26.1	20.8	15.4	13.3	11.6	48.0	40.4	11.6
199-K-194 (C7694)	I-001	18.8	61.8	Hanford	1.90	18.4	2159	2126	100	100	96.7	90.6	82.4	72.7	62.1	54.1	48.1	40.7	36.7	33	17.6	49.4	33.0
	I-002	20.3	66.5	Ringold	2.60	16.5	2210	2161	100	100	88.8	80.8	73	64.5	54.1	45.9	38.3	32.1	29	26.2	27.0	46.8	26.2
	I-003	21.9	71.9	Ringold	1.70	22.3	2057	2033	100	100	83.3	69.6	58	47.4	39.6	35.2	30.2	23.5	20.1	17.2	42.0	40.8	17.2
	I-004	23.7	77.8	Ringold	1.60	16.3	2215	2188	100	100	85.1	73	66.1	58.5	51.2	45.6	34.2	26.1	23	20.3	33.9	45.8	20.3
199-K-195 (C7695)	I-006	4.6	15.0	Hanford	4.18	29.6	1863	1813	100	78.8	64.6	55.4	47	36.8	27.5	16.4	11.9	9.2	7.9	6.9	53.0	40.1	6.9
	I-007	6.0	19.8	Hanford	4.84	18.8	2148	2057	100	88.4	86.8	80.7	61.1	21.6	7.1	4.5	3.7	3.2	3	2.7	38.9	58.4	2.7
	I-008	7.6	24.8	Hanford	5.32	15.7	2231	2158	100	78.6	66	47	33.9	24.1	14.4	9.4	7.9	6.7	6.1	5.6	66.1	28.3	5.6
	I-009	9.1	30.0	Hanford	5.63	18.0	2171	2095	100	90.5	71.3	56.4	42.8	29.7	17.6	7.3	4.8	3.8	3.4	3	57.2	39.8	3.0
	I-011	12.2	40.1	Hanford	5.78	13.5	2289	2219	100	100	65.3	46.7	31.4	17.9	8.9	4.1	2.9	2.3	2	1.8	68.6	29.6	1.8
199-K-200 (C7831)	I-003	9.1	30.0	Ringold	4.57	21.0	2090	2063	100	67.7	51.6	38.5	30	24.8	21.2	18.8	15.9	9.7	6.7	4.9	70.0	25.1	4.9
199-K-201 (C7832)	I-003	9.3	30.4	Ringold	1.28	20.7	2100	2063	100	100	91.3	86	81.3	72.6	63	56	47.5	38.8	34.5	30.5	18.7	50.8	30.5

Note: Includes some samples from below the water table.

Depth refers to the top of the sample interval.

To convert from kg/m^3 to lb/ft^3, multiply by 0.0625.

Table 3-4. van Genuchten Parameters and Fitted Saturated Hydraulic Conductivity Data for Four Sandy Gravel Samples

Sample	Operable Unit	Well Number	Depth (m [ft])	% Gravel	q_s (cm^3/cm^3)	q_r (cm^3/cm^3)	α (1/cm)	n (-)	Fitted K_s (cm/s)	Fitted K_s (ft/d)
4-1086	100-K	199-K-110A	12.77 (41.89)	65	0.137	0	0.1513	1.189	0.0583	16.5
4-1090	100-K	199-K-111A	8.2 (26.90)	50	0.152	0.0159	0.0159	1.619	0.000405	1.15
4-1118	100-K	199-K-109A	10.3 (33.79)	66	0.163	0	0.2481	1.183	0.0389	11.0
4-1120	100-K	199-K-109A	18.9 (62.01)	63	0.131	0.007	0.0138	1.501	0.000285	0.806

Sources: RPP-RPT-35222, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report*.

van Genuchten, M. Th., 1980, "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils."

α = a fitting parameter

K_s = saturated hydraulic conductivity

n = a fitting parameter (dimensionless)

q_r = residual moisture content (dimensionless)

q_s = saturated moisture content (dimensionless)

Table 3-5. Summary of 100-K Aquifer and Aquitards of the Suprabasalt Aquifer System

Geologic Unit	Aquifer Type or Aquitard	Facies/Principal Sediment Types and Characteristics	Approximate Range of Thickness (m [ft])
Hanford formation	Unconfined aquifer	Cataclysmic flood deposits/sandy gravel, loose	0 to 30 (0 to 100) 4.6 to 20 (20 to 65) in K Reactor area
Ringold Formation unit E		Coarse-grained fluvial deposits/sandy gravel, cobbles-to-sand, weakly to semiconsolidated, non– to well-cemented	5.2 to 27 (17 to 95)
RUM	Aquitard	Paleosol and overbank deposits/sandy silt and silty clay	30 to 60 (100 to 200)
RUM water-bearing lenses (rare)	Confined water-bearing zone	Low-energy fluvial, silty gravely sand to fine silty sand	1 to 3 (3 to 10)
RUM	Aquitard	Paleosol and overbank deposits/sandy silt and clay	30 to 60 (100 to 200)
Ringold Formation unit C	Confined water-bearing zone	Low-energy fluvial deposit, sands, and gravel	3 to 9 (10 to 30)

Table 3-5. Summary of 100-K Aquifer and Aquitards of the Suprabasalt Aquifer System

Geologic Unit	Aquifer Type or Aquitard	Facies/Principal Sediment Types and Characteristics	Approximate Range of Thickness (m [ft])
RLM	Aquitard	Overbank/Paleosol-Lacustrine deposits, sand, and gravel	23 to 38 (75 to 125)
Ringold Formation unit B	Confined water-bearing zone	Low-energy alluvial and paleosols/sand, loose gravel	3 to 15 (10 to 50)
RLM	Aquitard	Overbank-Paleosol/Lacustrine deposits/silt and clay	23 to 38 (75 to 125)
Ringold Formation unit A	Confined water-bearing zone	Low-energy fluvial deposits, sand, and gravel	6 to 10 (20 to33)

RLM = Ringold Formation lower mud

RUM = Ringold Formation upper mud

Five wells have been drilled into the upper 15.2 m (50 ft) of the RUM at 100-K, including four drilled as part of RI characterization. Water-bearing transmissive units were found in two of these wells, 199-K-32B and RI well 199-K-192. The uppermost confined water bearing units in these two wells are found at different elevations within the RUM, and wells are about 400 m (1,320 ft) apart. The 0.9 m (3 ft) layer at well 199-K-32B consists of fine sand with traces of silt and clay, while the 2.7 m (9 ft) layer at well 199-K-192 consists of a gravelly, silty sand. Head measurements taken during drilling at well 199-K-192 indicate a vertical upward head differential of 3.3 m (10.7 ft). Well 199-K-32B displays an average 2.8 m (9.1 ft) vertical upward head differential compared to adjacent well 199-K-32A, which is screened in the upper unconfined aquifer. The static water level in well 199-K-32B rises to within an average of 15.2 m (50 ft) of the ground surface. At well 199-K-192, the water level rises to within 9.4 m (30.4 ft) of ground surface. Both head elevations are above the elevation of the unconfined aquifer surface. Pump test data, including hydraulic conductivity, are available from well 199-K-192. Hydraulic testing has not been performed at well 199-K-32B. Available well data are inadequate to determine the extent of these transmissive layers or connection between them. These units may correlate with the regionally extensive Ringold Formation unit C or may be localized.

Well 699-81-62 is located northeast of 100-K, where it was drilled 160 m (525 ft) into the Ringold Formation and another 288 m (945 ft) into the CRBG. Unpublished well logs for 699-81-62 and data from wells in 100-BC and 100-N were used to determine that Ringold Formation units A, B, and, possibly C are present beneath the 100-K surface (WHC-SD-EN-TI-011). Limited deep drilling investigations have also shown the presence of three confined aquifer zones in the suprabasalt aquifer system: Ringold Formation units A, B, and C.

The A, B, and C units comprise the bottom half of the Ringold Formation and are composed of fluvial gravels and sands, interbedded with overbank fine sand, silt, and clays. Ringold Formation units A, B, and C consist of clast-supported, pebble- to gravel-sized fraction particles with a fine to medium sand matrix. The overbank units are silty sands, silts, and clay-sized fraction deposits, which show some soil alteration/formation and comprise the RLM and RUM.

Table 3-6. Horizontal Saturated Hydraulic Conductivity in 100-K

Well Number	Northing (m)	Easting (m)	Ks (ft/d)	Ks (m/d)	Ks (cm/s)	Formation	Test Type/ Analysis Method	Reference
199-K-10	146628.1	568912.8	52	16	0.0185	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	PNL-10886
199-K-10	146628.1	568912.8	53	16.16	0.0187	Not reported	Pumping/Cooper and Jacob (1946)	PNL-8337
199-K-106A	146502.4	568697.4	9	2.68	0.0031	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-107A	146468.8	568579.9	5	1.55	0.0018	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-108A	146396.1	568687.2	3	0.98	0.0011	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-110A	146677.9	569230	4	1.1	0.0013	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-110A	146677.9	569230	32	9.79	0.0113	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-T1-221
199-K-111A	146968.9	569308.2	26	8	0.0093	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-111A	146968.9	569308.2	27	8.35	0.0097	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-TI-221
199-K-18	147400.8	569353.7	9	2.8	0.0032	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-19	147368.6	569458.5	6	1.83	0.0021	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-20	147687.2	569520.5	111	33.84	0.0392	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-21	147932.1	569769.9	16	5	0.0058	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-22	148097.4	570023.7	3	0.88	0.0010	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-32A	147006.7	569024.2	80	24.38	0.0282	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-33	146713.3	568573.7	19	5.79	0.0067	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-34	146501.9	568605.8	68	20.73	0.0240	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-35	146110.7	568832.3	124	37.8	0.0438	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-36	146390.7	569373.8	87	26.52	0.0307	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-37	148226.5	570216.2	145	44.2	0.0512	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-183	146439.70	568302.28	42.6	13	0.0150	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-184[b]	146366.32	568618.68	22.3	6.8	0.0079	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-185	146726.17	568574.92	75	23	0.0266	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-186	146625.36	568209.65	No data [a]	No data [a]	No data [a]	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-187	146054.68	569499.00	92	28	0.0324	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-188[b]	146370.11	569386.80	53	16	0.0185	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-189	146809.68	569150.27	2.9	0.9	0.0010	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-190	146873.27	568835.28	39	12	0.0139	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-191	146886.65	569711.20	3.3	1	0.0012	Ringold Formation unit E	Slug/KGS	Appendix C

Table 3-6. Horizontal Saturated Hydraulic Conductivity in 100-K

Well Number	Northing (m)	Easting (m)	Ks (ft/d)	Ks (m/d)	Ks (cm/s)	Formation	Test Type/ Analysis Method	Reference
199-K-192	147294.32	569393.27	0.7	0.2	0.0002	RUM/confined sand lens	Slug/KGS	Appendix C
199-K-193	146969.58	570641.99	3.6	1.1	0.0013	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-194	147281.98	571315.65	2.3	0.7	0.0008	Ringold Formation unit E	Slug/KGS	Appendix C
199-K-195 [b]	146086.38	568850.08	49.2	15	0.0174	Ringold Formation unit E	Slug/KGS	Appendix C

References: Bouwer and Rice, 1976, "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells."

CCN 024566, "Field Summary Report 100-H Area Well Production Testing."

Cooper and Jacob, 1946, "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History."

DOE/RL-93-79, *Limited Field Investigation Report for the 100-KR-4 Operable Unit.*

PNL-8337, *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System*.

PNL-10886, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*.

WHC-SD-EN-DP-090, *Borehole Data Package for the 100-K Area Groundwater Wells for CY 1994.*

WHC-SD-EN-TI-221, *Geology of the 100-FR-3 Operable Unit, Hanford Site South-Central Washington.*

a. Water level dropped too fast during test to record data, indicates high hydraulic conductivity.

b. Well was drilled into the RUM, but was completed and screened in the unconfined aquifer directly above the RUM.

RUM = Ringold Formation upper mud

Ringold Formation unit A lies on top of the CRBG. At well 699-81-62, a basal 2.1 m (7 ft) thick conglomerate was noted in a log that otherwise did not describe Ringold sediments. WHC-SD-EN-TI-011 delineates a total of 7.6 to 9.1 m (25 to 30 ft) of Ringold Formation unit A material beneath the RLM. The RLM is 30 m (100 ft) thick and is separated from the RUM by Ringold Formation unit B gravels and sands. Ringold Formation unit B is reported beneath 100-BC, thinning to the east in 100-K, where it is estimated to be 18.3 m (60 ft) thick. The RUM is in excess of 61 m (200 ft) thick and is separated by a 1.5 to 3 m (5 to 10 ft) thick sand and gravel that *The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral Columbia River System, South-central Washington and North-central Oregon* (Lindsey, 1996) interprets as Ringold Formation unit C (WHC-SD-EN-TI-011). Ringold Formation unit C lies about 16.8 to 18.3 m (55 to 60 ft) below the contact with Ringold Formation unit E.

3.6.3 Columbia River Basalt Group Hydrogeology

Based on the CRBG geology discussion in Section 3.4.2.5, the greatest porosity and permeability within a flow is usually found in the chilled basal margin and at the vesicular flow top. In addition, the interbeds usually are more permeable, although some units have reported low permeability. The dense, fractured interior of a basalt flow is typically of low permeability, as the fractures usually exhibit very close spacing. Regional fracture sets and local tectonic features around folds and faults provide greater porosities. These features combine to provide generally extensive lateral flow capabilities but limited vertical migration of groundwater. Estimated effective porosities (DOE/RW-0164) have been reported as 20% for interbeds, 10% for fractured basalt zones, 5% for vesicular basalt zones, and 1% for basalt flow interiors.

The Grande Ronde, Wanapum, and Saddle Mountain basalt formations are described in DOE/RW-0164 as being confined to semiconfined aquifers. Recharge for the confined aquifers of the Grande Ronde, Wanapum, and Saddle Mountain formations comes from the western margins of the Columbia Plateau where the formations outcrop, cross stream or river outcrops, and are covered with lesser thicknesses of sediments. The Basalt Waste Isolation Project studies concluded there was also significant movement of confined groundwater between adjacent basalt flows. The Wanapum and Saddle Mountains are recharged by precipitation at outcrops and subcrops around the margins of the Pasco Basin, as at the Saddle Mountains and Rattlesnake/Horse Heaven anticlines to the south. Locally, the Gable Mountain, Gable Butte, and Umtanum Ridge may provide recharge areas.

Across the Pasco Basin, head data indicate a vertically upward gradient for confined aquifers within the Grande Ronde and Wanapum formations. For the Saddle Mountain basalts, the hydraulic head data indicate that while vertical upward gradients are generally present, they decrease with greater depth in the basalt or may exhibit a downward vertical gradient. Vertical leakage between flows is unquantified. Water levels in well 699-81-62, screened across the Mabton Interbed (more than 406 m [1,331 ft] bgs), rose to an elevation of 125.87 m (412.9 ft) or to within 9.44 m (31 ft) of the ground surface.

Basalt aquifers are characterized as low-sulfate, low-chloride bicarbonate water with 200 to 300 µg/L of dissolved solids and a pH range of 7.5 to 8.5. In total, the three basalt formations exhibit similar geochemical properties, but may differ markedly within the formations.

Transmissivity values have been estimated from data across the Columbia Plateau (DOE/RW-0164). Wanapum and Saddle Mountain basalt formations fall within a range of 1×10E-4 to 9×10E-2 m^2/sec (100 to 90,000 ft^2/d), with a mean value of 2×10E-3 m^2/sec (2,000 ft^2/d). Storage coefficients for specific formations have not been calculated, but values of 2 to 6×10E-3 are reported.

Groundwater conditions within the basalt flows are regarded as having insignificant effect to groundwater conditions and contaminant distribution in the unconfined aquifer at 100-K.

3.7 Groundwater Flow Regime

The understanding of groundwater movement at 100-K and its effects on migration of associated contaminants is based on knowledge of historical conditions as well as current operating conditions that affect groundwater elevation, flow direction, and velocity. Hydrogeologic characterization of aquifer material presented in preceding subsections provides part of the picture, with understanding of the effects of water management related to reactor operations and recent operation of groundwater RAs providing additional information. Hydrogeologic characterization at 100-K requires understanding of the properties and behavior of the vadose zone, groundwater, and surface water regimes, together with their interactions. This section focuses on the groundwater flow patterns and rates under historic (predevelopment and operational) and recent conditions. Natural and artificial hydrologic processes influence groundwater flow patterns and contaminant distribution at 100-K.

The groundwater regime at 100-K can be separated into the following phases:

- Historic conditions, including the following:
  - Predevelopment (pre-1862) conditions, during which time there was little to no anthropogenic activity
  - Pre-Hanford Site (1862-1943) operations, when irrigated agriculture was implemented at numerous locations near the river, including operation of an irrigation canal across the Site
  - Operational (1943 to 1970s) conditions, during which reactors were constructed and operated at 100-K, and artificial recharge occurred through wastewater disposal to the vadose zone
  - Post-operational (post 1970s) conditions, during which effects from reactor and related operations ceased, and groundwater conditions began recovery to pre-Hanford conditions
- Current (recent) conditions during interim RAs. The RAs include waste site remediation in the vadose zone, and groundwater P&T systems.

The following section describes the groundwater flow regime in terms of these historical and current conditions. It focuses on conditions in the unconfined aquifer caused by groundwater contamination and related remedial activities within Ringold Formation unit E, and concludes with a discussion on the underlying RUM, and interactions between the RUM and unconfined aquifer.

3.7.1 Historical Groundwater Flow Conditions

General patterns of groundwater flow before the startup of operations at 100-K can be inferred from early maps of groundwater levels and from the distribution of natural recharge and discharge boundaries at the site. Together, these indicate that groundwater flow directions and rates in the 100-K area were dictated by natural recharge and discharge locations, leading to general patterns of flow from south-southwest to north-northeast. Groundwater ultimately discharged to the Columbia River, and fluctuations in groundwater levels within the unconfined aquifer resulted from natural changes in the stage of the Columbia River.

With the industrial development of the Hanford Site, various anthropogenic influences have dominated the directions and rates of groundwater flow. During KE and KW Reactor operations, large volumes of spent cooling water were discharged to the 107-KE and 107-KW retention basins, where the water

was held. This allowed the water to thermally cool and short-lived radionuclides to decay. After the holding period, the cooling water was discharged directly into the Columbia River. Reactor cooling water entered the vadose zone near the reactor operations under two common conditions. First, leaks developed in the retention basins from thermal expansion and contraction, allowing cooling water to leak from the basins and piping into the underlying vadose zone. This contributed to localized artificial recharge. Second, episodic fuel element failures contaminated the cooling water with radioactive fission products and fuel residues. Under these upset conditions, the cooling water was discharged directly to the vadose zone via the 116-K-2 Trench instead of to the river. The discharge of contaminated cooling water to the vadose zone reduced the amount of radioactive contaminants that ultimately reached the river. Infiltration and overland flow of contaminated cooling water from the116-K-2 Trench and from leaks at the retention basins resulted in contamination of the vadose zone and aquifer.

The local artificial recharge conditions caused by discharges of contaminated cooling water to the trench and leaks from the retention basins resulted in the buildup of an extensive groundwater mound in the unconfined aquifer at 100-K. Monitoring well hydrographs from 100-K indicate that wastewater elevated groundwater levels near the 116-K-2 Trench. These data indicate the groundwater mound began developing shortly after the start of discharges to the 116-K-2 Trench, and continued to expand until the late 1960s. The groundwater mounding peaked around 1967 (Figure 3-12), altering flow patterns in the area and creating a large groundwater mound. Figures 3-12 and 3-13 illustrate water table effects from the discharges. The groundwater levels observed before and after discovery of leaks at the retention basins show a steady increase in relation to historical water levels. In addition, possible influences of wastewater discharges that occurred in the 200 Area (i.e., the Central Plateau), which led to flow of groundwater through Gable Gap, are difficult to quantify.

Observations of reactor cooling water discharge groundwater mounding effects to the vadose zone in the Hanford 100 Areas during reactor operations is presented in HW-77170, *Status of the Ground Water Beneath Hanford Reactor Areas January 1962 to January 1963*. This report presents detailed descriptions of the groundwater mounds observed at all the Hanford reactor areas, including descriptions of the groundwater temperature effects caused by discharge of high volumes of near-boiling cooling water.

Natural processes continue to affect the groundwater flow regime and contaminant migration. However, since the cessation of operations, the effects of artificial operations (such as the high-volume liquid discharges into the 116-K-2 Trench) have diminished over time. Some residual effects have not completely dissipated, and other artificial processes continue to influence contaminant migration, particularly ongoing P&T operations, facility removal, and waste site remediation.

3.7.1.1 P&T System Influences

The KR4 P&T system was the first system installed and began operation in 1997; it was designed to remediate groundwater around the 116-K-2 Trench. The KW P&T system was the second system installed and began remediating Cr(VI) in the KW Reactor area in February 2007. The KX P&T system began operating in November 2009. The KX P&T system is used primarily to treat Cr(VI) in groundwater that migrated from the 116-K-2 Trench area toward N Reactor and near the proximal end of the trench near the KE Reactor.

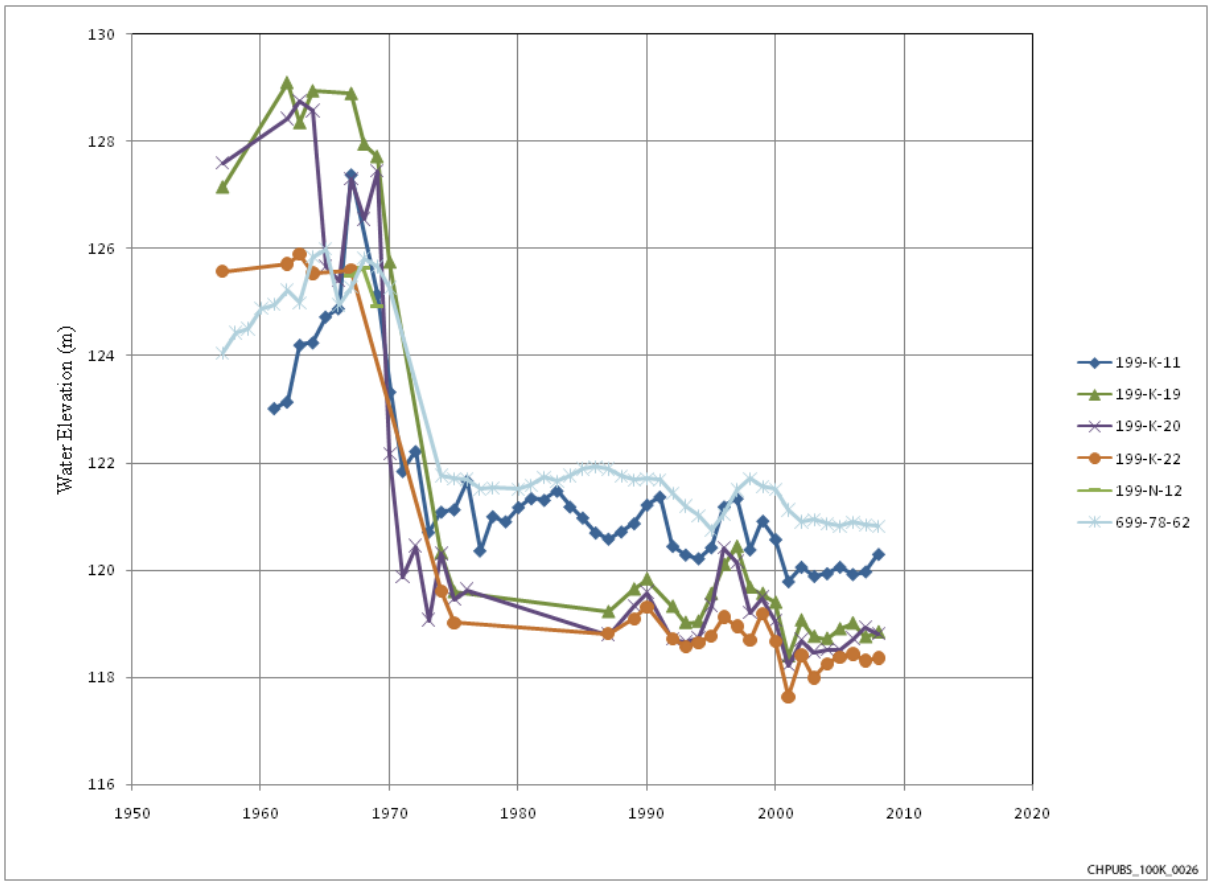
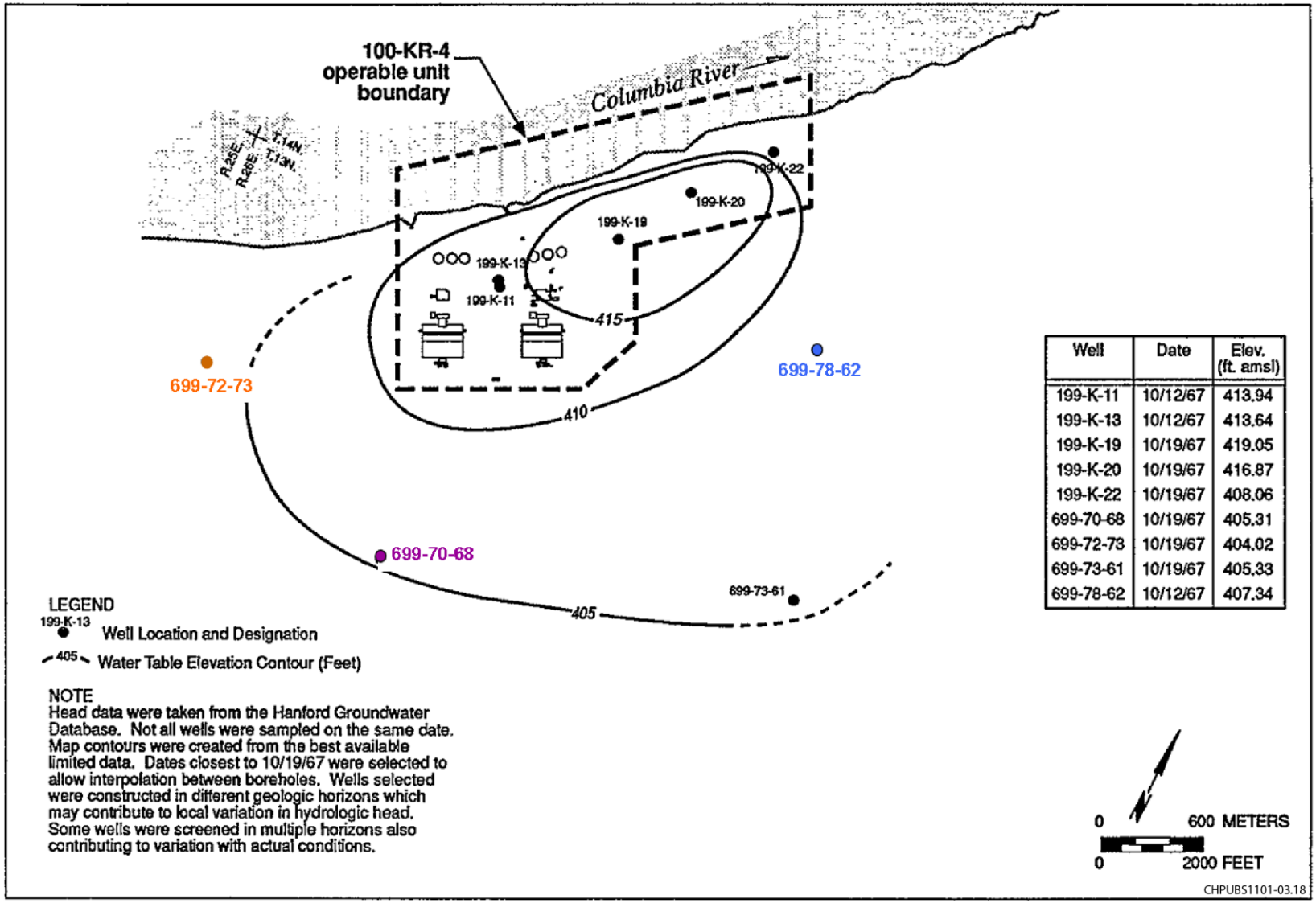


Figure 3-12. Selected Hydrographs from Wells near the 100-K Infiltration Trench

3.7.1.2 Horizontal Hydraulic Gradients and Flow Velocities

During reactor-related activities, including wastewater disposal to the subsurface, groundwater flow velocities between wastewater disposal areas and the Columbia River increased relative to predevelopment rates. Within a few years of the start of KE and KW Reactor operations, leaks from retention basins and pipelines caused groundwater mounds to form beneath the 116-K-2 Trench and 116-K-1 Crib and reactor area. The mounding increased the gradients and groundwater flow velocity between the leak and disposal areas and the Columbia River.

A study in 1962 (HW-71770) measured groundwater temperature and elevations at 100-K. The top of the groundwater mound below the 116-K-2 Trench was estimated at an elevation of 128 m (420 ft). The groundwater velocity, between the trench and the Columbia River, was estimated through isotopic analysis at 3.5×10^{-3} cm/s (10 ft/d). Groundwater velocities in the western end also led to local reversal of groundwater flow directions for some distance south-southeast (i.e., formerly upgradient) of the trench. Head differences measured between the 116-K-2 Trench bottom and inland well 699-78-62 indicated a probable inland groundwater gradient at a point 1,220 m (4,000 ft) southeast of the 116-K-2 Trench.



Well	Date	Elev. (ft. amsl)
199-K-11	10/12/67	413.94
199-K-13	10/12/67	413.64
199-K-19	10/19/67	419.05
199-K-20	10/19/67	416.87
199-K-22	10/19/67	408.06
699-70-68	10/19/67	405.31
699-72-73	10/19/67	404.02
699-73-61	10/19/67	405.33
699-78-62	10/12/67	407.34

Source: DOE/RL-90-21, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington*.

Figure 3-13. 1967 Water Table Elevations in the 100-KR-4 OU

The relatively sparse distribution of monitoring wells during this period is not ideal for accurately mapping the early groundwater table configuration. Figure 3-13 depicts the groundwater mound effects on the water table in 1967 as inferred from the available data. The head data shown in Figure 3-12 indicate the contoured water levels illustrated in Figure 3-13, which depict approximate conditions in 1967, represent the mound around its peak elevation. Discharges ceased in 1971, and conditions approaching normal horizontal hydraulic gradients were restored around 1974. The 1989 water table map that is presented in Figure 3-14 shows a return to more natural regional gradients and does not indicate a residual groundwater mound from operational discharges.

Chapter 5 further details the effects of wastewater infiltration on patterns of groundwater flow and contaminant migration near the KE and KW Reactors and the 116-K-2 Trench. Water level maps depict patterns of flow inland from the reactors and 116-K-2 Trench, and the likely effect of these groundwater flow patterns on contaminant migration.

3.7.1.3 Vertical Gradients

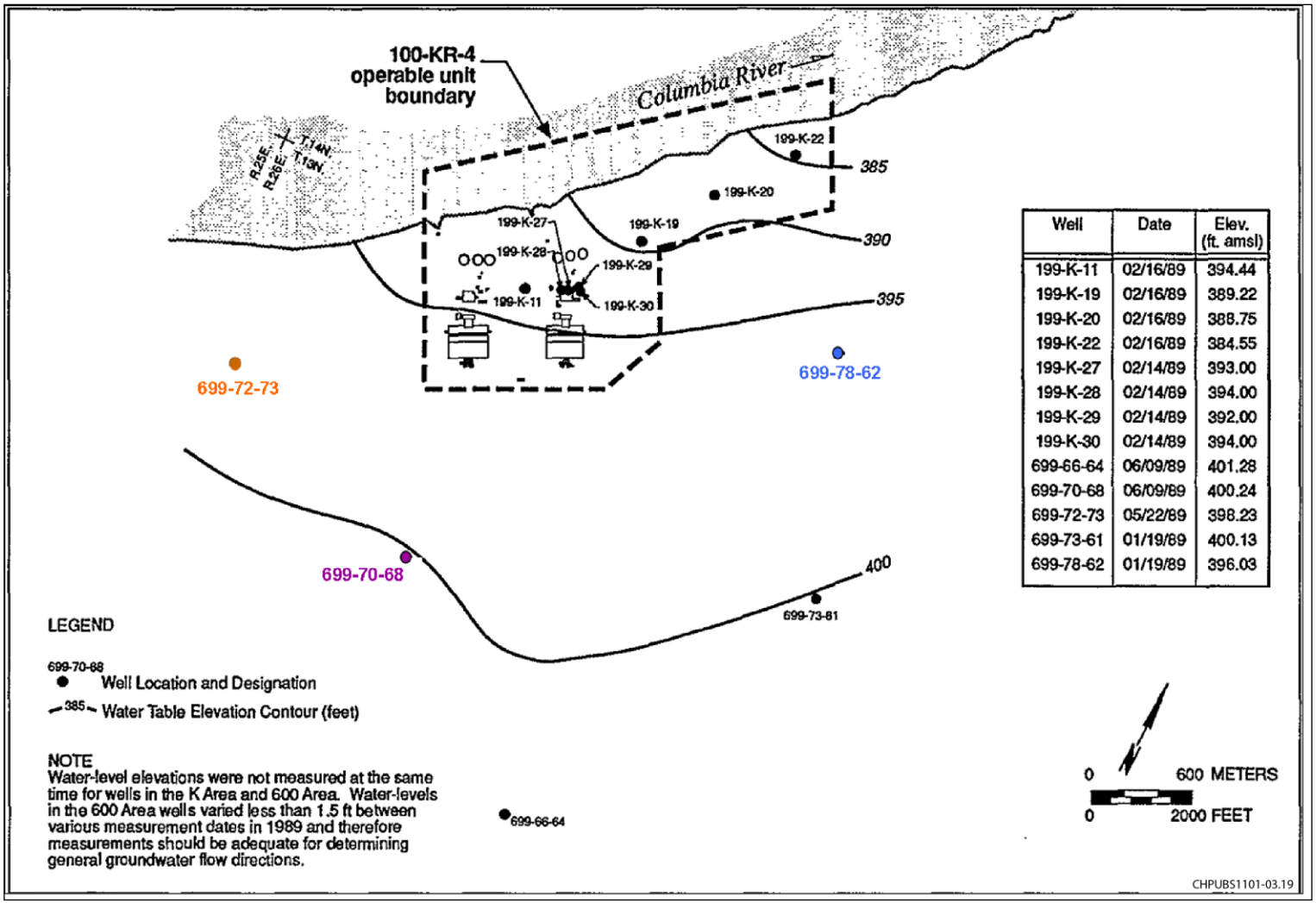
During operation of the reactors, infiltration and overland flow of contaminated cooling water from surface features and from leaks at the 107-KE and 107-KW retention basins created vertical (downward) gradients within the aquifer. The downward gradients increased potential for vertical migration of contaminants released to the aquifer. Although historical water level data from River Corridor reactor areas during the operational period are from wells with broadly similar screened intervals—making direct assessments of vertical gradients difficult—qualitative evaluation of the mounding conditions suggests that vertical hydraulic gradients would have caused vertical contaminant movement for mobile contaminants.

3.7.2 Current Groundwater Flow Conditions

Since the cessation of reactor operations and associated wastewater disposal, hydraulic gradients and groundwater flow returned to the northwest toward the Columbia River, with variations in response to changes in the stage of the Columbia River that are dictated by the spring snowmelt, summer season, and controlled releases at Priest Rapids Dam. Throughout the year, hydraulic gradients steepen toward the river during low river stage (fall and winter), and flatten—and may reverse—near the shoreline during high river stage (spring). Superimposed on these longer-term fluctuations are daily and even weekly fluctuations arising from controlled releases at Priest Rapids Dam.

Data obtained from river gauges along the Hanford Reach indicate that high river stage can be more than 3 m (10 ft) higher than low river stage. River stage can also fluctuate several meters over short periods (hours to days), based on operations at Priest Rapids Dam (DOE/RL-96-84). Depending on the local geology, changing river stage can influence groundwater elevations up to several hundred meters inland. The groundwater level response to changes in river stage is slower and of less magnitude farther inland than near the river. However, effects have been observed as far inland as Gable Gap, approximately 3,600 m (2.2 mi) to the southeast (DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). Groundwater elevations have varied up to 0.9 m/d (3 ft/d) in some wells nearest the river and up to approximately 1.8 m (6 ft) over the season in a few wells (PNL-9437, *Monitoring Groundwater and River Interaction Along the Hanford Reach of the Columbia River*).

Currently, groundwater elevation at 100-K is locally modified by the operation of extraction and injection wells of the P&T systems. Groundwater extraction wells produce local depressions in the groundwater surface; injection wells produce local mounds that raise the groundwater elevation. These effects are further imposed upon the groundwater elevation transients caused by river stage variations.



Well	Date	Elev. (ft. amsl)
199-K-11	02/16/89	394.44
199-K-19	02/16/89	389.22
199-K-20	02/16/89	388.75
199-K-22	02/16/89	384.55
199-K-27	02/14/89	393.00
199-K-28	02/14/89	394.00
199-K-29	02/14/89	392.00
199-K-30	02/14/89	394.00
699-66-64	06/09/89	401.28
699-70-68	06/09/89	400.24
699-72-73	05/22/89	398.23
699-73-61	01/19/89	400.13
699-78-62	01/19/89	396.03

Source: DOE/RL-90-21, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington*.

Figure 3-14. 1989 Water Table Elevations in the 100 KR-4 OU

3.7.2.1 Horizontal Gradients and Groundwater Velocities

Current hydraulic gradients are generally northwest toward the Columbia River, but show some seasonal variation in response to changes in river stage. Gradients steepen towards the river during low river stage (fall and winter), and flatten—and may reverse—near the river shoreline during high river stage (spring). Local gradients are also strongly influenced by the operation of the KR, KW, and KX P&T systems. The saturated thickness of the unconfined aquifer under current conditions is presented in Figure 3-15. This map was created by subtracting the elevation of the RUM contacts from unconfined monitoring well water level elevations for August to September 2010, and contouring the resulting thicknesses. An inferred water table elevation map of the shallow unconfined aquifer at 100-K is shown in Figure 3-16. This figure is based on groundwater elevation observations in monitoring wells and derived elevations at extraction and injection wells. The figure indicates the general groundwater flow pattern from inland areas toward the Columbia River and the apparent modification of the water table surface caused by operation of extraction and injection wells.

Under current conditions, previous studies have suggested that hydraulic gradients range from about 0.003 to 0.006, and groundwater flows at an average rate of 1.2×10^{-4} to 3.5×10^{-4} cm/s (0.024 to 0.072 ft/d), as estimated from hydraulic gradients and migration rates of plumes (PNNL-14031, *Evaluation of Potential Sources for Tritium Detected in Groundwater at Well 199-K-111A, 100-K Area*). The groundwater flow rate between the KE Reactor and the river has been estimated to be 1.4×10^{-4} cm/s (0.4 ft/d), based on the migration of a plume created by a leak from the KE FSB in 1993 (PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*). An increased groundwater flow rate is observed beneath the KW Reactor as compared to below the KE Reactor, and the calculated direction of groundwater flow downgradient from the KE Reactor is most often to the northwest, with gradients ranging between 0.0034 and 0.0055 (PNNL-14031).

To evaluate the variation in the groundwater gradient direction and magnitude at 100-K, as influenced by current P&T operations, a three-point gradient analysis was performed using water levels measured during 2010. A “mesh” of triangles was created between monitoring wells that are outfitted with dataloggers and transducers that record water levels essentially continuously. With some exceptions (detailed below), each triangle in the mesh—referred to as an “element”—is defined by three monitoring wells. A gradient vector consisting of a magnitude and azimuth (direction) was calculated for each element, using measured water levels in the three wells. For this analysis, weekly gradients were calculated for each element, using weekly-average water elevation measurements in groundwater monitoring wells. The presence of extraction and/or injection wells within any one three-point element introduces some degree of uncertainty in the net calculated gradient. Injection and extraction wells may exert effects on either the direction and/or magnitude of gradient within the element.

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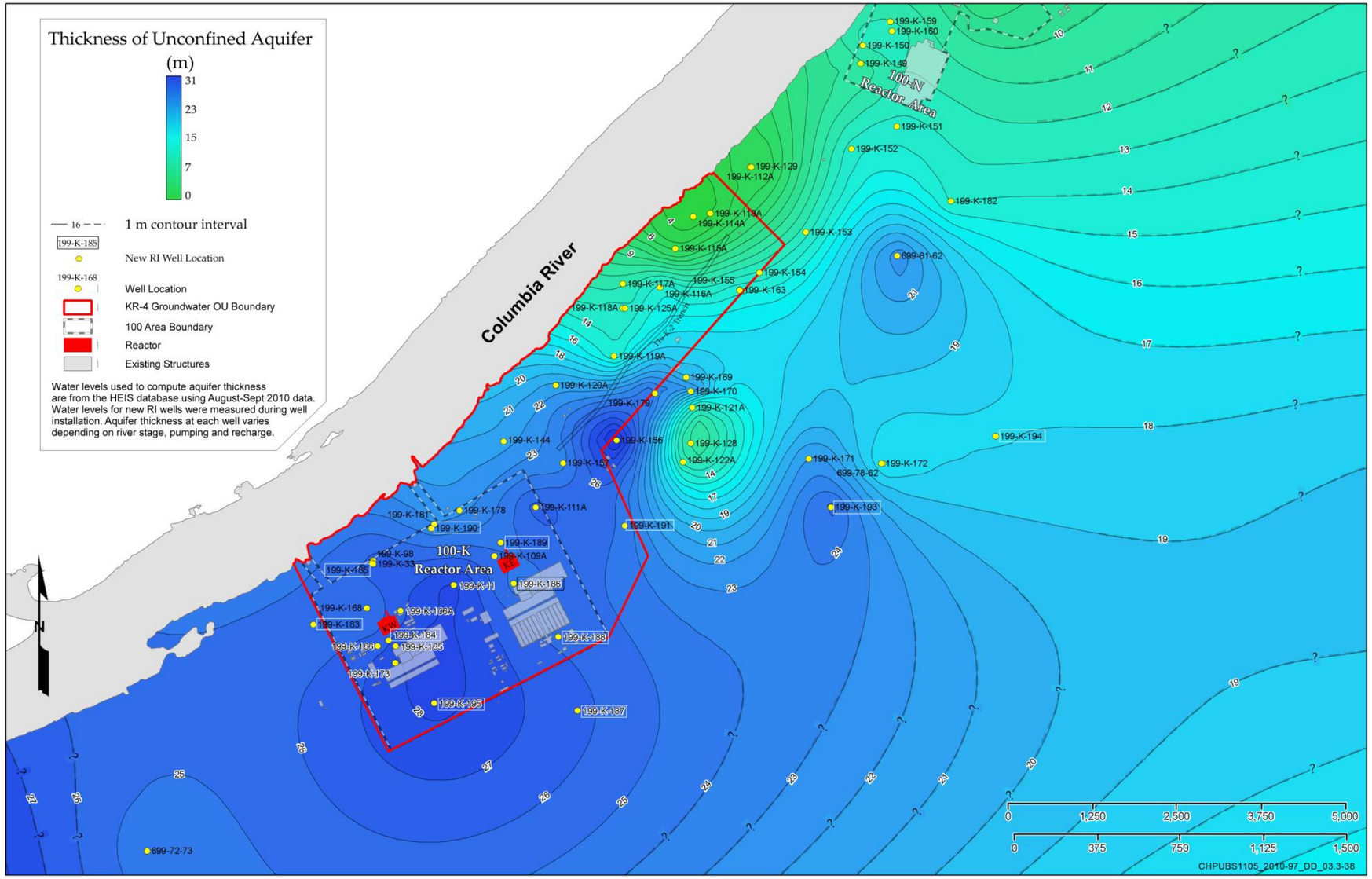

Figure 3-15. Unconfined Aquifer Thickness at 100-K for August to September 2010

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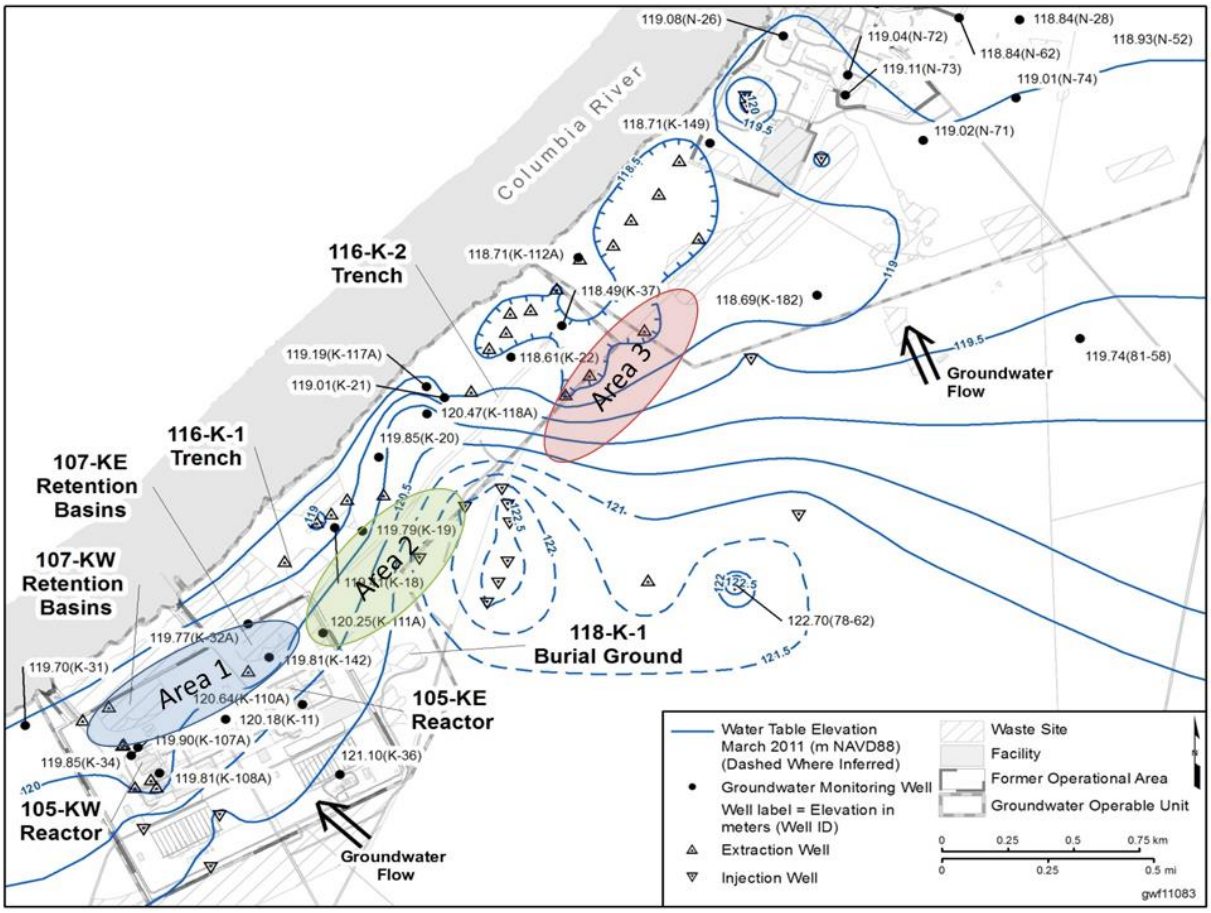


Source: NAVD88, *North American Vertical Datum of 1988*.

Figure 3-16. Water Table Elevation Map for 100-K Area in March 2011 Indicating Inferred Groundwater Flow Directions

The three-point gradient method is most effective if water levels vary linearly between the three wells used to define the triangular element. If an injection or extraction well lies inside an element, however, water level mounding or depression generated by the injection/extraction well will result in a different gradient than would be calculated assuming a planar water table passing through the three monitoring wells. Element triangles were therefore drawn such that injection wells lie outside of the triangles. If it was not possible to draw appropriate triangles using existing monitoring wells, water levels at the triangle vertices were inferred from weekly-average water level maps prepared for DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*. These water level maps were calculated using a universal kriging technique that explicitly accounts for the effects of injection and extraction on groundwater levels (SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*).

Results of the three-point gradient analysis suggest geographic variations in average hydraulic gradients can be broadly grouped in three general areas (shown in Figure 3-16) as follows:

- Area 1: the area downgradient of the KE and KW Reactors
- Area 2: the area east of the KE Reactor and toward the 116-K-2 Trench
- Area 3: the area east of the 116-K-2 Trench also referred to as K-North

Radial diagrams illustrating gradient magnitude and direction in each area are presented in Figures 3-17 through 3-19. Within 100-K Area, an azimuth direction of approximately 320 degrees would indicate a flow direction perpendicular to the Columbia River. The radial diagrams presented in Figures 3-17 through 3-19 illustrate the variations in weekly average gradient for representative elements in each of the three general areas identified above. The direction the lines point indicates the calculated azimuth direction (i.e., the flow direction). The length of the line indicates the relative magnitude of the groundwater gradient. The line colors reflect the general seasonality of the observations; blue indicating spring, green indicating summer, yellow indicating fall, and red indicating winter.

In Area 1, hydraulic gradients during 2010 varied in magnitude from approximately 0.0005 to 0.008. The gradient direction was to the north-northwest toward the Columbia River for most of the year; however, gradients shifted to the north-northeast for a brief period during May and June 2010, coinciding with high stage in the Columbia River. The flow direction in this area exhibited a range of approximately 90 degrees azimuth over the course of the year. A radial graph showing the weekly gradients for a representative element in Area 1 is presented in Figure 3-17.

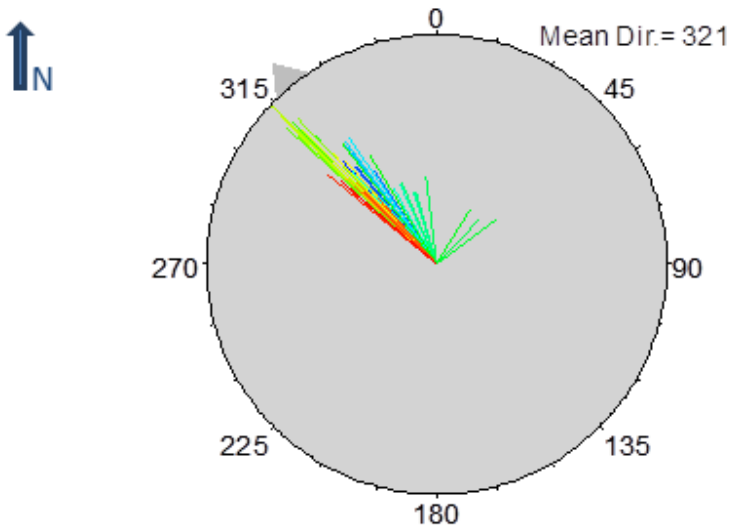


Figure 3-17. Weekly Average Gradient in 2010 for a Representative Element in Area 1

In Area 2, hydraulic gradients during 2010 varied in magnitude from approximately 0.003 to 0.03. Gradient directions were consistently to the north-northwest, with decreases in magnitude that coincide with high river stage (June) and periods of decreased extraction in the KR P&T system (January and October). The range of groundwater flow direction in this area was about 40 degrees azimuth. A radial graph showing the weekly gradients for a representative element in Area 2 is presented in Figure 3-18.

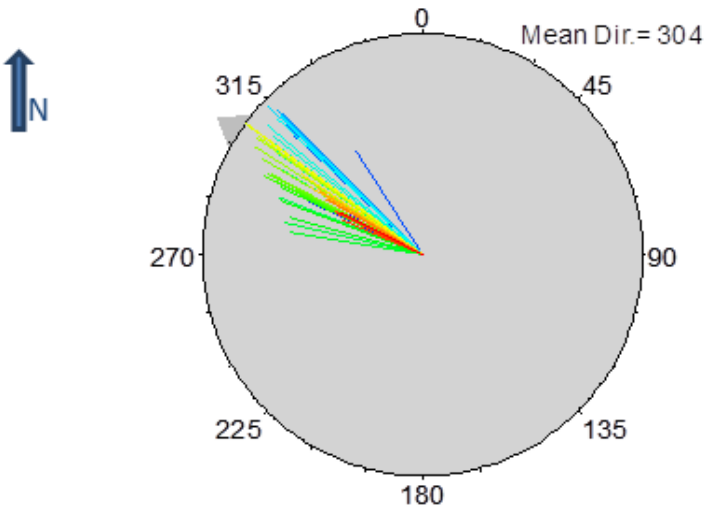


Figure 3-18. Weekly Average Gradient in 2010 for a Representative Element in Area 2

In Area 3, hydraulic gradients during 2010 varied in magnitude from approximately 0.0003 to 0.004. The gradient direction was generally to the north-northwest toward the Columbia River for most of the year; however, gradients shifted to the south-southwest (away from the Columbia River) for a brief period in June 2010, coinciding with high river stage. Groundwater flow in this area exhibited a range of about 180 degrees azimuth; indicating a complete direction reversal for part of the year; this effect is apparently related primarily to operation of an extraction well nearby. A radial graph showing the weekly gradients for a representative element in Area 3 is presented in Figure 3-19.

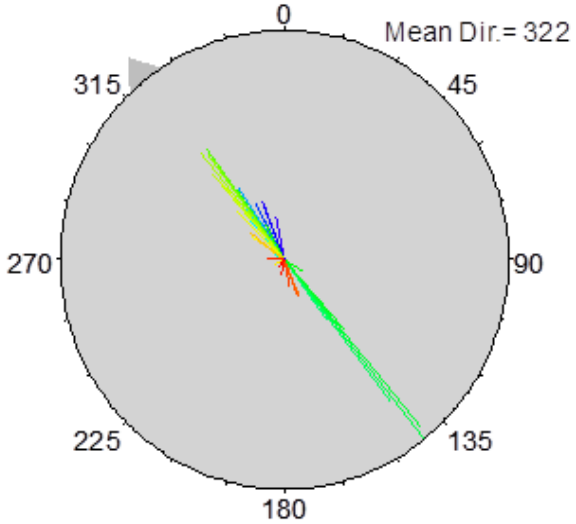


Figure 3-19. Weekly Average Gradient in 2010 for a Representative Element in Area 3

The approximate magnitude, direction, hydraulic conductivity, and groundwater velocity for each area are summarized in Table 3-7. (Note: the tabulated range of values for gradient direction in Table 3-7 does not reflect periods of complete gradient reversal observed in some areas due mainly to P&T operations at neighboring wells.)

Table 3-7. Average Hydraulic Gradients for 2010

Area	Approximate Hydraulic Gradient Magnitude	Approximate Flow Direction (Azimuth)	Hydraulic Conductivity in Ringold Unit E (cm/s)	Groundwater Velocity in Ringold Unit E (cm/s)
1	0.0005-0.008	257-319	0.0058 to 0.012	0.000016 to 0.00053
2	0.003-0.03	276-323	0.0012 to 0.0058	0.000020 to 0.00097
3	0.0003-0.004	273-336	0.012 to 0.046	0.000020 to 0.0010

3.7.2.2 Vertical Gradients

Three factors make a very detailed evaluation of current vertical hydraulic gradients across 100-K difficult. First, the current monitoring well network consists mainly of wells screened in Ringold Formation unit E. Although screened intervals vary between wells, the screen intervals of neighboring wells often overlap as a result of the need to monitor certain intervals within the aquifer. Second, natural stresses (such as recharge) that would result in significant vertical gradients are limited, except close to the Columbia River, where three-dimensional flow occurs in response to stage-driven cycles. Third, operation of the extensive P&T extraction and injection wells, by design, generates vertically and horizontally convergent/divergent flow, overwhelming ambient vertical gradient patterns.

Until the recent addition of monitoring wells installed within the RUM, vertical gradients between Ringold Formation unit E and the RUM were estimated using water levels measured during 2010 in the nested well pair 199-K-32A and 199-K-32B. The well pair is located downgradient of the KE and KW Reactors, about 250 m (820 ft) from the Columbia River shoreline (Figure 3-20). Monitoring well 199-K-32A is screened within Ringold Formation unit E, and well 199-K-32B is screened within the RUM. Both wells were monitored continuously during 2010 using transducers outfitted with data loggers.

Figure 3-21 shows daily average water levels for each well and for river stage measured at the K-river gauge, which is situated about 280 m (919 ft) to the west-northwest of the 199-K-32 well pair. Both wells exhibit a rapid response to changes in river stage; however, the magnitude of the response is greater in well 199-K-32A, which is screened in Ringold Formation unit E, than it is in 199-K-32B, which is screened in the RUM.

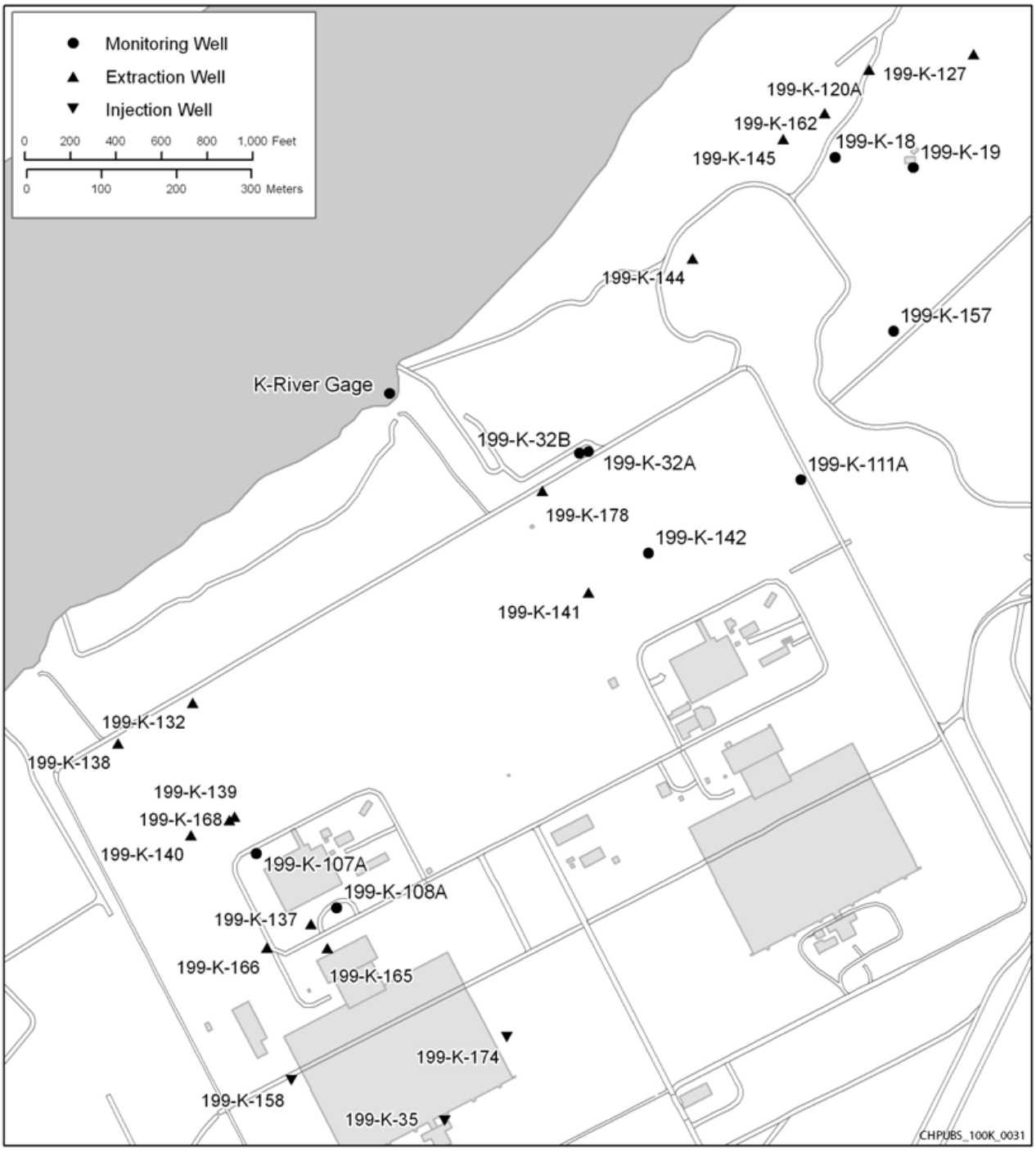


Figure 3-20. Location of Nested Well Pair 199-K-32A/199-K-32B and Nearby Wells

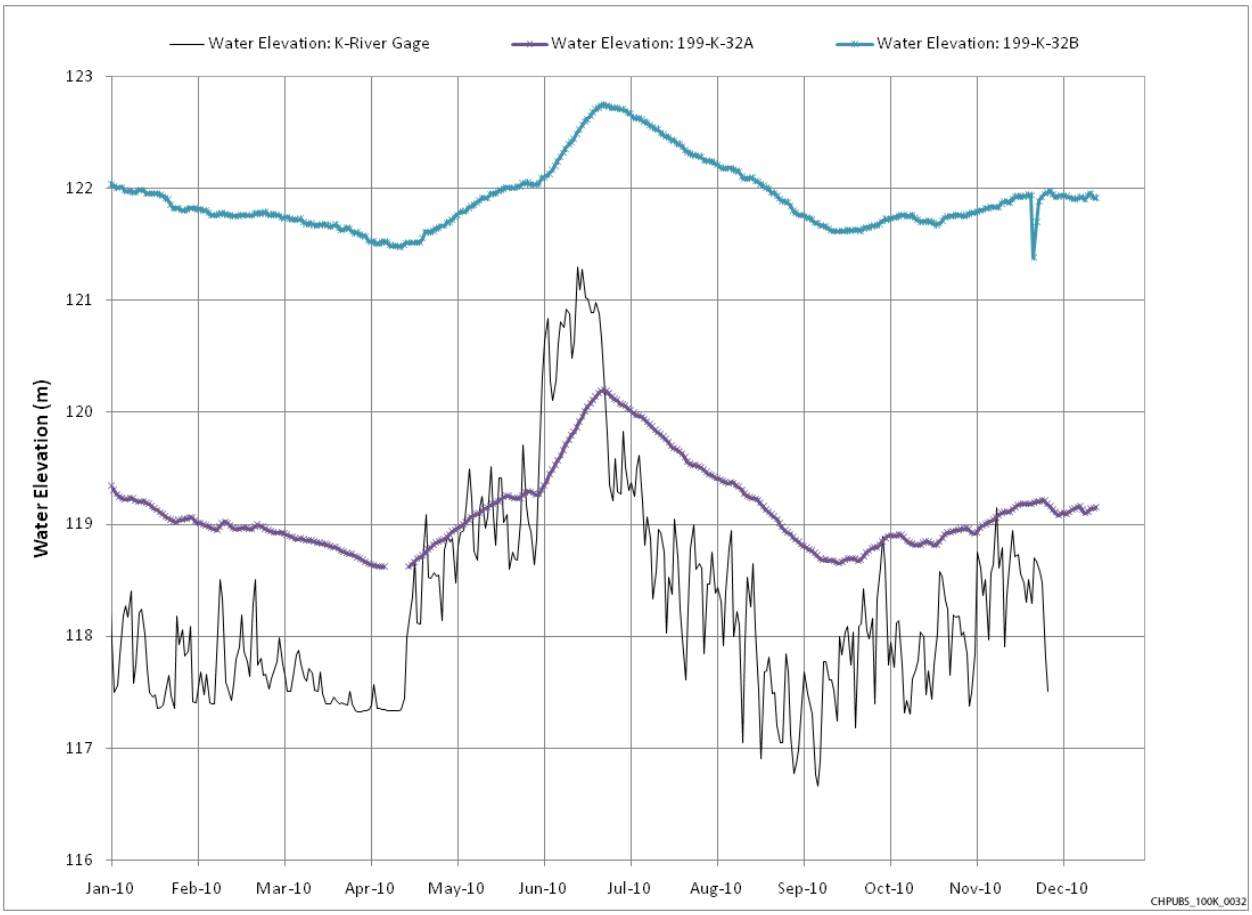


Figure 3-21. Daily Average Water Elevation Measured in Wells 199-K32A and 199-K-32B, with K-River Gauge

Figure 3-22 shows the difference in daily average water elevation measured in the well pair, along with daily average river stage. Hydraulic head in well 199-K-32B ranges from 2.5 to 3.0 m (8.2 to 9.8 ft) higher than in well 199-K-32A, indicating upward gradients from the RUM to Ringold Formation unit E, consistent with a discharge zone near the river shoreline. However, the magnitude of the gradient reflects seasonal variation. Upward gradients are smallest during high river stage conditions (June), and largest during low river stage conditions (September).

In 2010, extraction well 199-K-178, located about 75 m (246 ft) to the southwest of the 199-K-32 well pair, was installed as part of the KX groundwater P&T remedy. It began operating in late March 2010, and typically extracted at about 40 to 80 gal/min between April and December 2010. Figure 3-23 shows the difference in daily average water elevation measured in the 199-K-32A/199-K-32B well pair, with daily extraction rate (in gal/min) in well 199-K-178. Although the difference plot (Figure 3-22) displays a response to changes in pumping rates—suggesting that vertical gradients at this location are not strongly controlled by nearby pumping wells—it is certainly the case that discerning any effects that pumping may have on vertical gradients is made more difficult because of the overwhelming response of groundwater levels in this area to stage changes in the Columbia River.

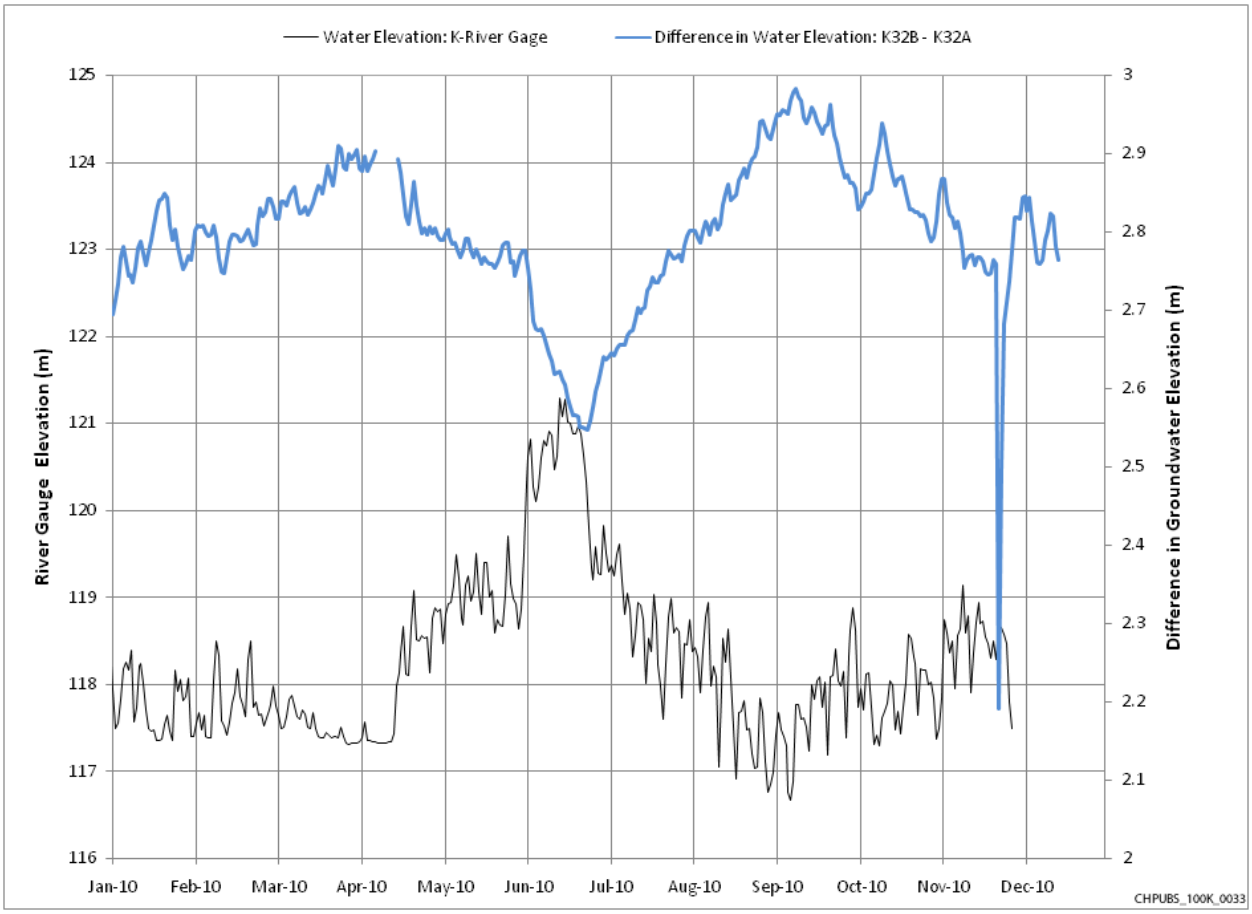


Figure 3-22. Difference in Daily Average Water Elevation Measured in the 199-K-32 Nested Well Pair (199-K-32B Minus 199-K-32A), with Daily Average K-River Gauge

Available water level data suggest the presence of slightly steeper gradients near the KE Reactor compared to the KW Reactor. A plausible explanation for this difference is that the aquifer material near the KE Reactor is of relatively low hydraulic conductivity, and that the KW Reactor was built on a more solid foundation than the KE Reactor, which limited significant leaks and thus decreased downward vertical gradients. Relatively low hydraulic conductivities found at either end of the 116-K-2 Trench are demonstrated by the comparison of conductivity values at wells 199-K-18 (0.0032 cm/s) and 199-K-22 (0.0010 cm/s) versus high conductivity values found at well 199-K-20 (0.0392 cm/s) at the center of the trench (see Areas 1, 2, and 3 in Table 3-7). The relatively low hydraulic conductivity at 100-K is evidenced by the length of the trench necessary to accommodate inflow liquid waste during operations without breaching the trench (100-KR-4 LFI [DOE/RL-93-79]).

The 100-K horizontal hydraulic conductivity is estimated at 0.0008 to 0.0512 cm/s (2.3 to 145 ft/d), as presented in Table 3-6, and an effective (as opposed to calculated) porosity range has been estimated at 10 to 20%. Table 3-6 summarizes information on horizontal saturated hydraulic conductivity (100-KR-4 RPO Model Data Package [SGW-41213]), and more recent data collected during the RI. The hydraulic conductivity values are based on slug tests and pumping test field data developed in 100-K. As part of a modeling effort (SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*), the hydraulic conductivity data were evaluated to estimate representative values for Ringold Formation unit E and the Hanford formation. The K_s values recorded in monitoring wells completed within the 100-KR-4 OU range from a minimum of 0.0008 cm/s (2.3 ft/d) in

Monitoring well 199-K-194 to a maximum of 0.0512 cm/s (145 ft/d) at Monitoring well 199-K-37 and were estimated for the Ringold Formation unit E portion of the Ringold Formation. Horizontal saturated hydraulic conductivity values are unavailable for the RUM unit.

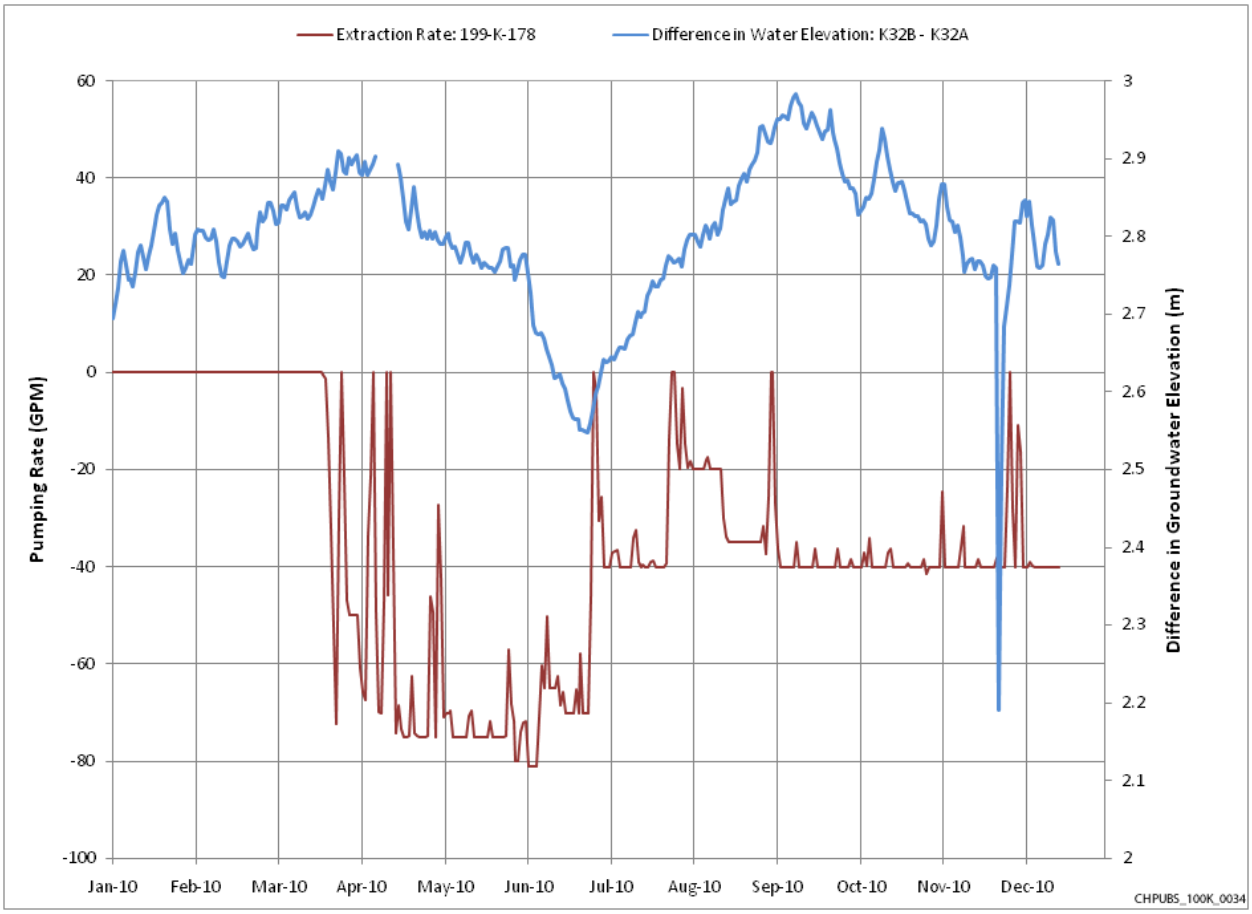
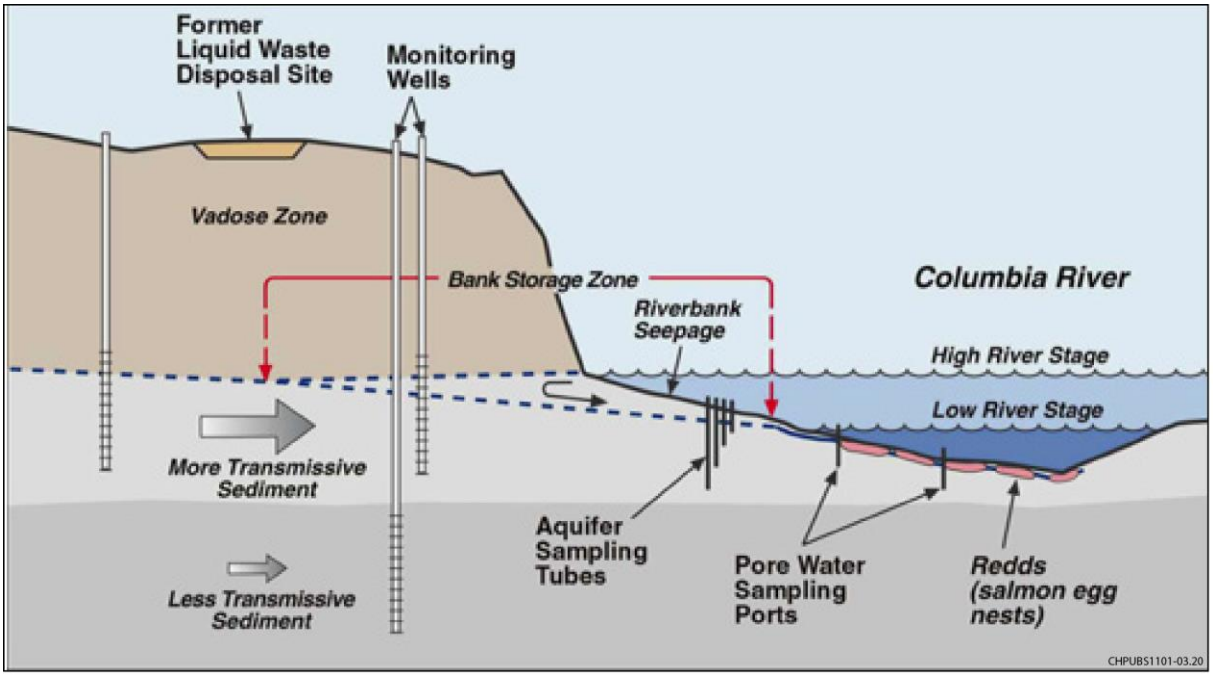


Figure 3-23. Difference in Daily Average Water Elevation Measured in the 199-K-32 Nested Well Pair (199-K32B Minus 199-K32A), with Extraction Rate at Well 199-K-178

3.7.3 Groundwater/Surface Water Interactions

Knowledge of groundwater and surface water interactions is essential to understanding the rate and magnitude of contaminants potentially entering the Columbia River. The zone of interaction is represented by the boundary between groundwater and river water below the river and near the shoreline. Groundwater discharge into the river environment occurs across the riparian zone as seeps or springs that release groundwater that flows across the riparian zone to the river and via direct subsurface discharge of groundwater into the river channel substrate. Section 4.5 discusses pore water, surface water, and sediment sampling results, and Figure 3-24 illustrates the zone of interaction and riverbank seepage.



Note: Modified from PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project*.

Figure 3-24. Illustration of Zone of Interaction and River Bank Seepage

Groundwater flow, especially near the river, is strongly influenced by river stage, which varies seasonally and is controlled by the upstream Priest Rapids Dam. The rise and fall of river stage create a dynamic zone of interaction between groundwater and river water, and influence flow patterns, transport rates, contaminant concentrations, and attenuation rates within the system (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project*).

Physical, chemical, and biological processes that potentially alter the characteristics of approaching groundwater occur within the zone of interaction. Data suggest that physical processes (e.g., changes in gradient and physical mixing of river water with groundwater) are the primary influences on contaminant concentrations and fluxes where groundwater discharges into the river. Chemical processes (e.g., precipitation reactions involving varying concentrations of calcium carbonate, pH, or reduction-oxidation conditions) may render contaminants less mobile as they adsorb to sediments or precipitate.

Riverbank seep discharges to the river, as shown in Figure 3-25, are visible as the river stage declines following seasonal periods of high water. Conversely, during high river stage, these seep areas are submerged as river water enters the riverbanks and forms either a layered system or a mixture during interaction with approaching groundwater. Data from the seeps and along the riverbank indicate that riverbank storage water composition varies dramatically from almost entirely river water during high river stage to primarily groundwater during low river stage (PNNL-13674).

Figure 3-25. Riverbank Releases to the Columbia River during Operations

Along the 100 Area shoreline, riverbank seepage composed of contaminated groundwater creates potential pathways for contaminants to enter the Columbia River (PNL-5289). Potential mixing of river water with groundwater may produce lower contaminant concentrations in the seep discharges than can be found in upgradient groundwater. These lower contaminant concentrations may be attributed to the bank storage phenomenon, where infiltrated river water stored in the riverbank during high river stage returns to the river via seeps during lower river stage (PNNL-17603, *Hanford Site Environmental Report for Calendar Year 2007*).

3.7.4 Aquifer Intercommunication

Aquifer intercommunication occurs when groundwater moves vertically between aquifers, such as the unconfined aquifer and lower transmissive zone of the RUM, or between the RUM transmissive zone and Ringold Formation unit B confined aquifer. There is the potential for movement of water between the Columbia River basalt confined aquifer system and Ringold Formation unit A confined water-bearing zones. For groundwater movement to occur between different aquifers, a difference in potentiometric head must exist and a permeable flow path must exist through which water can flow. The vertical hydraulic gradient between the shallow unconfined aquifer and the first confined aquifer unit within the underlying RUM has been shown to be upward at wells close to the Columbia River in 100-K (i.e., 199-K-192 and 199-K-32B). Intercommunication between aquifers can occur several ways:

- Natural vertical head differences between aquifers push water through the intervening aquitard
- Artificial differences in head push water through an intervening aquitard

- Erosional unconformities provide a pathway for groundwater to move between aquifers; for instance, where the RUM unit surface may have been eroded by Pleistocene floods, possibly exposing the upper transmissive zone sands to the unconfined aquifer
- Artificial pathways along poorly constructed wells or boreholes connecting aquifers

Erosional unconformities are considered the most likely significant mechanism for direct physical interconnection between the unconfined aquifer and confined aquifer zones within the upper RUM. The potential for pathways along poorly constructed wells also exists; however, older wells suspected of having poor construction have been decommissioned.

3.7.5 Groundwater Geochemistry

The groundwater geochemistry evaluation provides an understanding for water source, such as river versus inland and degree of mixing. The evaluation also identifies conditions within the aquifer that can be interpreted to infer flow paths and changing aquifer characteristics. Geochemistry also provides information for evaluating potential efficacy of treatment technologies.

Groundwater data was evaluated for the distribution of the major ions in various wells within 100-K. The major ions evaluated include calcium, chloride, sulfate, carbonate, sodium, potassium, and magnesium. The distribution of these ions was compared between wells with different geology, various levels of contamination, and the water of the Columbia River. To compare the concentrations of the ions, laboratory analytical results are collected. The concentrations are then converted from micrograms per liter or milligrams per liter to the milliequivalent per liter of the ion, based on its atomic weight.

As presented in Table 3-8, the milliequivalent per liter concentrations vary greatly across 100-K, but when the distribution is plotted as a stiff diagram, patterns develop. Stiff diagrams for various wells based on the data in Table 3-8, and the Columbia River, are presented in Figure 3-26. Groundwater monitoring wells were evaluated from near the KE and KW Reactors and the 116-K-2 Trench; however, not all wells had adequate data to conduct analysis. Several groups with a similar chemistry/ion pattern or distribution emerged during evaluation.

Two major groupings can be distinguished in 100-K. Monitoring wells within these groups tend to exhibit a similar ion distribution, or pattern, to some varying degrees. One is centered on the KW Reactor and the other around the 116-K-2 Trench. Around the KW Reactor, several monitoring wells show a similar pattern. These are identified on Figure 3-26 with rust coloring. Monitoring well 199-K-35 is presented as a representative stiff diagram. The distinguishing feature in the geochemistry is the lack of chloride in the groundwater from those wells, which still has a relatively moderate level of magnesium and sodium plus potassium. The other major pattern at 100-K is present near the 116-K-2 Trench. Groundwater in this area has slightly more chloride and sulfate than the first group, with less sodium and potassium. The resulting pattern appears to “pinch” towards the middle between the chloride and the sodium plus potassium axis. These wells are identified on Figure 3-26 in purple, with well 199-K-152 used as a representative diagram. The distribution pattern in this group of wells is closest to that of the Columbia River, which is also presented on Figure 3-26.

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Table 3-8. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-106A		199-K-107A		199-K-108A		199-K-11		199-K-110A		199-K-111A		199-K-132	
Sampling Date	6/13/2010		10/18/2009		6/13/2010		6/11/2010		4/15/2010		6/11/2010		6/15/2010	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	160	3.2	120	2.4	140	2.8	120	2.4	130	2.6	140	2.8	120	2.4
Ca	73,900	4	48,400	2	57,800	3	39,700	2	71,000	4	50,300	3	56,000	3
Cl	26,500	0.7	14,300	0.4	10,800	0.3	8,240	0.2	51,300	1.4	7,870	0.2	13,100	0.4
Mg	17,400	1	9,860	1	12,500	1	10,800	1	11,300	1	11,700	1	6,450	1
pH	7.64		7.75		7.72		7.91		7.52		7.91		7.5	
K	7,790	0.2	5,040	0.1	6,010	0.2	5,210	0.1	3,830	0.1	5,960	0.2	3,000	0.1
Na	23,000	1.0	15,500	0.7	21,300	0.9	14,400	0.6	7,600	0.3	14,000	0.6	15,500	0.7
SO_4	40,700	1	35,700	1	36,200	1	37,700	1	15,900	0	37,000	1	33,600	1
Well ID	199-K-152		199-K-157		199-K-18		199-K-182		199-K-20		199-K-22		199-K-31	
Sampling Date	6/22/2010		3/8/2010		6/11/2010		6/22/2010		6/16/2010		6/11/2010		6/11/2010	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	94	1.9	110	2.2	63	1.3	91	1.8	91	1.8	91	1.8	120	2.4
Ca	35,600	2	67,400	3.4	71,100	3.5	39,600	2	42,200	2	60,500	3	46,000	2
Cl	6,530	0.2	16,200	0.5	14,000	0.4	11,200	0.3	17,500	0.5	20,400	1	15,000	0.4
Mg	10,400	1	10,500	0.9	11,700	1.0	12,300	1	9,360	1	10,400	1	10,600	1
pH	8.03		7.93		8.3		8.03		7.67		8.06		7.71	
K	4280	0.1	4,800	0.1	4,180	0.1	4,390	0.1	4,330	0.1	2,770	0.1	5,220	0.1
Na	9,600	0.4	15,500	0.7	4,680	0.2	10,500	0.5	7,620	0.3	8,470	0.4	15,400	0.7
SO_4	36,600	1	80,100	1.7	94,800	2.0	45,300	1	37,700	1	74,500	2	37,000	1

Table 3-8. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-135		199-K-142		199-K-34		199-K-37		699-73-61		199-K-32B		199-K-192	
Sampling Date	10/18/2009		6/11/2010		6/30/2010		6/24/2010		6/18/2010		6/24/2010		6/24/2010	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	490	9.8	94	1.9	140	2.8	97	1.9	110	2.2	134	2.7	146	2.9
Ca	225,000	11.2	28,000	1.4	59,600	3	38,800	2	34,100	2	25,500	1	25,500	1
Cl	18,900	0.5	6,280	0.2	18,200	0.5	10,500	0.3	6,620	0.2	4,590	0.1	3,900	0.1
Mg	26,800	2.2	5,590	0.5	10,700	1	8,570	1	9,480	1	14,500	1	18,000	1
pH	7.05		8.16		7.72		8.25		8.13					
K	5,650	0.1	3,710	0.1	2,180	0.1	3,700	0.1	4,930	0.1	4,270	0.1	5,120	0.1
Na	10,200	0.4	7,250	0.3	17,300	0.8	9,370	0.4	15,000	0.7	29,700	1.3	25,800	1.1
SO_4	11,800	0.2	10,400	0.2	20,000	0	42,100	1	34,900	1	38,600	1	38,600	1
Well ID	199-K-35		199-K-19		199-K-21		199-K-23		199-K-29		199-K-30		Columbia River Below Priest Rapids Dam	
Sampling Date	3/19/1993		6/15/1993		6/25/1993		10/10/2011		12/2/2010		12/2/2010		5/1/1994	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	120	2.4	86	1.7	68	1.4	210	4.2	110	2.2	120	2.4	52	1.0
Ca	34,800	2	45,500	2	39,700	2	67,900	3	50,200	3	50,400	3	18300	1
Cl	6,200	0.2	6,200	0.2	5,900	0.2	26,800	0.8	20,500	0.6	23,500	0.7	1300	0.0
Mg	9,480	1	6,460	1	7,830	1	17,300	1	11,500	1	9,860	1	4470	0
pH			7.60		7.90		7.85		7.77		7.87			
K	5,040	0.1	3,120	0.1	1,540	0.0	15,900	0.4	4,830	0.1	4,820	0.1	645	0.0
Na	13,300	0.6	5,370	0.2	3,250	0.1	25,200	1.1	9,360	0.4	11,000	0.5	2470	0.1
SO_4	22,000	0	53,400	1	53,700	1	33,600	1	19,100	0	28,400	1	9900	0

Table 3-8. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-184		199-K-186		199-K-189		199-K-200	
Sampling Date	7/20/2011		5/11/2011		10/10/2011		7/19/2011	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	110	2.2	170	3.4	100	2.0	98	2.0
Ca	41,600	2	53,400	3	49,100	2	63,200	3
Cl	11,300	0.3	15,000	0.4	38,200	1.1	20,700	0.6
Mg	11,500	1	11,000	1	11,600	1	11,000	1
pH	8.15		7.38		7.86		7.73	
K	5,930	0.2	4,720	0.1	6,590	0.2	2,980	0.1
Na	15,200	0.7	7,340	0.3	10,900	0.5	10,700	0.5
SO_4	32,800	1	11,800	0	23,500	0	74,700	2
Well ID	199-K-36	Time Series						
Sampling Date	3/19/1993		12/4/1996		10/23/2003		6/10/2010	
Concentration Units	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L
Alkalinity	127	2.5	140	2.8	120	2.4	130	2.6
Ca	45,000	2	136,000	7	47,400	2	49,200	2
Cl	3,900	0.1	147,000	4.1	27,500	0.8	24,400	0.7
Mg	11,400	1	34,100	3	12,300	1	12,400	1
K	5,180	0.1	7,150	0.2	6,850	0.2	5,810	0.1
Na	13,200	0.6	21,600	0.9	31,300	1.4	21,300	0.9
SO_4	52,000	1	160,000	3	47,800	1	53,800	1

Table 3-8. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-107A		Time Series											
Sampling Date	4/28/1999		10/3/2005		10/12/2006		10/19/2007		4/15/2009		8/12/2009		12/3/2010	
Concentration Units	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L
Alkalinity	126	2.5	115	2.3	110	2.2	120	2.4	120	2.4	120	2.4	120	2.4
Ca	44800	2	44400	2	42000	2	46900	2	45100	2	46200	2	49200	2
Cl	8030	0.2	7600	0.2	6680	0.2	10200	0.3	11900	0.3	11500	0.3	19300	0.5
Mg	9760	1	8910	1	9240	1	8970	1	9540	1	8780	1	10600	1
K	6490	0.2	4850	0.1	4670	0.1	5290	0.1	4970	0.1	4390	0.1	4590	0.1
Na	19100	0.8	16000	0.7	17300	0.8	15600	0.7	16400	0.7	13900	0.6	17000	0.7
SO_4	39600	1	32500	1	33900	1	37200	1	35200	1	35500	1	40500	1
Well ID	199-K-108A		Time Series											
Sampling Date	4/28/1999		10/12/2006		4/1/2008		10/6/2008		4/15/2009		10/22/2009		12/8/2010	
Concentration Units	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L
Alkalinity	162	3.2	110	2.2	160	3.2	150	3.0	170	3.4	140	2.8	140	2.8
Ca	64200	3	61300	3	69700	3	67800	3	63900	3	62800	3	53800	3
Cl	9880	0.3	26000	0.7	20700	0.6	22900	0.6	17200	0.5	8070	0.2	10800	0.3
Mg	14500	1	13900	1	13800	1	13300	1	13700	1	12800	1	11900	1
K	7650	0.2	4520	0.1	6090	0.2	4530	0.1	6010	0.2	6010	0.2	6080	0.2
Na	24500	1.1	16600	0.7	23200	1.0	25800	1.1	25500	1.1	22000	1.0	21900	1.0
SO_4	60600	1	30300	1	70700	1	33700	1	37100	1	54100	1	35400	1

Note: Alkalinity = mg/L as $CaCO_3$.

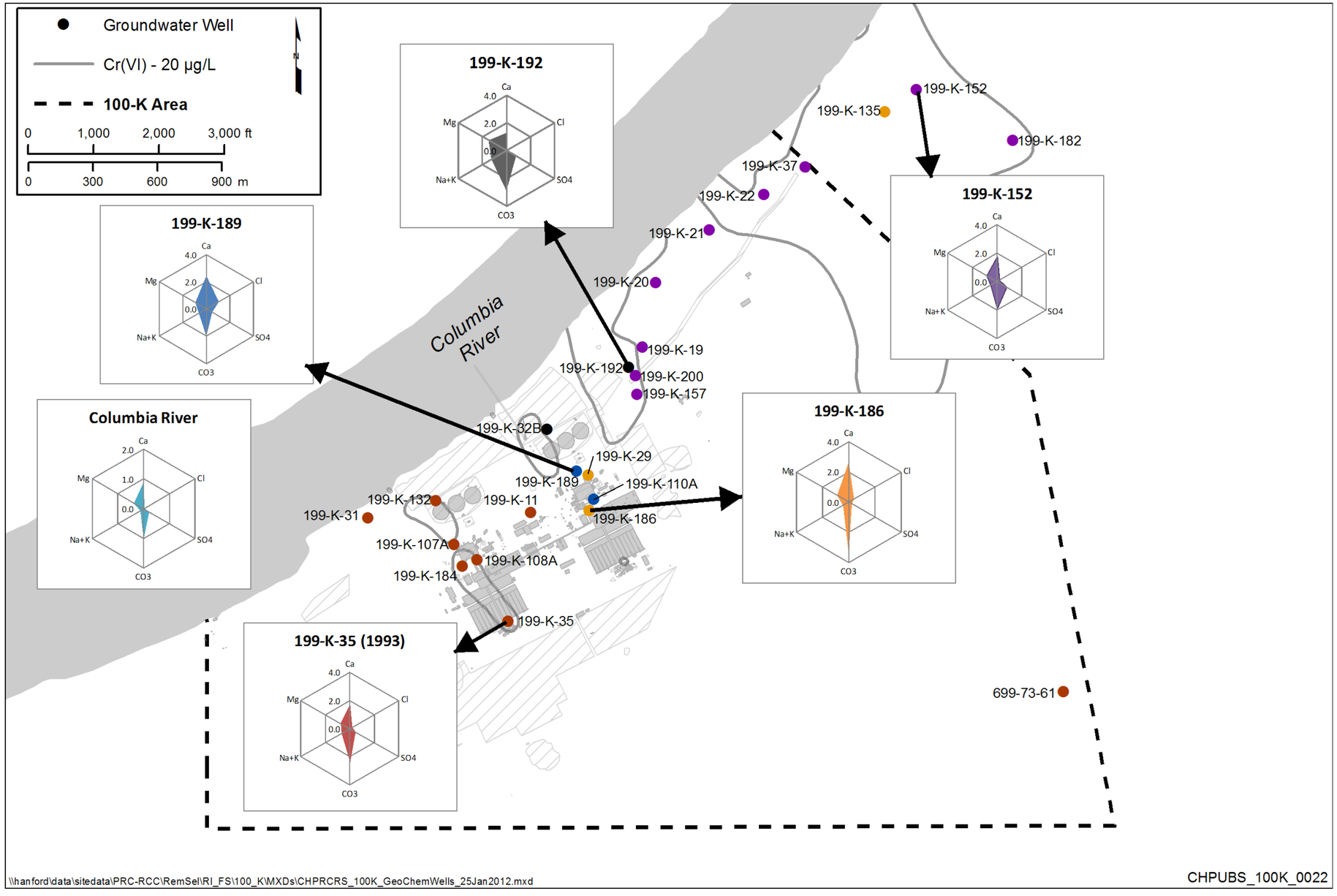

Figure 3-26. Monitoring Wells and Major Ion Chemistry in the 100-KR-4 OU

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Three wells have a more distinct and unusual pattern: wells 199-K-186, 199-K-29, and 199-K-135. Monitoring wells 199-K-186 and 199-K-29 are located near each other and the KW Reactor, upgradient from the Cr(VI) plume. These three wells are shown in Figure 3-26 in orange, with well 199-K-186 presented as a representative diagram. Well 199-K-29 is located on the downgradient side of the KE Reactor, and well 199-K-186 is on the opposite side of the reactor. These two wells have a high level of calcium and carbonate, with very little sodium plus potassium or sulfate and no other apparent similarities. Monitoring well 199-K-135 is located to the north of the 116-K-2 Trench. The geochemistry of well 199-K-135 has been altered significantly by the injection of calcium polysulfate during a remediation test conducted in 2005 (DOE/RL-2006-17). The groundwater signature is very similar to well 199-K-186; however, the ratio of calcium to the other ions is exaggerated.

Two of the wells in 100-K are completed in the first water-bearing unit of the RUM (wells 199-K-192 and 199-K-32B), and both had adequate data for geochemistry analysis. The geochemical signature for both wells is similar, which is to be expected for wells screened within the same geologic unit. The stiff diagram for well 199-K-192 is considered as representative of both these wells and is presented in Figure 3-26. Unlike other wells that are screened in the RUM, low levels of Cr(VI) have been identified in well 199-K-32B. As shown in cross section H-H' (Figure C-H), the water-bearing unit encountered in well 199-K-32B, if this same unit extends to the northeast, would intersect the same groundwater as identified in well 199-K-162. A connection between the sand layer identified and screened in wells 199-K-162 (located in a dip in the RUM) and 199-K-32B is a possible explanation for the low levels of Cr(VI) identified in well 199-K-32B.

Monitoring wells 199-K-110A and 199-K-189 also show a similar chemistry signature to each other, but one that is different from the other wells at 100-K (shown in dark blue in Figure 3-26). The chloride component is greater in these two wells than the other wells, with low levels of sulfate and sodium plus potassium. Within 100-K, there are several other wells where the chemistry signature could be classified with one group or another, but the pattern is not as clearly defined.

To evaluate the potential effect of contamination or remediation activities on the geochemical signature of groundwater, three groundwater monitoring wells were evaluated over a time series: wells 199-K-36, 199-K-107A, and 199-K-108A. Monitoring wells 199-K-108A and 199-K-107A are located near each other and the KW Reactor. The groundwater geochemistry signature of well 199-K-107A from 1999 through 2009 shows little change and is similar to the signature of well 699-73-61. The Cr(VI) concentrations in well 199-K-107A during that period range from about 600 µg/L in 1999 to about 50 µg/L in August 2009; however, well 699-73-61, which has a similar pattern of major ions, has Cr(VI) concentration levels below detection. The Cr(VI) concentrations in monitoring well 199-K-108A fluctuate between levels from up to 250 µg/L to below detection. The geochemical signature, however, is not consistent during any of these time periods. The pattern of ion distribution in well 199-K-36 is also lacking a distinctive pattern, consistent with the other two wells. There is no apparent correlation to a particular distribution of ions and the level of contamination.

3.8 Artificial Water Systems

Artificial water systems at 100-K are the river water intake and filtration system, fire suppression lines, and the groundwater P&T system. The P&T systems are currently the only systems that affect the groundwater system. Since 1997, P&T system extraction and injection wells have contributed to localized groundwater depression and groundwater mounding, respectively, at 100-K. As a result, the groundwater flow regime in 100-K has varied significantly as extraction and injection wells were turned off and on, in addition to the seasonal variability.

3.9 Demography and Land Use

3.9.1 Demographics

A detailed discussion of the population surrounding the Hanford Site, including adjacent counties and cities, is presented in the NEPA Characterization Report (PNNL-6415).

3.9.2 Land Use

In June 2000, the HRNM was established within the boundaries of the Hanford Site. Clinton, 2000, *Proclamation 7319—Establishment of the Hanford Reach National Monument*, mandates preservation of the natural and cultural resources within the HRNM and specifically included the possibility of adding lands to the HRNM as they are remediated. In 2015, the Manhattan Project National Historical Park was officially established, and the B Reactor became a national park. DOE's reasonably anticipated future use of 100-K is conservation and preservation. As described in DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, and DOE/EIS-0222-SA-01, *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, the area is reserved for the management, protection, and preservation of archaeological, cultural, ecological, and natural resources. Limited public access would be consistent with resource preservation. EPA and Ecology believe that other uses, including residential use, are reasonably anticipated future land use for these areas.

3.9.3 Groundwater Use

Currently, ICs restrict 100-K groundwater use to limited research purposes and for monitoring and treatment, as approved by EPA. No water supply wells are located in 100-K.

3.10 Ecology

The Hanford Site is located in the mid-latitude, semiarid climate of the Columbia Plateau with a free-flowing section of the Columbia River passing through it, supporting a rich diversity of plant and animal species. Species diversity is maintained through the long-standing management practices of DOE, which leave most of the land area relatively undisturbed. Only about 6% of Hanford Site land has been disturbed or is actively used by DOE for waste disposal and storage. The native terrestrial and aquatic ecological resources found on the Hanford Site are becoming increasingly rare throughout the Columbia Basin region. Preservation of these areas is important as agricultural, industrial, and residential development continues.

Knowledge of the ecological setting is a compilation of ecological data obtained from multiple biological inventories of plant and wildlife species and ecological characterizations from the following reports:

- NEPA Characterization Report (PNNL-6415) and PNNL-13688, *Vascular Plants of the Hanford Site*, provide detailed summaries of the ecology, biological resources, and hydrology for the entire Hanford Site, with selected information grouped by major operational areas.
- DOI, 1994, *Hanford Reach of the Columbia River: Comprehensive River Conservation Study and Environmental Impact Statement – Final*, provides general information on the riparian and aquatic environments found within the Hanford Reach.
- RCBRA Literature Review (PNNL-SA-41467) provides detailed characterization data for the 100 and 300 Areas, including comprehensive lists of plant and wildlife species occurring in or near the study area.

DOE has been conducting ecological characterization on the Hanford Site since the early 1970s, and environmental reports are produced annually (e.g., DOE/RL-2014-52, *Hanford Site Environmental Report for Calendar Year 2014*). Other ecological reports pertaining to the River Corridor include The Nature Conservancy surveys (Hall, 1998, *Biodiversity Inventory and Analysis of the Hanford Site: 1997 Annual Report*; Pabst, 1995, *Biodiversity Inventory and Analysis of the Hanford Site: 1994 Annual Report*; Soll, et al., 1999, *Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999*; Soll and Soper, 1996, *Biodiversity Inventory and Analysis of the Hanford Site: 1995 Annual Report*) and PNNL-13688.

3.10.1 River Corridor Flora

Historically, much of the River Corridor upland zone was a native shrub-steppe habitat. The most prevalent shrub was big sagebrush (*Artemisia tridentata*), with smaller quantities of rabbitbrush (*Chrysothamnus* sp. and *Ericameria* sp.), and an understory dominated by Sandberg's bluegrass (*Poa secunda*, formerly *sandbergii*). During the Euro-American settlement of the area, a large portion of the reactor area was disturbed by farming. Construction activities for the reactor projects further disturbed the vegetation and soils in the area. These two major changes in use resulted in changes to the native plant community, creating areas that have been kept free of vegetation and areas that have partially recovered to various levels of plant succession (RCBRA [DOE/RL-2007-21, Volume I]).

The vegetation in the River Corridor upland zone operating areas is typically sparse and consists of early successional species such as cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*), tumblemustard (*Sisymbrium altissimum*), and bur ragweed (*Ambrosia acanthicarpa*). Most operating areas, including waste sites, were historically maintained free of vegetation for contamination control, fire prevention, and maintenance purposes. Large areas of cheatgrass and exotic annual species present in the 100-D, 100-F, White Bluffs, and Hanford townsite areas that resulted from pre-Hanford farming and homesteading are described as "abandoned old fields." More detailed descriptions of vegetation by reactor area can be found in the RCBRA Literature Review (PNNL-SA-41467). Distribution of vegetation types before the 2000 wildfire is presented in Figure 3-27. The fire did not reach the area within the River Corridor.

Vegetation found in riparian zones reflects the transition between aquatic and upland ecosystems. Changes to the composition of shoreline vegetation over time have been influenced by moderation in the river elevation changes controlled by the Priest Rapids Dam. Because of steepness of the shoreline, the transition from riparian to upland vegetation is abrupt. Dominant vegetation within the riparian zone includes mulberry (*Morus alba*), willow (*Salix* sp.), Siberian elm (*Ulmus pumila*), northern wormwood (*Artemisia campestris*), sweet clover (*Melilotus alba* or *M. officinalis*), and reed canarygrass (*Phalaris arundinacea*) (RCBRA [DOE/RL-2007-21, Volume I]).

Vegetation in the nearshore river zone consists of macrophytes and periphyton. Macrophytes are sparse in the Columbia River because of strong currents, rocky bottom, and frequently fluctuating water levels. Where macrophytes are found, they commonly include duckweed (*Lemna* sp.) and the native rooted pondweeds *(Potamogeton* spp. and *Elodea canadensis*). Macrophytes provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Since the late 1980s, Eurasian milfoil (*Myriophyllum spicatum*), an introduced macrophyte, has increased to nuisance levels and may encourage increased sedimentation of fine particulate matter. Periphyton communities develop on suitable solid substrate wherever there is sufficient light for photosynthesis and adequate currents to prevent sediment from covering the colonies.

3.10.2 River Corridor Fauna

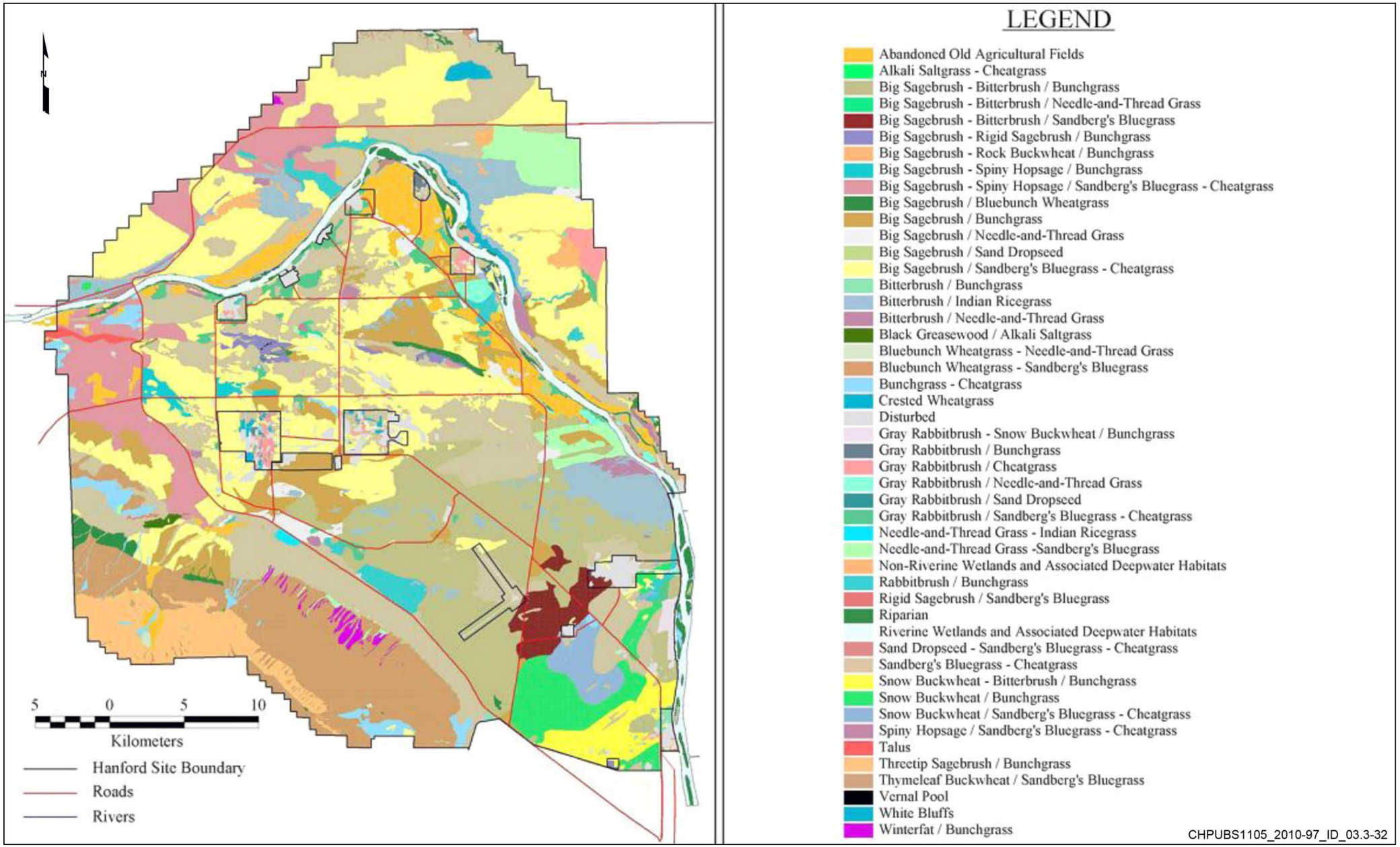
Wildlife use of habitat overlaps considerably between the riparian and upland zones. Use of the riparian zone is likely higher than that of the upland zone associated with the CERCLA waste sites because of its

proximity to the Columbia River. River access results in greater species diversity and the presence of higher-density and higher-stature vegetation that remains productive over a longer period (RCBRA [DOE/RL-2007-21, Volume I]). Species lists have been compiled for the major classes of vertebrates that have been observed on the Hanford Site or within the Hanford Reach of the Columbia River and include 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and more than 45 species of fish (NEPA Characterization Report [PNNL-6415]). As far as invertebrates are concerned, a total of 1,509 species-level identifications have been completed, and the collection of 40,000 specimens has resulted in the identification of 43 new taxa and 142 new findings in the state of Washington (*Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999* [Soll et al., 1999]). The high diversity of insect species on the Hanford Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat.

Terrestrial mammals of the upland environment that might be found in and adjacent to the 100 and 300 Areas include the mule deer (*Odocoileus hemionus*), badger (*Taxidea taxus*), coyote (*Canis latrans*), Great Basin pocket mouse (*Perognathus parvus*), northern pocket gopher (*Thomomys talpoides*), black-tailed jackrabbit (*Lepus californicus*), and cottontail rabbit (*Sylvilagus nuttalii*) (WHC-EP-0620, *100 Areas CERCLA Ecological Investigations*). The abundance of these species and the occurrence of others vary according to the soil type and vegetative community. While other large mammals, such as elk (*Cervus elaphus*), are infrequently observed in the 100 and 300 Areas upland reactor areas, the number of individual large mammals present per unit area may increase as habitat quality and shrub cover improve through natural recovery and waste site restoration. Because most of the site is dominated by shrub-steppe, the Hanford mammal community is representative of upland species that occur in shrub-steppe habitats. Habitat generalists, such as the ubiquitous coyote (*Canis latrans*), mule deer (*Odocoileus hemionus*), deer mouse (*Peromyscus maniculatis*), and Great Basin pocket mouse (*P. parvus*), can be found in many different habitats (DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*).

Nine bat species were identified at the Hanford Site during The Nature Conservancy surveys in 1997 and 1998, and an additional eight species were listed as potentially present (Soll et al., 1999). Eleven bat roosts have been identified; however, none of the roosts have been identified within the 100-N Area (HNF-56359, *Hanford Site Summer Bat Monitoring Report for Calendar Year 2013*). Roosts along the River Corridor, including maternity colonies of Yuma myotis (*Myotis yumanensis*) and pallid bats (*Antrozous pallidus*), were at the 100-F and 100-D/H Areas (WCH-512, *2011 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*).

Several species of birds present in the upland zone rely on structures such as buildings, fences, and utility poles for some of their habitat needs. Raptors, such as red-tailed hawks (*Buteo jamaicensis*), are present and frequently nest on buildings, utility poles and towers, and trees along the river. Nonvegetated areas provide nesting habitat for nighthawks (*Chordeiles minor*) and killdeer (*Charadrius vociferus*). Canada geese (*Branta canadensis*) use open cheatgrass areas for winter grazing. Following restoration, improvements in shrub coverage will provide important habitat for native shrub-steppe bird species such as the horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), savannah sparrow (*Passerculus sandwichensis*), loggerhead shrike (*Lanius ludovicianus*), and possibly sage sparrow (*Amphispiza belli*). Raptors will continue to be present, but as the shrubs develop and the open grassy areas shrink in size, wintering geese will likely avoid the area, preferring the cheatgrass areas associated with nearby abandoned farm fields and orchards. A list of bird species observed in the 100 Area is available in *100 Areas CERCLA Ecological Investigations* [WHC-EP-0620]. A catalogue of Hanford Site avian species is in the NEPA Characterization Report (PNNL-6415).



Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*.

Figure 3-27. Distribution of Vegetation Types and Area before the 2000 Fire

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Research efforts have assessed winter bird populations in cottonwood/willow (*Populus*/*Salix*) communities of the Columbia River shoreline (Rickard, 1964, "A Vagrant Occurrence of the Black Phoebe in Southeastern Washington"; Rickard and Rickard, 1972, "Comparison of Winter Bird Populations After a Decade"), quantified shorebird response to water fluctuations in the Columbia River nearshore environment (Books, 1985, "Avian Interactions with Mid-Columbia River Water Level Fluctuations"), and evaluated habitat selection and use by spring migrant passerines (Duberstein, 1997, "Riparian Stopover Habitat Selection by Spring Transient Landbirds of South-Central Washington"). The information gathered during these research efforts has been used to document the status and ecology of the Hanford Site's avian wildlife.

Common reptiles found in upland environments at the Hanford Site include the rattlesnake (*Crotalus viridis*), gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and side blotch lizard (*Uta stansburiana*) (PNL-8942, *Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern*; WHC-EP-0601, *A Synthesis of Ecological Data from the 100 Areas of the Hanford Site*). A variety of snakes common to the upland areas may also use the riparian habitat. Other reptiles that may be found in the riparian zone include the western terrestrial garter snake (*Thamnophis sirtalis*) and the painted turtle (*Chrysemys picta*) (Hallock, 1998, *Herpetofauna of the Hanford Nuclear Reservation, Grant, Franklin and Benton Counties, Washington*; PNNL-14516, *Synthesis of Ecological Data Collected in the Riparian and Riverine Environments of the Hanford Reach*). Amphibians in the riparian and near-shore environments of the Hanford Reach include mostly Woodhouse's toads (*Bufo woodhousii*), but bullfrogs (*Rana catesbeiana*) and Great Basin spadefoot toads (*Scaphiopus intermontanus*) have been documented (HNF-56676, *Hanford Site Anuran Monitoring Report for Calendar Year 2013*).

The dominant ground-dwelling invertebrate species in the upland environment are harvester ants (*Pogonomyrmex owyheei*) and darkling beetles (family *Tenebrionidae*). Harvester ants can exist on vegetated and nonvegetated soils and have been documented on waste sites (PNL-2774, *Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport*). Darkling beetles, however, rely on vegetative matter in the soil during their larval stage and, therefore, are not expected to occur in areas void of vegetation (PNL-2465, *Darkling Beetle Populations (*Tenebrionidae*) of the Hanford Site in Southcentral Washington*). Areas that were not used as waste sites or have not been affected by Hanford Site operations likely have less soil disturbance and may support a more robust and diverse community of soil-dwelling fauna than previously disturbed or remediated sites.

More than 45 species of fish have been identified in the Hanford Reach of the Columbia River. Of these species, Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), Coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Other fish of importance to sport anglers are the native mountain whitefish (*Prosopium williamsoni*) and white sturgeon (*Acipenser transmontanus*). Introduced species like smallmouth bass (*Micropterus dolomieui*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizostedion vitreum*) are also popular. Other large fish populations include introduced common carp (*Cyprinus carpio*) and native species such as redside shiner (*Richardsonius balteatus*) and largescale suckers (*Catostomus macrocheilus*). Smaller fish, such as sculpin (*Cottus* sp.), are associated with shoreline habitats and have small home ranges (RCBRA [DOE/RL-2007-21, Volume I]).

3.10.3 Threatened and Endangered Species

Several species are recognized by state or federal agencies as having special status based on the risk of extinction. Threatened and endangered species are considered at risk and, as such, these species were not identified for sacrificial sampling and subsequent analyses for the risk assessment effort. Data for selected surrogate species were required for contaminant or biological characterization based on the guild in which

the special status species were identified (DOE/RL-2004-37, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA*, Table 5-1). The list of state and federally listed species of concern, including candidate, sensitive, and monitored species thought or known to occur on the Hanford Site, is updated annually in the Hanford Site Environmental Report (e.g., DOE/RL-2017-24).

Two species of federal-listed endangered fish—the Upper Columbia River spring-run Chinook salmon and the steelhead—occur in the Hanford Reach. The spring-run Chinook salmon do not spawn in the Hanford Reach, but use it as a migration corridor. The fall-run Chinook salmon do spawn in the Hanford Reach, but in 2016, redds were not observed in areas adjacent to 100-K (DOE-RL/2017-24). Steelhead spawning has been observed in the Hanford Reach. However, redds have not been observed in areas adjacent to 100-K (HNF-59116). The bull trout is listed as threatened by the National Marine Fisheries Service, but it is not considered a resident species and is rarely observed in the Hanford Reach (DOE/RL-2005-40, *100-B/C Pilot Project Risk Assessment Report*).

DOE employs the following protective measures for endangered salmon and steelhead:

- Water diversions meet state screening criteria or appropriate administrative controls, including discharges that meet National Pollutant Discharge Elimination System (NPDES) permit requirements. Removal of native riparian or emergent vegetation is minimized. Where possible, construction projects do not simplify shoreline structures, and final construction produces banks at a 3:1 slope.

- Silt-loaded surface runoff is minimized along the shoreline, and disruptive activities in the river or on the shoreline are avoided from April to November.

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. DOE continues to protect nest and roost sites on the Hanford Site under DOE/RL-94-150, Rev. 0, *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (hereinafter called the Bald Eagle Management Plan). This plan was revised in 2009 (DOE/RL-94-150, Rev. 1) to account for the de-listing of the bald eagle. Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (2,600 to 2,400 ft). The Washington State Department of Fish and Wildlife requires protection of roosting trees for bald eagle habitat and foraging areas (WAC 232-12-292, "Permanent Regulations," "Bald Eagle Protection Rules").

Species identified by federal or state agencies as threatened or endangered are updated annually in the Hanford Site Environmental Report (e.g., DOE/RL-2017-24). Tables 3-9 and 3-10 provide those flora and fauna species listed by the State of Washington as threatened or endangered, including candidate, sensitive, and monitored species thought or known to occur on the Hanford Site. In April 2013, two plant species, Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tuplashensis*), were listed as threatened species under the federal *Endangered Species Act of 1973* (78 FR 23984, "Endangered and Threatened Wildlife and Plants; Threatened Status for *Eriogonum codium* (Umtanum Desert Buckwheat) and *Physaria douglasii* subsp. *tuplashensis* (White Bluffs Bladderpod) and Designation of Critical Habitat") (Table 3-9). The rule was reaffirmed late in 2013 and was effective as of December 20, 2013 (78 FR 23984). Neither of these two plant species is present within the 100-KR-1 or 100-KR-2 OUs, as discussed in Section 7.2.1. The Umtanum desert buckwheat and White Bluffs bladderpod are not located in riparian areas because both species are found in upland habitats (WNHP and WDNR, 2011, *Field Guide to the Rare Plants of Washington*). No other plants or animals known to occur on the Hanford Site are currently on the federal list of endangered and threatened species, but one mammal species (Washington ground squirrel) is currently a candidate for federal listing (Table 3-10).

Table 3-9. Flora Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Upland			
Minuartia pusilla var. *pusilla*	Annual sandwort	ST	--
Oenothera caespitosa ssp. *caespitosa*	caespitose evening-primrose	SS	--
Orobanche californica	California broomrape	SE	--
Astragalus columbianus	Columbia milk-vetch	SS	--
Nicotiana attenuata	coyote tobacco	SS	--
Cuscuta denticulata	desert dodder	ST	--
Camissonia pygmaea	dwarf evening-primrose	SS	--
Astragalus geyeri	Geyer's milk-vetch	ST	--
Cryptantha leucophaea	gray cryptantha	SS	--
Aliciella leptomeria	Great Basin gilia	ST	--
Corispermum villosum	Hairy bugseed	SS	--
Pediocactus nigrispinus (P. simpsonii var. *robustior)*	Hedgehog cactus	SS	--
Lomatium tuberosum	Hoover's desert parsley	SS	--
Loeflingia squarrosa var. *squarrosa*	loeflingia	ST	--
Cryptantha scoparia	miner's candle	SS	--
Erigeron piperianus	Piper's daisy	SS	--
Cistanthe rosea	rosy pussypaws	ST	--
Calochortus macrocarpus	sagebrush-mariposa lily	SS	--
Camissonia minor	small-flower evening primrose	SS	--
Cryptantha spiculifera	Snake River cryptantha	SS	--
Ribes cereum	squaw currant	SE	--
Mimulus suksdorfii	Suksdorf's monkey-flower	SS	--
Eremogone (Arenaria) franklinii var. *thompsonii*	Thompson's sandwort	SS	--
Eriogonum codium	Umtanum desert buckwheat	SE	FT
Physaria (Lesquerella) douglasii ssp. *tuplashensis*	White Bluffs bladderpod	SE	FT

Table 3-9. Flora Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Eatonella nivea	white eatonella	ST	--
Riparian			
Lipocarpha aristulata	awned halfchaff sedge	ST	--
Eleocharis rostellata	beaked spike-rush	SS	--
Hypericum majus	Canadian St. John's-wort	SS	--
Ammannia robusta	grand redstem	ST	--
Rotala ramosior	lowland toothcup	ST	--
Rorippa columbiae	Columbia yellowcress	ST	--

References: DOE/RL-2017-24, Hanford Site Environmental Report for Calendar Year 2016.

WNHP, 2017, "2017 Endangered, Threatened, and Sensitive Vascular Plant List" by the Washington Natural Heritage Program."

FC = federal candidate
FT = federal threatened
SC = state candidate
SE = state endangered
SM = state monitored
SS = state sensitive
ST = state threatened

Table 3-10. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Birds			
Pelecanus erythrorhynchos	American white pelican	ST	--
Haliaeetus leucocephalus	bald eagle		--
Athene cunicularia	burrowing owl	SC	--
Aechmophorus clarkii	Clark's grebe	SC	--
Gavia immer	common loon	SS	--
Buteo regalis	ferruginous hawk	ST	--
Otus flammeolus	flammulated owl	SC	--
Aquila chrysaetos	golden eagle	SC	--
Centrocercus urophasianus	greater sage grouse	ST	--

Table 3-10. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Melanerpes lewis	Lewis' woodpecker	SC	--
Lanius ludovicianus	loggerhead shrike	SC	--
Accipiter gentilis	northern goshawk	SC	--
Falco peregrinus	peregrine falcon		--
Amphispiza belli	sagebrush sparrow	SC	--
Oreoscoptes montanus	sage thrasher	SC	--
Grus canadensis	sandhill crane	SE	--
Aechmophorus occidenalis	western grebe	SC	--
Mammals			
Lepus californicus	black-tailed jackrabbit	SC	--
Sorex merriami	Merriam's shrew	SC	--
Urocitellus townsendii (formerly *Spermophilus townsendii*)	Townsend's ground squirrel	SC	--
Urocitellus washingtoni (formerly *Spermophilus washingtoni*)	Washington ground squirrel	SC	--
Lepus townsendii	white-tailed jackrabbit	SC	--
Reptiles/Amphibians			
Sceloporus graciosus	northern sagebrush lizard	SC	--
Masticophis taeniatus	striped whipsnake	SC	--
Bufo boreas	Western toad	SC	--
Insects			
Gomphus lynnae	Columbia clubtail (Dragonfly)	SC	--
Cicindela columbica	Columbia River tiger beetle	SC	--
Boloria selene atrocostalis	Silver-bordered fritillary	SC	--
Aquatics			
Salvelinus confluentus	bull trout	SC	FT
Anodonta californiensis	California floater (mussel)	SC	--
Oncorhynchus tshawytscha	chinook salmon	SC	FE
Rhinichthys falcatus	leopard dace	SC	--
Catostormus platyrhynchus	mountain sucker	SC	--

Table 3-10. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Lampetra tridentata	Pacific lamprey	SM	--
Oncorhynchus mykiss	Steelhead (Upper Columbia)	SC	FT
Lampetra ayresi	river lamprey	SC	--
Fisherola nuttalli	Giant Columbia River limpet	SC	--

References: DOE/RL-2017-24, *Hanford Site Environmental Report for Calendar Year 2016*.
WDFW, 2018, "Species of Concern List" Online database, https://wdfw.wa.gov/conservation/endangered/.

FC = federal candidate
FE = federal endangered
FT = federal threatened
SC = state candidate
SE = state endangered
SM = state monitored
SS = state sensitive
ST = state threatened

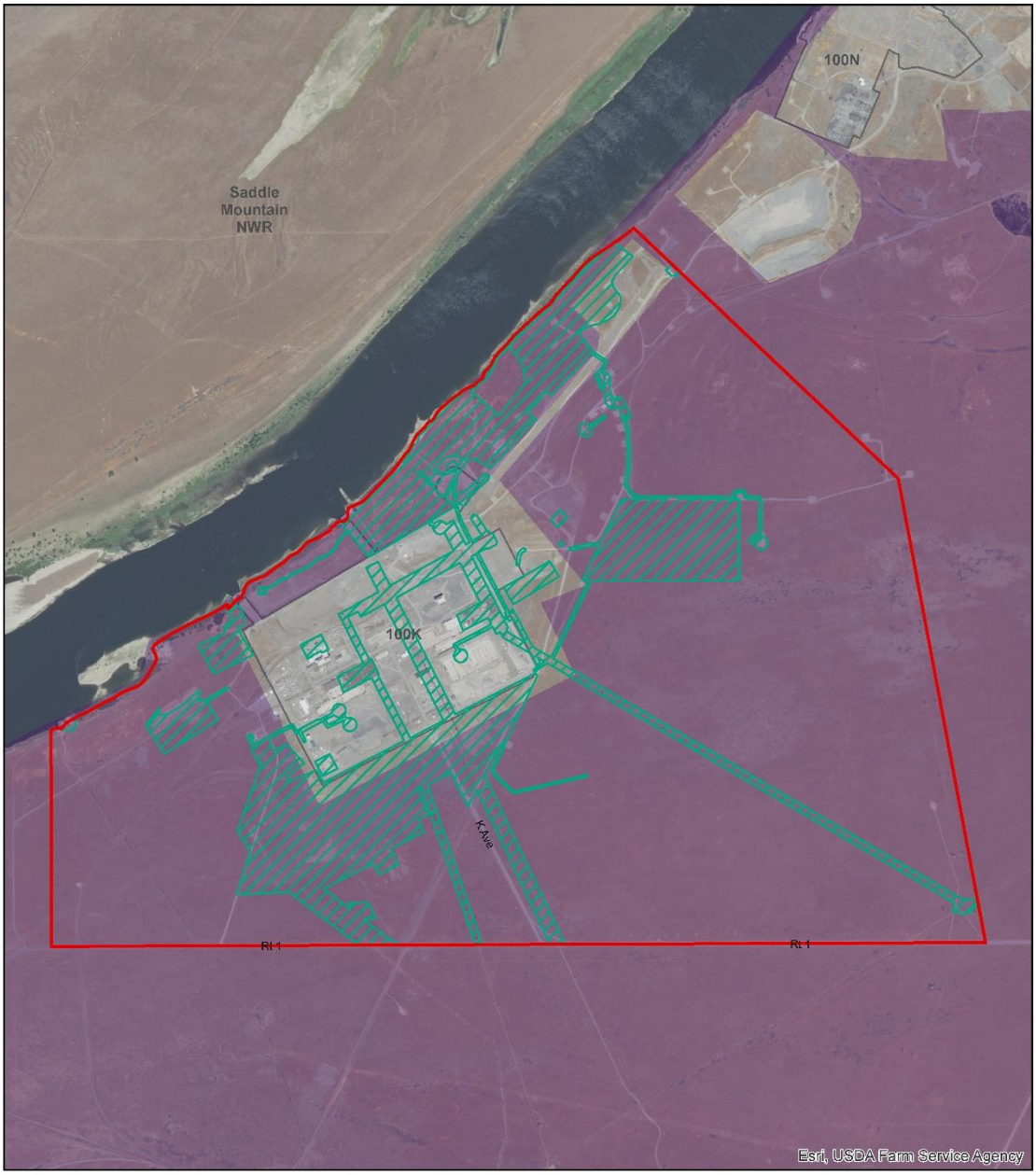
3.11 Cultural Resources

Significant cultural and historical heritage resources have been established from the riverfront environment to the ridge tops (DOE/EIS-0119F). Some of the most important archaeological sites in the region are located at the Hanford Site. Most of these sites are eligible for listing on 36 CFR 60, "National Register of Historic Places" (NRHP) as individual sites or as archaeological districts. Cultural, environmental, and historical 100 Area information is provided in detail in the Integrated Work Plan (DOE/RL-2008-46). Information specific to 100-K is included in this section.

Restricted access to the Hanford Site has facilitated the preservation of historic, cultural, and archaeological sites. Furthermore, hydroelectric and agricultural developments have not destroyed these culturally significant sites, as has been experienced elsewhere in the Columbia River Basin. Other natural resources and sacred sites important to the Native American communities with ancestral ties to the Hanford Site have been preserved (PNL-9785, *Data Compendium for the Columbia River Comprehensive Impact Assessment*). Through the cultural resources review process, DOE, contractor cultural resource specialists, Tribal Nations representatives, and project and site planners work together to protect resources important to the Native American community and other interested parties.

3.11.1 Previously Conducted Archaeological Surveys and Reports

Based on overlay analysis with the Cultural and Historic Resources Program (CHRP) Database, 213 cultural reviews have been conducted at 100-K since 1987. Figure 3-28 shows the areas surveyed and a summary of the reviews conducted is in Table 3-11. Areas without survey coverage (e.g., due to access restrictions) may still have been addressed within the scope of a listed review.



LEGEND

- 100-K Study Area
- Surveys Conducted After 2008
- Surveys Conducted Before 2009
- Operational Areas

NOTES:
Survey Data based on the CHRP GIS Database housed at MSA. The data may not be complete, accurate or in accordance with WISAARD data.

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Previously Surveyed Areas Intersecting the Study Area
100-K Area
Hanford Site, Benton County, Washington

N

0 0.2 0.4 0.6 0.8 1 Miles

Figure 3-28. Archaeological Survey Areas at 100-K

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
1987-100-004	*100-K Trench*	--
1987-100-012	*Groundwater Well Water Collection Tanks*	--
1987-100-014	*Mary Walker Wells 100-K*	--
1988-100-005	*100-K Light Pole Installation*	--
1988-100-016	*1706KE Broken Marker Replacement*	--
1989-100-009	*100-KE And 100-D Underground Storage Tank Removal*	--
1989-100-012	*100-K 1908 Outfall Line*	--
1989-100-019	*183KE Alum Storage Tanks*	--
1990-100-001	*100KE Underground Storage Tank (UST) Removal*	--
1990-100-002	*105KW Underground Storage Tank (UST) Removal*	--
1990-100-003	*Engineering Study, 100K Water Supply And Distrib.*	--
1990-100-011	*100-K Fire Hydrant #15 Repair*	--
1990-100-012	*100-K Fire Hydrant #5 Repair*	--
1991-100-001	*100K Soil Washing Sample Collection*	--
1991-100-019	*100K Utilities Trench, Trailers 1722K And 1701K*	--
1992-100-011	*100 K Soil Bores*	--
1992-100-012	*100 K Groundwater monitoring well*	--
1992-100-019	*KW Chiller Units*	--
1992-100-020	*KE Basin Heat*	--
1992-100-025	*100-KR-1 Op Unit*	--
1992-100-027	*100-K Conduit Line*	--
1992-100-033	*Demolition of Building1702-KW*	--
1992-100-034	*Demolition of Building1702-KE*	--
1992-100-037	*105KE Pole 500 Perimeter Lights Cable Repair*	--
1993-100-019	*Correction Action Backfill 118-B-4 & 116-K-2*	--
1993-100-025	*1721K Trailer Transformer Upgrade*	--
1993-100-027	*100 K Area Facilities Operations*	--
1993-100-028	*100 K Facilities Stabilization*	--
1993-100-033	*Relocate 1118N from 100N to 100K*	--
1993-100-036	*165 KW Underground Storage Tank Removal*	--
1993-100-040	*165KW Electrical Supply System Modification*	--
1993-100-048	*105KE/KW Basins Monitoring Equipment Replacement*	--

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
1993-100-064	*100K Area Emergency Evacuation Alarms Upgrade*	--
1993-100-066	*Removal of 105KE Contaminated Transformer*	--
1993-100-069	*105N PIOPS Printer Relocation,100K*	--
1993-100-070	*Decontamination of the 107 KE,KW & C Basins*	--
1993-100-079	*1117N Trailer Move to K Area*	--
1994-100-006	*1721K Transformer Upgrade*	--
1994-100-011	*Continuous Air Monitor Installations at 105KE*	--
1994-100-013	*K West Field Storage Basin*	--
1994-100-014A	*105KE/KW Security Upgrades*	--
1994-100-014B	*105KE/KW Seismic Upgrades*	--
1994-100-035	*K-Pools for Salmon Rearing*	--
1994-100-040	*K Basin Seismic Leak Response Actions*	--
1994-100-045	*K Area 90-Day RCRA Waste Storage Facility*	--
1994-100-048	*Post Holes at 100KW*	--
1994-100-051	*105KE Basin Spent Nuclear Fuel/Sludge Pilot Run*	--
1994-100-052	*HLAN/Phone Expansion to 183KE*	--
1994-100-053	*100K Area Systems & Facilities Upgrades*	--
1995-100-008	*100-KR-2*	--
1995-100-013	*100K Action Plan*	--
1995-100-021	*Access Control Gate for K West & East Basin*	--
1995-100-027	*100K Area PIV Repair*	--
1995-100-270	*Excavate PIV South Of 1717-K*	--
1995-100-041	*W-405 K Basin Essential Systems Recovery*	--
1995-100-047	*105K East and 105K West Office Area HVAC Upgrades*	--
1995-100-048	*HPIF's for 1706KE, KER, & KEL*	--
1995-100-053	*Repack Fire Hydrant #8 Isolation Valve, 105KE*	--
1995-100-055	*Whelen Siren Install, NW of 1720-K*	--
1995-100-057	*Salmon Habitat/Pore Water Investigations @100D & K*	--
1995-100-058	*YIN Fish Rearing in 100K pools*	--
1995-100-059	*1701/100K stop sign move*	--
1995-600-049	*WSU 600 Area Block Survey*	--
1996-100-009	*HPIF for 1717-K Building modification(s).*	--

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
1996-100-013	*100-K Pump and Treat System*	--
1996-100-013a	*K-118 Replacement Groundwater Extraction Well*	--
1996-100-018	*Walkway installation at 100K*	--
1996-100-019	*Spent Nuclear Fuel Activities at 100 K Area*	--
1996-100-021	*Repair line leak south of 105KW*	--
1996-100-026	*100-K area essential system upgrade, project W-405*	--
1996-100-027	*Trailers relocation to 100K*	--
1996-100-032	*100 K outfall for fish flushing*	--
1996-100-037	*105 KE floodplain fence*	--
1996-100-050	*K Basins personnel Facility Upgrades*	--
1997-100-004	*105KE and 105KW Reactor and Basin Modifications*	--
1997-100-006	*100 K Com Cable to Construction Trailer*	--
1997-100-013f	*118-K-1 Solid Waste Burial Grounds Remedial Design*	Yes
1997-100-013G	*Group Four 100-K Remedial Action-Backfill*	--
1997-100-014	*Deactivate MCC #7, 107 KE*	--
1997-100-021	*Installation of Aquifer Sample Tubes*	--
1998-100-001	*Placing 3-Strand Barbed Wire Fence Along 100KW*	--
1999-100-003	*New Wells at 100-D, 100-N and100-K*	--
2000-100-002	*Ground leak mitigation connex boxes-105KE & 105KW*	--
2000-600-025	*L-292 Retro-fit 100K Sirens*	--
2001-100-006	*Spent Nuclear Fuel Project 100 K Five Year Cultural Resources Review*	--
2001-600-027	*FY01 Fire Assessment: 100 Area Fires*	--
2001-600-033	*FY01 Low Water River Survey*	--
2003-100-007	*100-KR Pump and Treat Pipe under road*	Yes
2003-100-015	*Well Decommissioning at 100-K and 100-N*	Yes
2003-100-017	*Collect Soil Gas at 118-K-1, 100-K Area*	Yes
2003-100-021	*D&D of Spent Nuclear Fuel at 100K*	--
2004-100-004	*105KE, Update Outside Lighting, 100-K Area*	Yes
2004-100-024	*Electrical Pole Replacement, 100-K Area*	Yes
2004-100-026	*Communications link at 1720K/100K*	Yes
2004-600-005	*118-K-1 Burial Ground Remedial Design*	Yes
2005-100-004	*100 KR 4 Pump and Treat*	Yes

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
2005-100-017	*100-KR-4 Pump and Treat*	--
2005-100-020	*D&D of Buildings 183-KW and 190-KW, 100-K Area*	Yes
2005-100-021	*Road Improvement near 199-K-126*	Yes
2005-600-030	*L-325 13.8KV Distribution line to 100K Area*	--
2006-100-016A	*Install four new extraction/injection wells within 100-K fence line*	Yes
2006-100-039	*Setup and Install Double Wide Trailer South of MO-054 in the 100-K Area*	Yes
2006-100-049	*Setup and Install Single Wide Trailer East of MO-442 in the 100-K Area*	Yes
2006-100-050	*100-KR-4 Pump and Treat Expansion -Construction of 3 KR-4 Pump and Treat Buildings-100 K Area*	--
2006-100-053	*Install 3 Monitoring Wells near 100-K and 600 Area*	Yes
2007-100-013	*New Well at 100-KW*	Yes
2008-100-006	*Install well C6386 near BPA Substation as part of KR-4 Pump and Treat Project*	Yes
2008-100-010	*Power Poles and Road Crossings at 100-KR-4 Pump and Treat*	--
2008-100-011	*Revised Scope for KR4 Pump and Treat Building- cancelled combined under 2008-100-010*	--
2008-100-018	*Install aquifer tubes at 6 locations along the K Terrace*	--
2008-100-019	*Install 4 new Injection Wells to support the 100KR-4 Pump and Treat Project*	--
2008-100-025	*FY08 K-West Characterization Wells*	Yes
2008-600-023	*4600 Crane Movement to the 100K Area from the 200 West area along existing roads to support 105KE Demolition*	Yes
2009-100-003	*Well-drilling at four sites in the 100-KW area*	Yes
2009-100-005	*Characterization Sampling of Waste Sites 100-K-78, 126-K-2, and 600-29 in the 100-K Area*	Yes
2009-100-006	*Road Imrovements West of 100-KW, 100K Area*	Yes
2009-100-007	*Demolition of 119KE, 1713KE and 1714KE buildings in the 100K Area.*	Yes
2009-100-008	*Excavate Road Crossings at 100-KR-4*	Yes
2009-100-015	*Remedial Action at Waste Site 100-K-2 in the 100K Area*	Yes
2009-100-015a	*Installation of an Underground Water Line to Supply Dust Suppression Water for the 118-K-1 Burial Ground in the 100-K Area*	Yes
2009-100-016	*Remediation of waste sites in the 100-K Area Floodplain, 100-K Area Hanford Site*	--

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
2009-100-016a	*Remedial Action of the 100-K-80 and 100-K-96 Effluent Pipelines, 100-K-81 Structure, 100-K-80 Spillway, and 116-K-3 (1908-K) Structure, Ammendment to 2009-100-016*	--
2009-100-019	*Soil Remediation, groundwater drilling, investigation sampling and remedial soil excavation activities within the 100-K Area fenceline*	Yes
2009-100-023	*FY09 100-KR-4 KEX Plhase II Realignment*	--
2009-100-028	*Three wells at the KR4 Pump and Treat Project*	Yes
2009-100-029	*Two wells at the KR4 and Treat Project*	Yes
2009-100-029a	*Installation of Above Ground Piping and Cables to Well 199-K-182 in Support of the KX Pump and Treat System*	--
2009-100-036	*Support Facilities and Haul Roads for 100-K Waste Site Remediation Activities*	Yes
2009-100-038	*Electrical Panel Rack Installation On 1607-K Buiding in 100-K Area*	Yes
2009-100-041	*100K River Water Isolation Project*	Yes
2009-100-042	*ARRA K-West Area Mobile Office Installation*	Yes
2009-100-043	*Remedial Action Activities at Waste Site 100-K-2 & 118-K-1 in the 100K Area*	Yes
2009-600-011	*Install Mobile Offices and Trailers across the Hanford Site to support ARRA projects (200 East, 200 West, 100K area, 2101M, S&GW Shops, WSCF and MO281*	Yes
2009-600-018	*100k River Water Isolation Project*	--
2009-600-018A	*100-K River Water Isolation Project Lay-Down Area*	Yes
2010-100-002	*ARRA $$- Install 7 Mobile Offices and 3 Mobile Office/Restrooms Near the 105-KW in the 100K-West Area*	Yes
2010-100-009	*Install 12 aquifer tubes near the 100-H, 100-D and 100-K Areas.*	Yes
2010-100-014	*Confirmatory Sampling at Waste Sites 100-K-63 and 100-K-64 Sites, 100-K Area*	Yes
2010-100-025	*100-KR-4, 4 phase III RPO wells*	--
2010-100-030	*1606-K2 Conex Box, Trench Relocation and Extended Culvert, 100-K Area*	Yes
2010-100-033	*Install Characterization Boreholes at the K-2 Trench in the 100-K Area*	Yes
2010-100-040	*RIFS Wells in the K-Reactor Area*	Yes
2010-100-043	*Installation of 3 Wells 199-K-192, 199-K-193, & 199-K-194*	--
2010-100-045	*Confirmatory Sampling at Waste Site 600-29 in the 100-K Area*	Yes
2010-100-046	*Surface Sampling at Waste Site 100-K-78 in the 100-K Area*	Yes
2010-100-050	*Confirmatory Sampling at 100-K-78 in the 100-K Area*	Yes

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
2010-100-055	*Confirmatory Sampling at Waste Sites 100-K-85, 100-K-86, 100-K-88, 100-K-89, 100-K-90 and 100-K-92 in the 100-K Area*	Yes
2010-100-059	*100-K Remediation for waste site 100-K-63*	--
2010-100-062	*100K Air Monitoring Stations Relocation*	Yes
2010-100-063	*FY10100-KR-4 RI/FR Wells*	Yes
2010-100-064	*MO872 - 100K East Relocation*	Yes
2010-100-075	*100-KWest/Sites 3&4 Parking Lot, laydown yard for conex boxes*	Yes
2010-100-075a	*100-Kwest/Sites 3&4 Parking Lot and Laydown Area Expansion*	Yes
2010-100-077	*Confirmatory Sampling for Waste Site 100-K-78*	--
2010-100-079	*100-K D&D Activities*	Yes
2010-100-082	*100K West Tool Crib Install*	Yes
2010-100-085	*KW Road Crossing No. 18 (for the KW/KX/KR-4 Phase 3 Realignment)*	Yes
2010-100-090	*100-K pipe racks, conex boxes, and parking area for large vehicles*	Yes
2010-100-092	*Relocation of Well 199-K-196 in the K-Area Pump and Treat System*	Yes
2010-100-103	*Remediation of Waste Sites 100-K-87, 100-K-91, 100-K-93, 100-K-95 and 128-K-2 in the 100-K Area*	Yes
2010-100-107	*Conduct routine quarterly inspection and maintenance of the C7L10 Electrical Line located between 100-K and 100-N Area*	--
2010-100-110	*D&D, 100K, 105K Reactor Building*	Yes
2010-100-113	*Additional CERR for Area exisiting Laydown Yard, New Trailers, and the 105-KW*	Yes
2010-100-116	*D&D of 100-K Riverstructures (181-KW, 181-KE and 1908-K)*	--
2010-100-120	*KX Well Realignment*	Yes
2010-100-120A	*Ammendment: Road Crossings at 100-KR-4 Pump-and-Treat to Support KX Well Realignment*	Yes
2010-100-121	*Grading additional laydown/storage area west and northwest of the 105-KW*	Yes
2010-600-054	*Miscellaneous Restoration Railroad Removal*	Yes
2011-100-013	*100-K Field Remediation (Duration from 11/10/10 through 10/10/12)*	--
2011-100-015	*"Inside the Fence" of 100K Field Remediation*	--
2011-100-019	*Grounding rod/well in Support of Electrical Upgrades for D&D Transition Within the KE-Electrical Substation*	Yes
2011-100-020	*Well within the perimeter fence of the KE Electrical Substation*	Yes
2011-100-021	*New Operations Trailer at KX Process Building 1608KA*	Yes

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
2011-100-022	*Installation of a second grounding well at the A9 Switch Yard of the 100-K*	Yes
2011-100-024	*Debris Removal at Miscellaneous Restoration Sites K-025, K-026, K-027 and K-029 in the 100-K Area*	--
2011-100-031	*100K Fiber Optic Cable and HLAN Replacement, Pump and Treat Facilities*	--
2011-100-037	*Remedial Action for the 128-K-2 Burn Pits, 100-K Area, Hanford Site, Benton County, Washington*	--
2011-100-047	*Remedial Actions at Waste Sites 100-K-84, 100-K-86, 100-K-89, 100-K-92, and 600-29 in the 100-K Area, Hanford Site, Benton County, Washington*	--
2011-100-103	*Use of Existing Laydown Yard and Installation of Mobile Office Trailer Locations to Support D&D activities in the 105-KW Reactor Area, 100-K Area, Hanford Site, Richland, WA*	Yes
2012-100-005	*Sludge Treatment Plant (STP) Mobile Office Site, 100-K Area*	--
2012-100-015	*Installation of a Gravel Parking Lot Near the 189-K Building in the 100 K Area*	--
2012-100-020	*Construction and Demolition of the 105-KW Annex Temporary Facility to Support the Sludge Treatment Project at the 100-K Area of the Hanford Site, Benton County, Washington*	--
2012-100-021	*Use of Borrow Pit 23 for Cocooning of the 105KE Reactor, 100-K Area*	--
2012-100-022	*Grade 100 Area Pump & Treat Access Roads, 100-K, 100-N & 100-H Areas*	--
2012-100-024	*Design, Construction, and Continued Use of Borrow Pit 36 Located in the 100-K Area of the Hanford Site, Benton County, Washington*	--
2012-100-026	*KW Well Re-Alignment, K-173 Well Conversion*	--
2012-600-013	*Removal of Nine Miscellaneous Restoration Debris Items (SG4K-001, SG4-005, SG4-007, SG4-022, SG4-173, SG4-419, SG4-420, SG4-426, and SG4-434) in and around the Segment 4 Area in the 600 Area of the Hanford Site, Benton County, Washington*	--
2012-600-029	*Sitewide Noxious Weed Control*	--
2012-600-035a	*Beryllium Sampling at the Hanford Site Group 1: 18 Locations on the Fitzner-Eberhardt Arid Lands Ecology Reserve and One Location on Gable Butte, Benton County, Washington*	--
2012-600-035b	*Beryllium Sampling at the Hanford Site Group 2: 5 Locations Within Previously Recorded Archaeological Sites, Benton County, Washington*	--
2012-600-035c	*Beryllium Sampling at the Hanford Site Group 3: 15 Locations Within Previously Surveyed Areas, Benton County, Washington*	--

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
2012-600-035d	*Beryllium Sampling at the Hanford Site Group 4: 38 Locations Where No Archaeological Surveys Have Been Conducted, Benton County, Washington*	--
2013-100-001	*Maintenance of the 100-KW Pump and Treat Access Road in the 100-K Area of the Hanford Site, Benton County, Washington. MSA. Richland, Washington*	--
2013-100-008	*Nature and Extent Characterization at Waste Sites 100-K-64 and 100-K-111 in the 100-K Area of the Hanford Site, Benton County, Washington*	--
2013-100-024	*Drilling, Sampling and Installation of Four (KR-4) Groundwater Wells (C8289, C8292, C8293, and C8795) in the 100 K Area of the Hanford Site, Benton County, Washington*	--
2013-100-025	*Installation of Two KR-4 Wells Outside the Fenceline, 100-K Area, Hanford Site, Benton County, Washington*	--
2013-100-031	*100-K Well Realignment*	--
2013-600-010	*Probabilistic Seismic Hazard Analysis (PSHA) of the Hanford Site and the Hanford Reach National Monument, Benton County, Washington*	--
2013-600-012b	*Removal of 8 Meteorological Towers and Associated Infrastructure in Benton, Franklin, and Grant Counties*	--
2013-600-028	*Environmental Surveillance Sampling Throughout the Hanford Site, Benton County, Washington*	--
2014-100-001	*Installation of One Concrete Slab at the KR4 Pump and Treat, 100-K Area, Hanford Site, Benton County, Washington*	--
2014-600-008	*Installation of 3 100-KR-4 Wells (199-K-208, 199-K-207 and 199-K-209) in the 600 Area, Hanford Site, Benton County, Washington*	--
2015-100-001	*Installation of a New Meteorological Tower at 100K Area*	--
2015-100-003	*Removal of the Calcium Polysulfide Equipment*	--
2015-100-004	*Repair Caisson Extension for Sanitary System Storage Tank SANS-TK-9030 in the 100 K Area, Hanford Site, Benton County, Washington*	--
2015-100-014	*100 K Well Realignment (in TCP) in the 100 K Area, Hanford Site, Benton County, Washington*	--
2015-100-017	*Replacement of Pole K273 for Relocation of Ambient Air Monitor N534 Transformer and Installation of Poles K381, K382, and K383 in the 100 K Area of the Hanford Site, Benton County, Washington*	--
2016-100-002	*Well Alignments for FY2016 (outside TCP) within the KR-4 Operable Unit in the 100 K Area, Hanford Site, Benton County, Washington*	--
2016-100-015	*Construction of 1 Well (199-K-227), Associated Pad and Road in 100-KR-4 OU in the 100 K Area, Hanford Site, Benton County, Washington*	--

Table 3-11. Summary of Cultural Resource Reports at 100-K

HCRC Number	Title	Finding of No Potential to Cause Effects?
2016-600-005	*The Hanford Site 230 kV North Loop Transmission System Reconditioning and Sustainability Upgrades in the 600 Area, Hanford Site, Benton County, Washington*	--
2017-100-007	*Installation, Operation, Maintenance, and Decommissioning of Groundwater Wells 100-K-231/C9919 & 100-K-232/C9920; Associated Pads; and Access in the 100-KR-4 Operable Unit, 100 K Area, Hanford Site, Benton County, Washington*	--
2017-100-008	*Archaeological Investigation in Support of the Installation, Operation, Maintenance, and Decommissioning of Groundwater Well 100-K-233/C9921, Associated Pad, and Access; along with the drilling of a replacement well for well 100-K-114A/B2801 in the 100-K Area of the Hanford Site, Benton County, Washington*	--
Programmatic Agreement	*Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington. DOE/RL-96-77*	--

HCRC = Hanford Cultural Resources Case

3.11.2 Previously Documented Cultural Resources in 100-K

Based on the CHRP Database, 40 documented cultural resources have been identified in 100-K, summarized in Table 3-12. While the identified isolates and sites may not be individually eligible for listing on the NRHP, many are contributing elements or within the boundaries of State Historic Register or National Register-listed Archaeological Districts.

Table 3-12. Summary of Cultural Resources at 100-K

Type	Total	Age			NRHP Eligibility		
		Precontact	Historic	Multi-Component	Eligible	Not Eligible	Unevaluated
Isolate	10	7	3	0	0	10	0
Site	30	13	13	4	11	3	16
Total	40	20	16	4	11	13	16

NRHP = National Register of Historic Places

In general, archaeological sites on the Hanford Reach, including 100-K, tend to be on the alluvial flats and lower terraces near the shorelines and islands of the Columbia River. Shoreline sites are generally long and narrow, and run parallel to the river. Inland prehistoric sites have been discovered on Gable Butte, Rattlesnake Mountain, and near the few isolated seeps. Prehistoric settlement patterns and seasonal rounds in this section of the Columbia Basin were associated with nonagricultural practices that included

fishing, upland root gathering, and hunting. Archaeological evidence suggests that precontact settlement patterns consisted of consolidated winter villages and dispersed summer camps.

3.11.3 Historic Structures in 100-K

Stipulations for administering undertakings at the Hanford Site affecting the built environment to satisfy DOE's responsibilities under Sections 106 and 110 of the *National Historic Preservation Act of 1996* are provided in DOE-RL-96-77, *The Programmatic Agreement Among the US Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, WA* (hereinafter called the Programmatic Agreement). The Programmatic Agreement specifically addresses the Hanford Site built environment constructed during the Manhattan Project and Cold War Era (1943-1990). As a stipulation of the Programmatic Agreement, DOE-RL-97-56, *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan* (hereinafter called the Treatment Plan) outlines treatment of the built environment comprising the Hanford Site Manhattan Project and Cold War Era Historic District. The Treatment Plan identifies properties and informs appropriate mitigation measures. Table 3-13 lists the historic district status for buildings identified in the Treatment Plan at 100-K.

Table 3-13. Historic Structures at 100-K

Facility ID	Description	Historic District Status		
		Contributing with Documentation Required	Contributing with no Documentation Required	Non-Contributing/ Exempt
105KE	Reactor Building		X	
105KW	Reactor Building	X		
107KE/ 107KEA/ 107KEB/ 107KEC	Retention Basin		X	
107KW/ 107KWA/ 107KWB/ 107KWC	Retention Basin	X		
110KE	Gas Storage Facility			X
110KW	Gas Storage Facility			X
115KE	Gas Recirculation Building		X	
115KW	Gas Recirculation Building		X	
116KE	Reactor Exhaust Stack		X	
116KW	Reactor Exhaust Stack	X		
117KE	Exhaust Air Filter Building		X	
117KW	Exhaust Air Filter Building	X		
119KE	Exhaust Air Sampling Building			X
119KW	Exhaust Air Sampling Building	X		
151KE	Electrical Substation (230 KV)			X

Table 3-13. Historic Structures at 100-K

Facility ID	Description	Historic District Status		
		Contributing with Documentation Required	Contributing with no Documentation Required	Non-Contributing/ Exempt
151KW	Electrical Substation (230 KV)			X
1614.2K	None		X	
1614K1	None		X	
1614K3	Environmental Gamma Monitoring Station		X	
165KE	Power Control Building		X	
165KW	Power Control Building		X	
166KE	Oil Storage Vault			X
166KW	Oil Storage Vault			X
167K	Cross Tie Tunnel Building		X	
1705KE	Effluent Water Treatment Pilot Plant			X
1706KE	Rad Con Count Lab Facility	X		
1706KER	Water Studies Recirculation Building	X		
1713KE	Shop Building			X
1713KER	Warehouse		X	
1713KW	Warehouse			X
1714KE	Oil and Paint Storage Shed			X
1714KW	Oil and Paint Storage Shed			X
1717K	Maintenance/Transportation Shop	X		
1720K	Administrative Office Building	X		
1724K	Maintenance Shop		X	
1724KA	Equipment Shed			X
1724KB	Gas Bottle Storage Facility			X
181KE	River Pump House		X	
181KW	River Pump House	X		
182K	Emergency Water Reservoir Pump House		X	
183.1KE	Headhouse		X	
183.1KW	Headhouse	X		
183.2KE	Sedimentation Basins		X	
183.2KW	Sedimentation Basins	X		
183.3KE	Basins/Filters		X	
183.3KW	Basins/Filters	X		
183.4KE	Reservoir and Clearwells		X	

Table 3-13. Historic Structures at 100-K

Facility ID	Description	Historic District Status		
		Contributing with Documentation Required	Contributing with no Documentation Required	Non-Contributing/ Exempt
183.4KW	Reservoir and Clearwells	X		
183.5KE	Lime Feeder Building		X	
183.5KW	Lime Feeder Building	X		
183.6KE	Lime Feeder Building		X	
183.6KW	Lime Feeder Building	X		
183KE	Chlorine Vault		X	
183KW	Chlorine Vault	X		
1908K	Outfall Structure		X	
1908KE	Effluent Water Monitoring Station	X		
190KE	Warehouse and Pump House		X	
190KW	Main Pump House	X		
MO048	Mobile Office North of 151KE			X
MO054	Office Trailer – South of MO500			X
MO101	Mobile Office at 1711K			X
MO102	Mobile Office North of MO402			X
MO205	Mobile Office at 190KE			X
MO214	Patrol Badgehouse (1701KA)			X
MO293	Office Trailer South of 183.2KE Basins			X
MO323	Mobile Office Southeast of 105KW			X
MO382	Mobile Office East of 1720K			X
MO401	Mobile Office at 1724K			X
MO402	Mobile Office at K Avenue and Wagner Street			X
MO420	None			X
MO422	Training Mobile Office			X
MO442	Office Trailer at 183.1KE			X
MO907	Mobile Office North of MO402			X
MO928	Mobile Office Northwest of MO402			X
MO955	Mobile Office South of 115KW			X

Note: Structures listed are based on the Hanford Central Mapping Services geographic information system data and may have been previously removed.

3.11.4 Traditional Cultural Properties in 100-K

Based on information gained through consultation with local Tribes, 100-K is in the vicinity of or overlaps at least one documented and potentially previously undocumented traditional cultural properties (TCPs.) A TCP is a type of historic property that is eligible for inclusion in the NRHP because of its association with cultural practices or beliefs of a living community that are rooted in the community's history and are important in maintaining the continuing cultural identity of the community. Due to the sensitive nature of TCPs, information associated with these resources is restricted from public disclosure.

3.11.5 Additional Cultural Resource Considerations

Additional cultural resource considerations for 100-K include:

- 100-K overlaps with a National Park Service boundary and the Hanford Reach National Monument boundary.
- 100-K overlaps both the Coyote Rapids Archaeological District (45DT37) and the Ryegrass Archaeological District (45DT30). The Coyote Rapids Archaeological District is listed on the State Register, and many sites and isolates identified in Section 3.11.2 are within or are contributing elements to this archaeological district. The Ryegrass Archaeological District is listed on the National Register. Many of the sites and isolates identified in Section 3.11.2 are within or are contributing elements to this archaeological district.
- 100-K overlaps with the 400-m (1,300-ft) cultural sensitivity buffer for the Columbia River.
- 100-K does not overlap with the 500-m (1,600-ft) cultural sensitivity buffer for Gable Mountain/Butte.

3.11.6 Cultural Resources Summary

Table 3-14 provides a summary of cultural resources information based on geospatial analysis and information in the previous sections.

Table 3-14. Cultural Resources Summary Information

Portion of 100-K Surveyed For Cultural Resources		88.6%
Portion of 100-K Surveyed in the past 10 Years		19.8%
Number of Known NRHP Eligible Archaeological Resources in 100-K		11
Number of Documented NRHP Not Eligible Archaeological Resources in 100-K		13
Number of Documented NRHP Unevaluated Archaeological Resources in 100-K		16
Manhattan Project and Cold War Era Historic District Facilities in Study Area	Contributing with Documentation Required	22
	Contributing with no Documentation Required	28
	Non-contributing/Exempt	31
Known TCPs in Study Area		Yes

NRHP = National Register of Historic Places
TCP = traditional cultural property

4 Nature and Extent of Contamination

This chapter continues to build on the CSM by describing the contaminants found in the environmental media (primarily soil and water) in 100-K. The nature and extent of contamination were determined from RI data, data from the Columbia River RI, data from previous field investigations, interim action remediation, and operational process information, as discussed in Section 2.1.2. This information supports risk assessment in subsequent chapters of this RI and will be used to support remedy evaluations in the FS (DOE/RL-2018-22).

Information from the long history of 100-K and information collected during the RI were used to meet the data quality objectives outlined in the 100-K Work Plan (DOE/RL-2008-46-ADD2) and 100-K SAP (DOE/RL-2009-41). Many of the data collected during remediation that have been previously documented in CVPs and LFIs (see Section 2.1.2) also are incorporated into the discussion of nature and extent.

Figures in this chapter illustrate concentrations of chemical and radiological analytes in soil and groundwater. Soil concentrations are reported in mg/kg or pCi/g. Groundwater contaminant concentrations generally are reported in µg/L or pCi/L. Analytical results are included in Appendix D.

Filled symbols on graphs in this chapter indicate detections during the analysis. Hollow symbols indicate that the analyte was not detected above limiting criteria, which are usually the method detection limit (MDL), practical quantitation limit (PQL), or minimum detectable activity (MDA). For chemical constituents, undetected results are reported as the limiting criteria. Undetected radionuclides are reported as either the limiting criteria or a counted value with laboratory correction for background radiation.

4.1 Background Concentrations

The identification of background concentrations of constituents in soil and groundwater is important in determining which waste sites may require remedial action and which contaminants in groundwater may require remedial action. Background refers to substances or locations that are not influenced by releases from a site and are usually described as naturally occurring (present in the environment in forms that have not been influenced by human activity) or anthropogenic (present in the environment as a result of human activities not specifically related to the CERCLA site in question). Some chemicals may be present in background because of both natural and artificial conditions, such as naturally occurring arsenic and arsenic from pesticide applications (EPA 540-R-01-003, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*).

Section 4.1.1 describes pre-Hanford practices that affected background concentrations of lead and arsenic, and Section 4.1.2 describes Hanford Site soil background concentrations as determined by sampling. Groundwater background concentrations for 100-K COPCs were derived from DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*, as corrected. Section 4.1.3 presents groundwater background concentrations.

4.1.1 Historical Agricultural Activities

As discussed in Chapter 1, historical agricultural lands are present in the River Corridor, including 100-K (Figure 1-4 in Chapter 1). The orchard area is not co-located with 100-K waste sites addressed under this RI except for the 100-K-63 site. Potential impacts to human health and the environment from residual lead arsenate that was applied as a pesticide before Hanford operations began is being assessed as part of the 100-OL-1 OU. Data collected for the 100-OL-1 OU RI show that surface exposure point concentrations of lead and arsenic are below MTCA Method A screening values at the former orchard area in 100-K.

4.1.2 Hanford Site Soil Background

Background soil concentrations derived for the Hanford Site are presented in Table 4-1 and are used as benchmarks to define contamination as well as COPCs. As such, a constituent detected below background (e.g., 90th percentile in DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, and DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*) is not considered a contaminant.

As part of the RI, investigations for collecting data and developing River Corridor background values in soil for selected metals were performed (Section 2.1.13). Revised, provisional background values for antimony, cadmium, mercury, selenium, silver, and thallium are presented in ECF-HANFORD-11-0038.

For anthropogenic radionuclides in soil samples at depth, including strontium-90, cobalt-60, cesium-137, europium-154, europium-155, plutonium-238, and plutonium-239/240, anthropogenic constituents were not excluded based on background concentration (i.e., all detects are presented, even if below background Hanford Site soil concentrations).

Naturally occurring radionuclides include potassium-40, radium-226, thorium-232, thorium-234, uranium-234, uranium-235, and uranium-238, which are present in all geologic materials that include the soil throughout the Hanford vadose zone.

Anthropogenic background radionuclides are radioactive isotopes that were produced or concentrated by non-Hanford related human activities (DOE/RL-96-12). Most of the anthropogenic background radionuclides were produced by aboveground nuclear explosions and nuclear accidents and were subsequently deposited as global fallout from dry and wet precipitation of atmospheric particles. However, the application of Hanford background concentrations for anthropogenic radionuclides such as cesium-137, plutonium-239/240, and strontium-90 are largely restricted to soil in the upper few tens of centimeters, but can extend to deeper soil affected by remobilization, transport, and depositional processes (e.g., eolian processes). In extreme cases, anthropogenic background radionuclides have been found to occur at depths up to 120 cm (47 in.) below the surface (DOE/RL-94-98, *Hanford Site Radiological Background: Data Quality Objective Issues and Recommendations*).

Table 4-1. Background Concentrations in Hanford Site Soil

Analyte	Abbreviation	90th Percentile	Reference
Radionuclides (pCi/g)			
Cobalt-60 [a]	Co-60	0.00842	DOE/RL-96-12
Cesium-137 [a]	Cs-137	1.05	DOE/RL-96-12
Europium-154 [a]	Eu-154	0.0334	DOE/RL-96-12
Europium-155 [a]	Eu-155	0.0539	DOE/RL-96-12
Uranium-233/234	U-233/234	1.1	DOE/RL-96-12
Uranium-235	U-235	0.109	DOE/RL-96-12
Uranium-238	U-238	1.06	DOE/RL-96-12
Plutonium-238 [a]	Pu-238	0.00378	DOE/RL-96-12
Plutonium-239/240 [a]	Pu-239/240	0.0248	DOE/RL-96-12
Strontium-90 [a]	Sr-90	0.178	DOE/RL-96-12

Table 4-1. Background Concentrations in Hanford Site Soil

Analyte	Abbreviation	90th Percentile	Reference
Nonradionuclides (mg/kg)			
Aluminum	Al	11,800	DOE/RL-92-24
Antimony	Sb	0.13	ECF-HANFORD-11-0038
Arsenic	As	6.47	DOE/RL-92-24
Barium	Ba	132	DOE/RL-92-24
Beryllium	Be	1.51	DOE/RL-92-24
Boron	B	3.89	ECF-HANFORD-11-0038
Cadmium	Cd	0.81	ECF-HANFORD-11-0038
Chromium (Total)	Cr	18.5	DOE/RL-92-24
Cobalt	Co	15.7	DOE/RL-92-24
Copper	Cu	22	DOE/RL-92-24
Lead	Pb	10.2	DOE/RL-92-24
Lithium	Li	13.3	ECF-HANFORD-11-0038
Manganese	Mn	512	DOE/RL-92-24
Mercury	Hg	0.0131	ECF-HANFORD-11-0038
Molybdenum	Mo	0.47	ECF-HANFORD-11-0038
Nickel	Ni	19.1	DOE/RL-92-24
Selenium	Se	0.78 [b]	ECF-HANFORD-11-0038
Silver	Ag	0.167	ECF-HANFORD-11-0038
Thallium	Tl	0.185	ECF-HANFORD-11-0038
Titanium	Ti	2,950	DOE/RL-92-24
Vanadium	V	85.1	DOE/RL-92-24
Zinc	Zn	67.8	DOE/RL-92-24
Nitrate	NO_3^-	52	DOE/RL-92-24
Nitrite	NO_2^-	Note [c]	DOE/RL-92-24

References: DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*.

DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*.

ECF-HANFORD-11-0038, *Soil Background for Interim Use at the Hanford Site*.

a. Cesium-137, cobalt-60, europium-154, europium-155, plutonium-238, plutonium-239/240, and strontium-90 are anthropogenic radionuclides whose background values only apply to surface soil samples.

b. The 90th percentile value for selenium is estimated because the majority of detections were below the minimum quantitation limit.

c. Not enough data are above detection limit to calculate background.

4.1.3 Hanford Site Groundwater Background

Background concentrations derived for Hanford Site groundwater are presented in Table 4-2 and are used as benchmarks to define contamination as well as COPCs. As such, a constituent detected below background is not considered a contaminant. The groundwater evaluation presented in Section 4.3 includes comparison to groundwater background levels.

Table 4-2. Background Concentrations in Hanford Site Groundwater

Groundwater Contaminant of Potential Concern	Units	90th Percentile	Comment
Radionuclides			
Carbon-14	pCi/L	--	Background not determined
Cesium-137	pCi/L	0.00843	Corrected from DOE/RL-96-61 [a]
Cobalt-60	pCi/L	0.0225	--
Europium-155	pCi/L	0.00518	Corrected from DOE/RL-96-61 [a]
Gross Alpha	pCi/L	2.7	Corrected from DOE/RL-96-61 [a]
Gross Beta	pCi/L	8.08	Corrected from DOE/RL-96-61 [a]
Iodine-129	pCi/L	0.0000939	Corrected from DOE/RL-96-61 [a]
Nickel-63	pCi/L	--	Background not determined
Radium-228	pCi/L	0.0649	Corrected from DOE/RL-96-61 [a]
Strontium-90	pCi/L	0.0146	Corrected from DOE/RL-96-61 [a]
Technetium-99	pCi/L	0.83	--
Tritium	pCi/L	119	--
Metals [b]			
Aluminum	µg/L	7.11	--
Antimony	µg/L	55.1	--
Arsenic	µg/L	7.85	--
Beryllium	µg/L	2.29	--
Cadmium	µg/L	0.916	--
Chromium (Total)	µg/L	2.4	--
Chromium (Hexavalent)	µg/L	--	Background not determined
Cobalt	µg/L	0.916	--
Copper	µg/L	0.81	--
Iron	µg/L	570	--
Lead	µg/L	0.917	--

Table 4-2. Background Concentrations in Hanford Site Groundwater

Groundwater Contaminant of Potential Concern	Units	90th Percentile	Comment
Manganese	µg/L	38.5	--
Mercury	µg/L	0.003	--
Nickel	µg/L	1.56	--
Selenium	µg/L	10.5	--
Thallium	µg/L	1.67	--
Uranium	µg/L	9.85	--
Zinc	µg/L	21.8	--
Anions			
Nitrate	mg/L	26.9	--
Volatile Organic Compounds			
8 Compounds	µg/L	--	Background not determined

References: DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

Petersen Personal Communication, 1998, "Hanford Sitewide Background Document."

a. Reference (Petersen Personal Communication, 1998) included in Appendix D.

b. Based on filtered groundwater samples.

4.2 Vadose Zone Contamination

This section describes the nature (type and concentration) and extent of remaining contamination in the vadose zone at 100-K. The vadose (or unsaturated) zone is the region extending from land surface to the seasonally high water table. Beneath the seasonally low water table is the saturated zone, which includes the unconfined aquifer. The layer between the high and low water table is sometimes part of the aquifer and sometimes part of the vadose zone, depending on the response to changes in Columbia River elevations. In this document, it is referred to as the periodically rewetted zone (PRZ).

The representative data for descriptions in this section include soil verification data collected as part of interim remedial actions (Section 2.1.2) and data collected from boreholes, test pits, and monitoring wells during this RI. This information is further supplemented by other site-specific characterization activities beyond the extent of interim action remediation. All data representing unremediated soil are considered in the refinement of the CSM and risk evaluations in subsequent chapters.

As described in Section 1.2.3.5, of the 197 sites at 100-K, 43 are not being considered in the scope of the RI and future FS. As further described in Section 1.2.3.5, an additional 22 sites have been identified for no further action based on site-specific considerations and are not addressed further under the RI process. The data used to evaluate the nature and extent of contamination at the other 132 sites are summarized in Table 4-3 and described in the following subsections. Data describing the residual condition are then used in refining the CSM and performing risk evaluations in subsequent chapters.

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
100-K-1	No	No		Interim action planning
100-K-3	Yes	Yes	100-K-36, 100-K-79:7 (partial); 100-K-68, 100-K-69, 100-K-70, 100-K-71, 100-K-47 (partial), and 100-K-56:2 (partial)	--
100-K-4	Yes	Yes		--
100-K-5	No	No		Interim action planning
100-K-6	Yes	Yes	100-K-46, 100-K-62, and 132-KE-1	--
100-K-13	No	No		Interim action planning
100-K-14	Yes	Yes	126-KE-2	--
100-K-18	Yes	Yes	100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, and 120-KW-7	--
100-K-19	Yes	Yes	100-K-18, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, and 120-KW-7	--
100-K-25	No	No		Interim action planning
100-K-27	No	No		Interim action planning
100-K-29	Yes	Yes		--
100-K-30	Yes	Yes		--
100-K-31	Yes	Yes		--
100-K-32	Yes	Yes		--
100-K-33	Yes	Yes		--
100-K-34	Yes	Yes	100-K-102 and 1607-K3	--
100-K-35	No	No		Interim action planning
100-K-36	Yes	Yes	100-K-3, 100-K-79:7	--
100-K-43	No	No		Interim action planning
100-K-46	Yes	Yes	100-K-6, 100-K-62, and 132-KE-1	--
100-K-47	Partial	Partial	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71, and 100-K-56:2 (partial)	Interim action planning
100-K-48	No	No		Interim action planning
100-K-49	No	No		Interim action planning

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
100-K-50	Yes	Yes	1607-K2	--
100-K-53	Yes	Yes		--
100-K-54	No	No		Interim action planning
100-K-55:1	Yes	Yes	116-KW-4	--
100-K-55:2	No	No		Interim action planning
100-K-56:1	Yes	Yes	116-KE-5	--
100-K-56:2	Partial	Partial	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71, and 100-K-47 (partial)	Interim action planning
100-K-56:3	No	No		Interim action planning
100-K-57	No	No		Floodplain soil investigation
100-K-60	No	No		Interim action planning
100-K-62	Yes	Yes	100-K-6, 100-K-46, and 132-KE-1	--
100-K-63	Yes	Yes		--
100-K-64	No	No		Floodplain soil investigation
100-K-68	Yes	Yes	100-K-3, 100-K-69, 100-K-70, 100-K-71, 100-K-47 (partial), and 100-K-56:2 (partial)	--
100-K-69	Yes	Yes	100-K-3, 100-K-68, 100-K-70, 100-K-71, 100-K-47 (partial), and 100-K-56:2 (partial)	--
100-K-70	Yes	Yes	100-K-3, 100-K-68, 100-K-69, 100-K-71, 100-K-47 (partial), and 100-K-56:2 (partial)	--
100-K-71	Yes	Yes	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-47 (partial), and 100-K-56:2 (partial)	--
100-K-72	No	No		Interim action planning
100-K-73	No	No		Interim action planning
100-K-74	No	No		Interim action planning
100-K-75	No	No		Interim action planning

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
100-K-77	Yes	Yes		--
100-K-78	No action determination	Yes		--
100-K-79:1	Yes	Yes	100-K-18, 100-K-19, 100-K-79:2, 100-K-97, 120-KW-5, and 120-KW-7	--
100-K-79:2	Yes	Yes	100-K-18, 100-K-19, 100-K-79:1, 100-K-97, 120-KW-5, and 120-KW-7	--
100-K-79:3	No	No		Interim action planning
100-K-79:4	No	No		Interim action planning
100-K-79:5	No	No		Interim action planning
100-K-79:6	No	No		Interim action planning
100-K-79:7	Partial	Partial	100-K-3, 100-K-36	Interim action planning
100-K-79:8	No	No		Interim action planning
100-K-79:9	No	No		Interim action planning
100-K-80	No	No		River pipeline evaluations
100-K-81	No	No		Interim action planning
100-K-82	No	No		Interim action planning
100-K-83	No	No		Interim action planning
100-K-84	Yes	Yes		--
100-K-85	No action determination	Yes		--
100-K-86	Yes	Yes		--
100-K-88	No action determination	Yes		--
100-K-89	Yes	Yes	600-29	--
100-K-90	No action determination	Yes		--
100-K-91	Yes	Yes		--
100-K-92	Yes	Yes		--

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
100-K-94	No	No		Interim action planning
100-K-95	Yes	Yes		--
100-K-96	No	No		River pipeline evaluations
100-K-97	Yes	Yes	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 120-KW-5, and 120-KW-7	--
100-K-98	No	No		Interim action planning
100-K-99	No	No		Interim action planning
100-K-101	No	No		Interim action planning
100-K-102	Yes	Yes	100-K-34 and 1607-K3	--
100-K-103	No	No		Interim action planning
100-K-104	No	No		Interim action planning
100-K-105	Yes	Yes		--
100-K-106	Yes	Yes		--
100-K-107	No	No		Interim action planning
100-K-108	No	No		Interim action planning
100-K-109	Yes	Yes		--
100-K-110	Yes	Yes		--
100-K-111	No	No		Floodplain soil investigation
100-K-113	No	No		River pipeline evaluations
100-K-114	No	No		River pipeline evaluations
100-K-132	No	No		Supplemental test pit and borehole data
116-K-1	Yes	Yes		LFI
116-K-2	Yes	Yes		LFI, RI Borehole (Data Gap 2) [1]
116-K-3	No	No		Interim action planning

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
116-KE-1	Partial	No		Remediation characterization sampling and interim action planning
116-KE-2	No	No		Interim action planning
116-KE-3	No	No		RI Borehole (Data Gap 2) [c] and interim action planning
116-KE-4	Yes	Yes		LFI
116-KE-5	Yes	Yes	100-K-56:1	--
116-KW-1	Partial	No		Remediation characterization sampling and interim action planning
116-KW-2	No	No		Interim action planning
116-KW-3	Yes	Yes		LFI
116-KW-4	Yes	Yes	100-K-55:1	--
118-K-1	Yes	Yes		--
120-KE-1	No	No		Interim action planning
120-KE-2	No	No		Interim action planning
120-KE-3	No	No		Interim action planning
120-KE-4	No	No		Interim action planning
120-KE-5	No	No		Interim action planning
120-KE-6	No	No		Interim action planning
120-KE-8	No	No		Interim action planning
120-KE-9	No	No		Interim action planning
120-KW-1	Yes	Yes	120-KW-2, 120-KW-3, and 120-KW-4	--
120-KW-2	Yes	Yes	120-KW-1, 120-KW-3, and 120-KW-4	--
120-KW-3	Yes	Yes	120-KW-1, 120-KW-2, and 120-KW-4	--
120-KW-4	Yes	Yes	120-KW-1, 120-KW-2, and 120-KW-3	--

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
120-KW-5	Yes	Yes	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, and 120-KW-7	--
120-KW-6	No	No		Interim action planning
120-KW-7	Yes	Yes	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, and 120-KW-5	--
126-KE-2	Yes	Yes	100-K-14	--
128-K-1	Yes	Yes		--
128-K-2	Yes	Yes		--
130-K-2	No	No		Interim action planning
130-KE-1	Yes	Yes		--
130-KE-2	No	No		Interim action planning
130-KW-1	No	No		Interim action planning
130-KW-2	No	No		Interim action planning
132-KE-1	Yes	Yes	100-K-6, 100-K-46, and 100-K-62	--
1607-K1	No	No		Interim action planning
1607-K2	Yes	Yes	100-K-50	--
1607-K3	Yes	Yes	100-K-34 and 100-K-102	--
1607-K5	No	No		Interim action planning
1607-K6	No	No		Interim action planning
600-29	Yes	Yes	100-K-89	--

Table 4-3. Nature and Extent Data for 2017 Conditions at 100-K Waste Sites

Site	Remediation Performed Under Interim Action RODs? [a]	Verification Data Available?	Grouped Waste Sites [b]	Other Data Sources Considered
UPR-100-K-1	No	No		RI Borehole (Data Gap 2) [c] and interim action planning

References: DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units.*

EPA/ROD/R10-95/126, *Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.*

EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites).*

EPA/ROD/R10-00/121, *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington*.

a. EPA/ROD/R10-95/126, EPA/ROD/R10-99/039, EPA/ROD/R10-00/121

b. Remediation, sampling, and interim closure for grouped waste sites were performed together due to spatial proximity.

c. Data gaps are from DOE/RL-2008-46-ADD2. Also see Table 2-2.

LFI = limited field investigation
RI = remedial investigation
ROD = record of decision

4.2.1 Waste Site Soil Verification Data

As described in Section 1.2.3.2, remediation has been performed at 100-K under three separate interim action RODs. These RODs generally addressed three different categories of waste sites: liquid effluent sites, burial grounds, and remaining sites. For all three categories, remedial actions were performed in accordance with the applicable revision of the 100 Area RDR/RAWP (DOE/RL-96-17), which included collection of verification soil data to demonstrate attainment of interim cleanup levels. In total, 67 sites at 100-K were remediated under interim action. The waste site locations are shown in Appendix A.

The verification data (provided in Appendix D) for remediated sites represent the residual condition considered for further evaluation in this RI. Previous waste site verification sampling and interim closure processes may have identified multiple decision units within a waste site or group of waste sites (Table 4-3). These decision units were identified to support discrete evaluation of different areas of the remediation footprint (e.g., separation of shallow and deep zone areas). These decision unit distinctions were maintained for further evaluation in this RI, but decision-making will ultimately apply to a waste site as a whole. Summary verification data values provided in the following subsections were obtained from interim closure documentation. The exposure point concentration (EPC) values for risk assessment in subsequent chapters utilize 95% UCL values recalculated to consider updated guidance, as described in Section 6.2.2.

Certain remaining sites were considered candidate sites under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) to be evaluated further for a remedial action decision under the 100 Area RDR/RAWP (DOE/RL-96-17). The analytical data collected for these evaluations are referred to as confirmatory data. When confirmatory data or other considerations resulted in a remediation decision, the candidate site was remediated consistently with the approach for other remaining sites, including collection of additional verification soil data. Confirmatory data that do not represent post-remediation

conditions were not considered further for this RI. However, for the sites for which confirmatory soil data resulted in a determination that no further interim action was warranted for all or a portion of the site, the applicable confirmatory data are considered as part of the overall verification data set provided in Appendix D.

Table 4-3 provides a list of the waste sites with verification data. These data are used in further risk evaluations for these waste sites in Chapters 5, 6, and 7.

4.2.2 RI Waste Site Characterization Results

The 100-K RI generated additional characterization data for three waste sites. These data are considered in conjunction with data generated during previous investigations and remedial actions to enhance understanding of the extent of contamination and refine the preliminary CSM, as outlined in the 100-K Work Plan (DOE/RL-2008-46-ADD2).

The following subsections summarize the maximum detected concentrations above background and the vertical extent of contamination at waste sites investigated further under the RI. Analytes that were not detected above background are not reported in these summary tables, figures, and associated text. Where a background value is not available or applicable for a detected analyte, detected values at the sampling location are reported.

Radiological data are decayed through 2017, and text discussions describe decay adjusted values. The soil analytical data set applicable to RI sampling includes radionuclides characterized as having short half-lives (e.g., <3 years), common laboratory contaminants, essential nutrients, and other nontoxic constituents. These constituents are commonly not discussed as detections, are primarily an artifact of the sampling and analysis process, not observed above background concentrations, or not a human health concern (i.e., nontoxic) per EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*, hereinafter called risk assessment guide. Analytes excluded from consideration in 100-K are identified in Table 4-4. Appendix D contains the soil analytical data set.

Table 4-4. 100-K Soil Analytes Excluded from Further Consideration

Analyte	Exclusion Rationale	Daughters	Half-Life
Radionuclides			
Actinium-228	Decayed daughter of Th-232/Ra-228; in equilibrium with parent; half-life <3 years	--	6.15 hr
Bismuth-214	Decayed daughter of Ra-226; half-life <3 yr	Tl-210 (1.3 min half-life) and Po-214 (164 µs half-life)	19.9 min
Cerium-144	Half-life <3 yr	Pr-144m (1.2 min half-life), Pr-144 (17.28 min half-life), and Nd-144 (stable)	284.6 days
Cesium-134	Half-life <3 yr	Ba-134 (stable)	2.065 yr
Cobalt-58	Half-life <3 yr	Ni-58 (stable)	70.88 days
Iron-59	Half-life <3 yr	Co-59 (stable)	44.51 days

Table 4-4. 100-K Soil Analytes Excluded from Further Consideration

Analyte	Exclusion Rationale	Daughters	Half-Life
Lead-212	Decayed daughter of Th-232/Ra-228; in equilibrium with parent; half-life <3 yr	--	10.6 hr
Lead-214	Decayed daughter of Ra-226; in equilibrium with parent; half-life <3 yr	--	26.8 min
Magnesium-54	Half-life <3 yr	Fe-54 (stable)	612.2 days
Potassium-40	Naturally occurring background radiation	--	1.28 billion yr
Radium-224	Decayed daughter of Th-232/Ra-228; in equilibrium with parent; half-life <3 yr	--	3.66 days
Radium-226	Only potential source from naturally occurring background radiation (insufficient in growth time for Hanford introduced U as decay daughter of U-234/Th-230)	--	1,600 yr
Radium-228	Naturally occurring background radiation	--	5.76 yr
Ruthenium-103	Half-life <3 yr	Rh-103m (56.12 min half-life) and Rh-103 (stable)	39.27 days
Ruthenium-106	Half-life <3 yr	Rh-106 (29.9 s half-life) and Pd-106 (stable)	1.020 yr
Sodium-22	Half-life <3 yr	Ne-22 (stable)	2.605 yr
Thorium-228	Naturally occurring background radiation (present in secular equilibrium with parent Ra-228 isotope); half-life <3 yr	--	1.91 yr
Thorium-230	Only potential source from naturally occurring background radiation (insufficient in growth time for Hanford introduced U as decay daughter of U-234)	--	77,000 yr
Thorium-232	Naturally occurring background radiation	--	14 billion yr
Thorium-234	Decayed daughter of U-238; in equilibrium with parent; half-life <3 yr	--	2.41 days
Tin-113	Half-life <3 yr	In-113m (1.658 hr half-life) and In-113 (stable)	115.1 days
Uranium-240	Half-life <3 yr	--	14.1 hr

Table 4-4. 100-K Soil Analytes Excluded from Further Consideration

Analyte	Exclusion Rationale	Daughters	Half-Life
Nonradionuclides			
Bismuth	No soil toxicity information available	--	--
Calcium	Essential nutrient	--	--
Chloride	Essential nutrient	--	--
Iron	Essential nutrient	--	--
Magnesium	Essential nutrient	--	--
Sodium	Essential nutrient	--	--
Potassium	Essential nutrient	--	--
Phosphate	Essential nutrient	--	--
Ammonia	No soil toxicity information available	--	--
Zirconium	No soil toxicity information available	--	--
Acetone	Laboratory contaminant	--	--
Bis(2-ethylhexyl) phthalate	Laboratory contaminant	--	--
Diethyl phthalate	Laboratory contaminant	--	--
Di-n-butylphthalate	Laboratory contaminant	--	--
Methylene chloride	Laboratory contaminant	--	--
Toluene	Laboratory contaminant	--	--

Review of the analytical data from the vadose zone RI soil samples indicated some of the total chromium and nickel results appeared anomalous compared to other results from neighboring intervals in the same boring and duplicate sample results. In some cases, these elevated chromium and nickel concentrations are also grouped with anomalous concentrations of other metals, including molybdenum. These metals are all constituents of various alloys of steel. The use of steel in drilling components is a standard method available to obtain environmental analytical samples and poses the potential of introducing some contamination attributable to the sampling approach. The shoes that were used on the split-spoons were made of 4140 alloy steel, the split-spoons were Drawn Over Mandrel 520 steel, and the stainless steel liners that were periodically used were 304 stainless. The 520 steel does not contain any chromium, molybdenum, or nickel and can, therefore, be discounted as a source of the elevated concentrations. The 4140 alloy steel contains between 0.8% and 1.1% chromium by weight and 0.15% to 0.25% molybdenum. The 304 stainless contains 18% to 20% chromium by weight and 8% to 12% nickel. Anomalous chromium or nickel results are discussed further in the context of the overall data set for each occurrence in the following subsections.

4.2.2.1 Nature and Extent of Contamination—116-K-2 Trench

The 116-K-2 Trench was used for disposal of diverted reactor effluent flows, including cooling water effluent, reactor floor drain effluents, and decontamination wastes. The location of the former trench is shown on Figure 4-1. The trench was excavated in 1955 as a replacement for the 116-K-1 Crib, measuring approximately 1,250 m (4,100 ft) long, 17 m (56 ft) wide at the top, and 5 m (16 ft) deep. Operational use occurred through 1971, with an estimated 300 billion L (80 million gal) of effluent discharged to the trench at flowrates up to 76,000 L/min (20,000 gal/min). The trench was backfilled in 1972 during shutdown activities at the 100-K Area.

The trench was investigated as part of the 1992 LFI for the 100-KR-1 OU (DOE/RL-93-78), with a borehole (A5748, Temporary Well 199-K-41) completed to 9 m (30 ft) bgs at the head end of the former trench. The site was remediated from February 2004 to October 2005, including excavation and disposal of contaminated soil to a maximum depth of 7.6 m (25 ft) bgs. Following the remediation, cleanup verification samples were collected from both the shallow zone and deep zone excavation surfaces. Based on evaluation of these samples, the site was determined to meet interim closure requirements.

The 116-K-2 waste site was selected for additional RI characterization in the 100-K Work Plan (DOE/RL-2008-46-ADD2) to address CSM uncertainties regarding contaminant distribution in the vadose zone. In addition, characterization was performed because residual contaminants had the potential to affect groundwater quality and contribute to localized Cr(VI) and tritium groundwater plumes. For the RI, two boreholes were sampled in 2010, one at the west (influent) end and the other on the east end of the trench. The western borehole (C7831, well 199-K-200) extended to a total depth of 18.1 m (59.3 ft) bgs, and the water table was encountered at 15.6 m (51.1 ft) bgs. The eastern borehole (C7832, well 199-K-201) extended to a total depth of 18.4 m (60.4 ft) bgs, and the water table was encountered at 15.3 m (50.1 ft) bgs.

Figure 4-1 shows the original 116-K-2 Trench footprint, the remediation footprint, and the locations of the LFI and RI boreholes. Tables 4-5 and 4-6 summarize the analytical data from the sampling events for the western and eastern ends of the trench, respectively, including LFI, RI, and cleanup verification sampling results above background concentrations. Figures 4-2, 4-3, and 4-4 present vertical profiles of analytes detected above background in the LFI, western RI, and eastern RI boreholes, respectively.

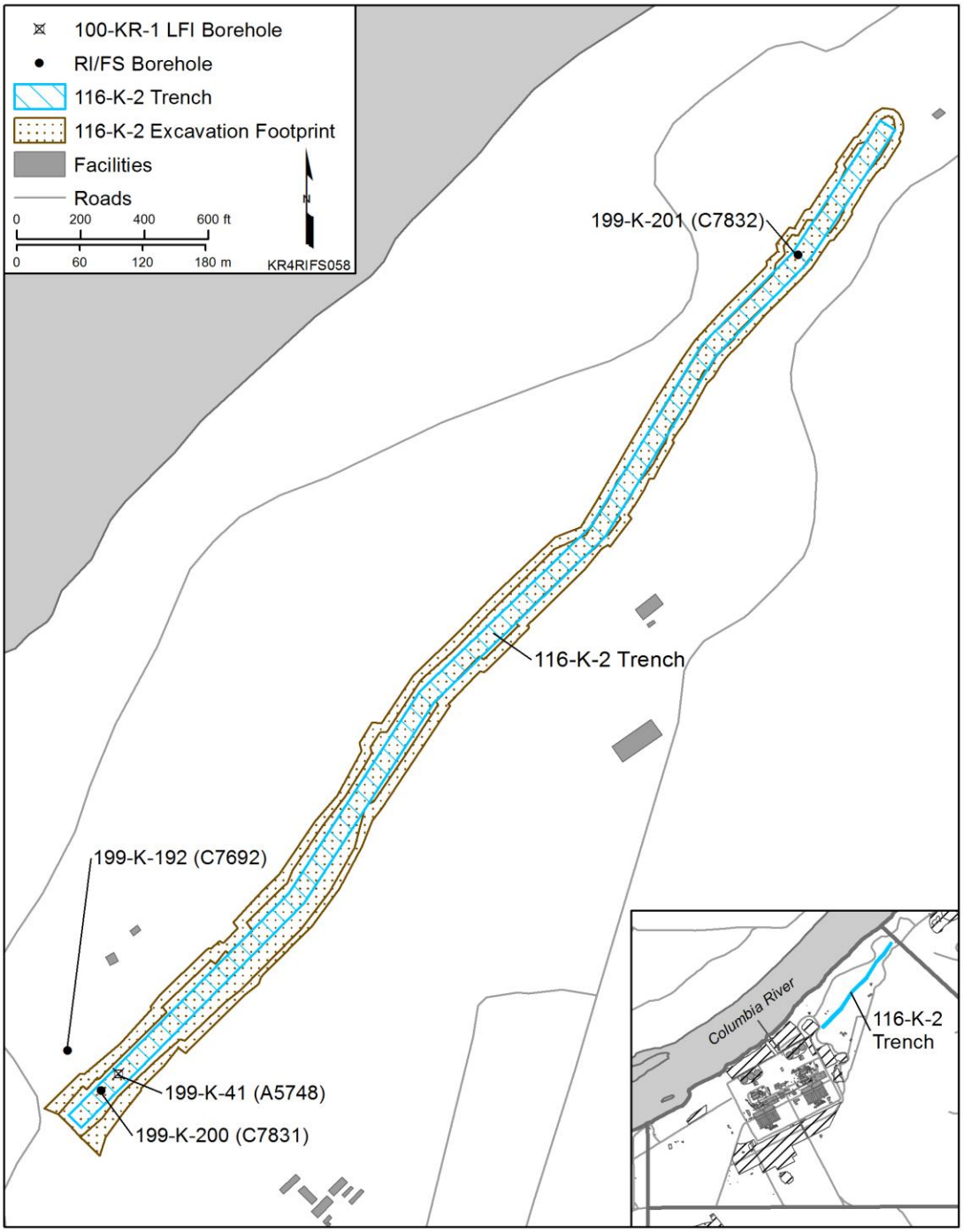


Figure 4-1. 116-K-2 Trench Remediation Footprint with LFI and RI Borehole Locations

In the western RI borehole (C7831), no radionuclides were detected from the uppermost sample interval about 7.9 m (26 ft) bgs, indicating that this material was backfill placed after remediation. The highest isotopic activities of cesium-137, cobalt-60, europium-152, nickel-63, plutonium-239/240, and strontium-90 were detected in the next interval at about 9.4 m (31 ft) bgs, with activities decreasing or undetected at greater depths. The observed activities are lower than those for verification sampling following remediation. Strontium-90 was the only radionuclide detected throughout the vadose zone profile, with a maximum concentration of 3.94 pCi/g decreasing to activities less than 2 pCi/g near and below the water table.

Cr(VI) was not detected in any of the samples from the western RI borehole (C7831), but total chromium above background was detected in several samples between about 9.4 and 13.7 m (31 and 45 ft) bgs. The maximum concentration of total chromium, 39.7 mg/kg, was at about 11 m (36 ft) bgs. Elevated nickel concentrations were observed coincident with elevated total chromium results, suggesting that these samples may have been affected by the steel used during drilling (see Section 4.2.2).

In the eastern RI borehole (C7832), cesium-137, cobalt-60, europium-152, europium-154, nickel-63, plutonium-239/240, and strontium-90 were detected in the upper sampling intervals from 6.6 to 8.5 m (21.8 to 27.8 ft) bgs. Observed activities are consistent with those for verification sampling following remediation. These isotopes were not detected at greater depths, with the exception of strontium-90. Strontium-90 activity levels decreased by an order of magnitude deeper in the vadose zone, but low activity detections continued intermittently to below the water table.

Cr(VI) was not detected in the upper samples from the eastern RI borehole, but was detected at up to 0.72 mg/kg in samples collected from the rewetted zone and below the water table. Elevated total chromium was detected in the upper sample intervals (6.6 to 10.0 m [21.8 to 32.9 ft] bgs), decreasing to background levels at greater depths. Elevated nickel concentrations were detected coincident with several, but not all, of the elevated total chromium results, suggesting that samples may have been affected by the steel used during drilling (see Section 4.2.2). Elevated concentrations of cadmium, mercury, and zinc were also detected in the uppermost sample intervals, decreasing to background levels below 9.1 m (30.0 ft) bgs.

Collectively, these data show that low levels of contamination remain in the deep vadose zone immediately below the previous remedial excavation. The majority of contaminants do not extend into the deeper vadose zone below 7.6 m (25 ft) bgs, but low activity levels of strontium-90 likely remain throughout the deep vadose zone underlying the former trench. No indications of a residual vadose zone source of Cr(VI) or tritium were identified in the RI samples.

Table 4-5. 116-K-2 Trench (West End)—Summary of Soil Contaminant Data

Analyte	Background	Concentration and Distribution													
		Cleanup Verification Data [a]				1992 LFI Borehole [b]					Remedial Investigation Borehole C7831 [c]				
		Shallow Zone [d]		Deep Zone		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (9.1 m/30 ft bgs)		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (17.9 m/58.6 ft bgs) [e]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)															
		Original	Decayed [f]	Original	Decayed [f]	Original	Decayed [f]		Original	Decayed [f]	Original	Decayed [f]		Original	Decayed [f]
Americium-241	N/A	ND	ND	ND	ND	13 (6.1/20)	12	7.4/24.3	U	N/A	U	N/A	N/A	U	N/A
Carbon-14	N/A	0.29	0.29	1.44	1.44	11 (6.1/20)	11	6.1/20	U	N/A	U	N/A	N/A	U	N/A
Cesium-137	N/A	1.10	0.84	117	88.8	1,900 (6.1/20)	1,100	8.4/27.5	U	N/A	1.04 (9.4/30.7)	0.886	9.9/32.5	U	N/A
Cobalt-60	N/A	0.023 (U)	N/A	4.23	0.873	370 (6.1/20)	14	9.1/30	0.077	0.003	0.299 (9.4/30.7)	0.119	9.4/30.7	U	N/A
Europium-152	N/A	0.626	0.338	76	41	1,600 (6.1/20)	440	8.4/27.5	U	N/A	0.625 (9.4/30.7)	0.436	9.4/30.7	U	N/A
Europium-154	N/A	0.129	0.0490	7.2	2.7	250 (6.1/20)	33	7.4/24.3	U	N/A	U	N/A	N/A	U	N/A
Europium-155	N/A	ND	ND	ND	ND	15 (6.1/20)	0.39	6.1/20	U	N/A	U	N/A	N/A	U	N/A
Nickel-63	N/A	1.77	1.63	650	600	ND	ND	ND	ND	ND	112 (9.4/30.7)	107	9.9/32.5	U	N/A
Plutonium-238	N/A	ND	ND	ND	ND	2.1 (6.1/20)	1.7	6.1/20	U	N/A	U	N/A	N/A	U	N/A
Plutonium-239/240	N/A	0.024 (U)	N/A	4.7	4.7	44 (6.1/20)	44	7.4/24.3	U	N/A	0.042 (9.4/30.7)	0.042	9.4/30.7	U	N/A
Strontium-90	N/A	0.201	0.151	6.3	4.7	15 (6.1/20)	8.3	9.1/30	2.5	1.4	3.94 (9.4/30.7)	3.34	17.9/58.6	1.60	1.35
Nonradionuclides (mg/kg)															
Antimony	0.130	ND		ND		ND		ND	ND		0.465 (13.0/42.5)		15.2/49.9	U	
Barium	132	ND		ND		122 (<BG) (9.1/30)		N/A	122 (<BG)		160 (13.0/42.5)		13.0/42.5	26.9 (<BG)	
Chromium	18.5	ND		ND		153 (6.1/20)		7.4/24.3	14.9 (<BG)		39.7 (10.8/35.5)		13.0/42.5	13.4 (<BG)	
Copper	22	ND		ND		44.9 (6.1/20)		9.1/30	30.7		23.4 (13.0/42.5)		13.0/42.5	15.4 (<BG)	
Cr(VI)	0	0.27 [g]		2.4		ND		ND	ND		U [h]		N/A	U	
Mercury	0.0131	ND		ND		3.9 (6.1/20)		8.4/27.5	U		0.079 (9.4/30.7)		12.1/39.7	U	
Molybdenum	0.47	ND		ND		ND		ND	ND		3.38 (13.0/42.5)		17.9/58.6	0.864	
Nickel	19.1	ND		ND		14 (<BG) (6.1/20)		N/A	10.1 (<BG)		24.5 (10.8/35.5)		10.8/35.5	10.5 (<BG)	
Silver	0.78	ND		ND		1.5 (9.1/30)		9.1/30	1.5		U		N/A	U	
Strontium	0.167	ND		ND		ND		ND	ND		34.4 (13.0/42.5)		17.9/58.6	22.1	
Thallium	0.185	ND		ND		U		N/A	U		U		N/A	U	
Tin	N/A	ND		ND		ND		ND	ND		1.09 (11.3/37.2)		15.2/49.9	U	

Table 4-5. 116-K-2 Trench (West End)—Summary of Soil Contaminant Data

Analyte	Background	Concentration and Distribution							
		Cleanup Verification Data [a]		1992 LFI Borehole [b]			Remedial Investigation Borehole C7831 [c]		
		Shallow Zone [d]	Deep Zone	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (9.1 m/30 ft bgs)	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (17.9 m/58.6 ft bgs) [e]
Zinc	67.8	ND	ND	143 (6.1/20)	6.1/20	35.5 (<BG)	42.7 (<BG) (7.6/24.9)	N/A	21.2 (<BG)
Tetrachloroethene	N/A	ND	ND	0.004 (6.1/20) [i]	7.4/24.3	U	U	N/A	U
Trichloroethene	N/A	ND	ND	0.002 (6.1/20) [i]	6.1/20	U	U	N/A	U

References: CVP-2006-00001, *Cleanup Verification Package for the 116-K-2 Effluent Trench.*

DOE/RL-93-78, *Limited Field Investigation Report for the 100-KR-1 Operable Unit.*

a. Verification sample results represent the 95% upper confidence limit concentration from the given decision unit(s) from CVP-2006-00001. Values that are followed by (U) indicate that all results in the associated data set were qualified as non-detected. The maximum depth of interim remedial action at 116-K-2 was 7.6 m (25 ft) bgs.

b. LFI borehole data obtained from DOE/RL-93-78 and HEIS. Analytes that were not detected above background in the cleanup verification data, LFI data, and RI data are not listed.

c. Data obtained from HEIS. Analytes that were not detected above background in the cleanup verification data, LFI data, and RI data are not listed.

d. Shallow zone value represents excavation footprint from areas shallower than 4.6 m (15 ft) bgs unless otherwise noted.

e. The maximum depth from which samples were collected is below the water table. The water table was encountered at 15.6 m (51.1 ft) bgs.

f. Decay-corrected to 2017. Cleanup verification 95% UCL values obtained using data sets with no reported detections are not decayed.

g. Result is from overburden.

h. None of the 13 vadose/sediment samples collected to characterize contamination in borehole C7831 detected Cr(VI). However, a field split sample collected for QA/QC purposes at 13.7 m (44.9 ft) bgs reported Cr(VI) at 0.982 mg/kg.

i. Result is an estimated value from detection(s) near the MDL. Data are not presented in profiles in Figure 4-2.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
LFI = limited field investigation
MDL = method detection limit
N/A = not applicable
ND = no data
QA/QC = quality assurance/quality control
RI = remedial investigation
U = undetected
UCL = upper confidence limit

Table 4-6. 116-K-2 Trench (East End)—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution									
	Background	Cleanup Verification Data [a]				Remedial Investigation Borehole C7832 [b]				
		Shallow Zone [c]		Deep Zone		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (17.5 m/57.7 ft bgs Unless Otherwise Noted) [d]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)										
		Original	Decayed [e]	Original	Decayed [e]	Original	Decayed [e]		Original	Decayed [e]
Carbon-14	N/A	0.70	0.70	1.26	1.26	U	N/A	N/A	U	N/A
Cesium-137	N/A	0.56	0.43	130	98.7	177 (6.6/21.8)	151	8.5/27.8	U	N/A
Cobalt-60	N/A	0.018 (U)	N/A	2.48	0.512	1.71 (6.6/21.8)	0.81	8.5/27.8	U	N/A
Europium-152	N/A	0.17 [f]	0.092	62.7	33.9	57.5 (7.8/25.7)	40.1	8.5/27.8	U	N/A
Europium-154	N/A	0.056 (U)	N/A	5.4	2.1	4.78 (7.2/23.5)	2.72	7.8/25.7	U	N/A
Nickel-63	N/A	3.56	3.28	880	810	422 (6.6/21.8)	402	8.5/27.8	U	N/A
Plutonium-239/240	N/A	0.023 (U)	N/A	6.9	6.9	3.59 (6.6/21.8)	3.59	7.8/25.7	U	N/A
Strontium-90	N/A	0.143	0.107	7.12	5.35	5.45 (6.6/21.8)	4.61	16.0/52.5	U	N/A
Nonradionuclides (mg/kg)										
Antimony	0.130	ND		ND		0.273 (10.6/34.9)		10.6/34.9	U	
Cadmium	0.563	ND		ND		1.85 (6.6/21.8)		7.8/25.7	0.072 (<BG)	

Table 4-6. 116-K-2 Trench (East End)—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Cleanup Verification Data [a]		Remedial Investigation Borehole C7832 [b]		
		Shallow Zone [c]	Deep Zone	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (17.5 m/57.7 ft bgs Unless Otherwise Noted) [d]
Carbon Disulfide	N/A	ND	ND	0.00229 (11.4/37.4)	11.4/37.4	U
Chromium	18.5	ND	ND	81.6 (6.6/21.8)	12.2/40.0	12.9 (<BG)
Copper	22	ND	ND	23.8 (6.6/21.8)	6.6/21.8	9.0 (<BG)
Cr(VI)	N/A	0.39	5.3	0.72 (15.1/49.7)	16.9/55.3	U
Mercury	0.0131	ND	ND	0.745 (7.2/23.5)	9.1/30.0	U
Molybdenum	0.47	ND	ND	2.82 (12.9/42.2)	17.6/57.7	1.39
Nickel	19.1	ND	ND	21.3 (10.0/32.9)	10.0/32.9	9.06 (<BG)
Strontium	N/A	ND	ND	51.3 (15.1/49.7)	17.6/57.7	21.9
Styrene	N/A	ND	ND	0.00992 (12.9/42.2)	12.9/42.2	U
Tin	N/A	ND	ND	2.87 (6.6/21.8)	17.6/57.7	1.03

Table 4-6. 116-K-2 Trench (East End)—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Cleanup Verification Data [a]		Remedial Investigation Borehole C7832 [b]		
		Shallow Zone [c]	Deep Zone	Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (17.5 m/57.7 ft bgs Unless Otherwise Noted) [d]
Zinc	67.8	ND	ND	209 (6.6/21.8)	7.8/25.7	20.4 (<BG)

Reference: CVP-2006-00001, *Cleanup Verification Package for the 116-K-2 Effluent Trench.*

a. Verification sample results represent the 95% upper confidence limit concentration from the given decision unit(s) from CVP-2006-00001. Values that are followed by (U) indicate that all results in the associated data set were qualified as non-detected. The maximum depth of interim remedial action at 116-K-2 was 7.6 m (25 ft) bgs.

b. Data obtained from HEIS. Analytes that were not detected above background in the cleanup verification and RI data are not listed.

c. Shallow zone value represents excavation footprint from areas shallower than 4.6 m (15 ft) bgs unless otherwise noted.

d. The maximum depth from which samples were collected is below the water table. The water table was encountered at 15.3 m (50.1 ft) bgs.

e. Decay-corrected to 2017. Cleanup verification 95% UCL values obtained using data sets with no reported detections are not decayed.

f. Result is from overburden.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
ND = no data
RI = remedial investigation
U = undetected
UCL = upper confidence limit

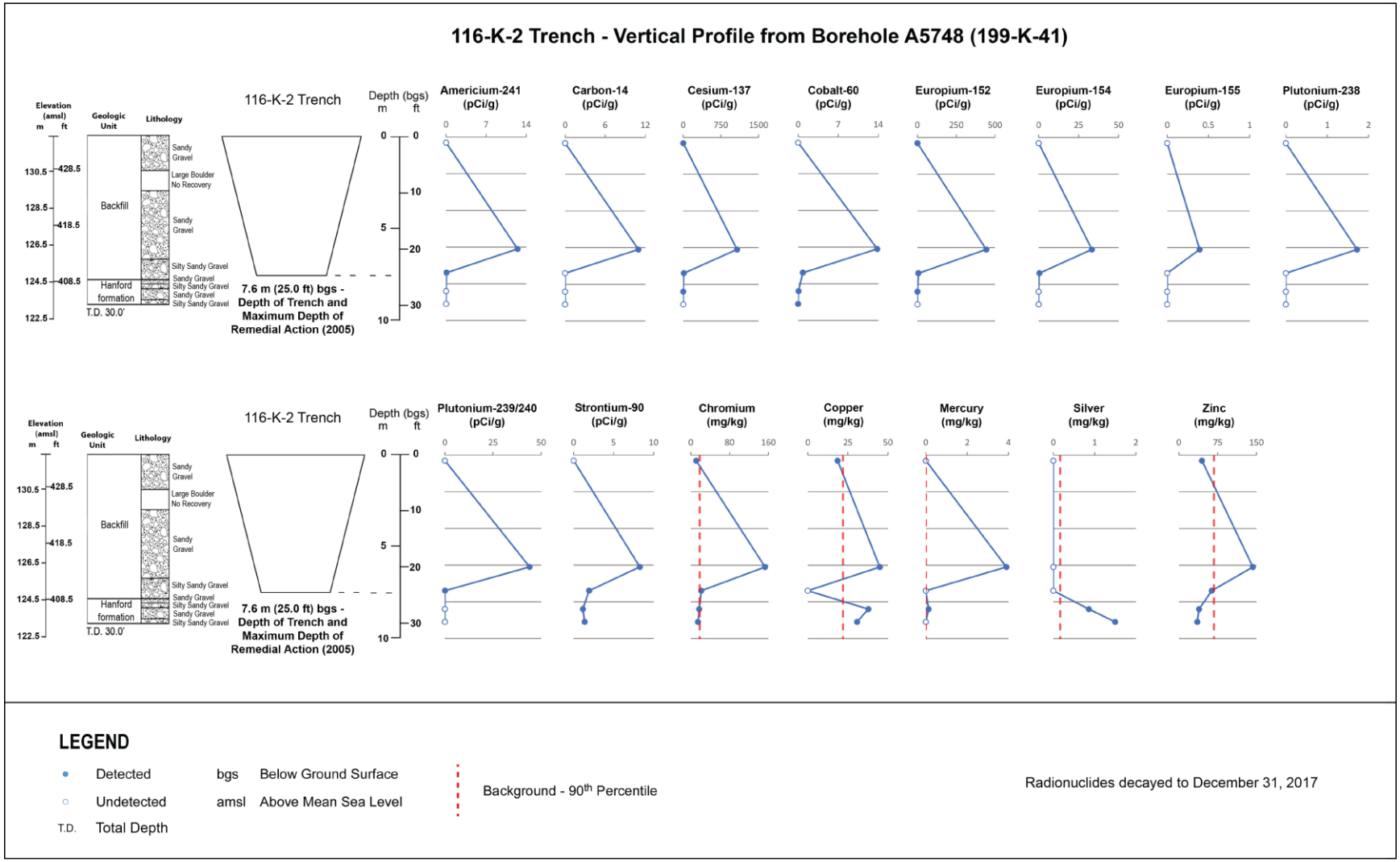


Figure 4-2. 116-K-2 Trench Vertical Profile from LFI Borehole A5748 (199-K-41)

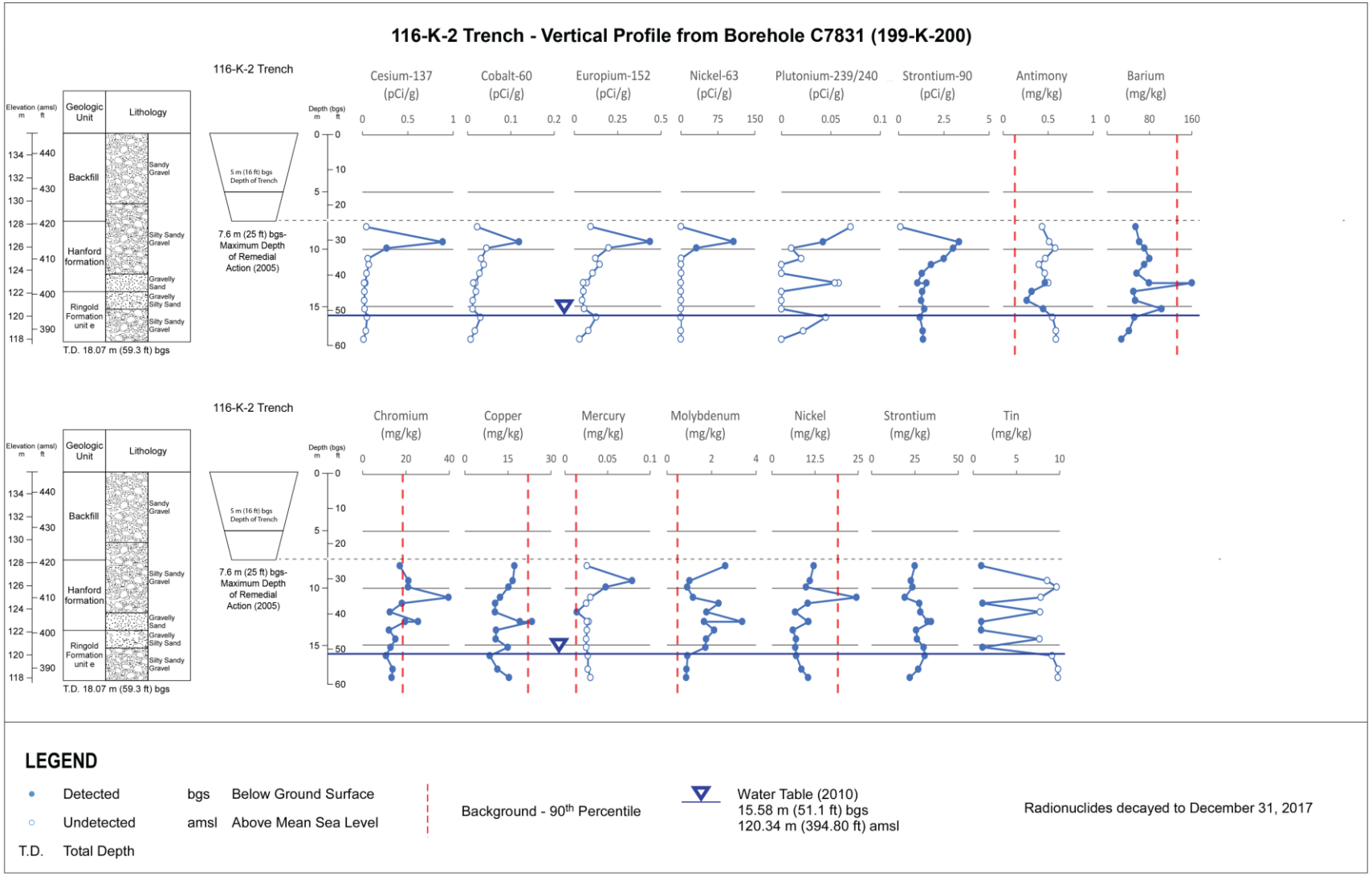


Figure 4-3. 116-K-2 Trench Vertical Profile from RI Borehole C7831 (199-K-200)

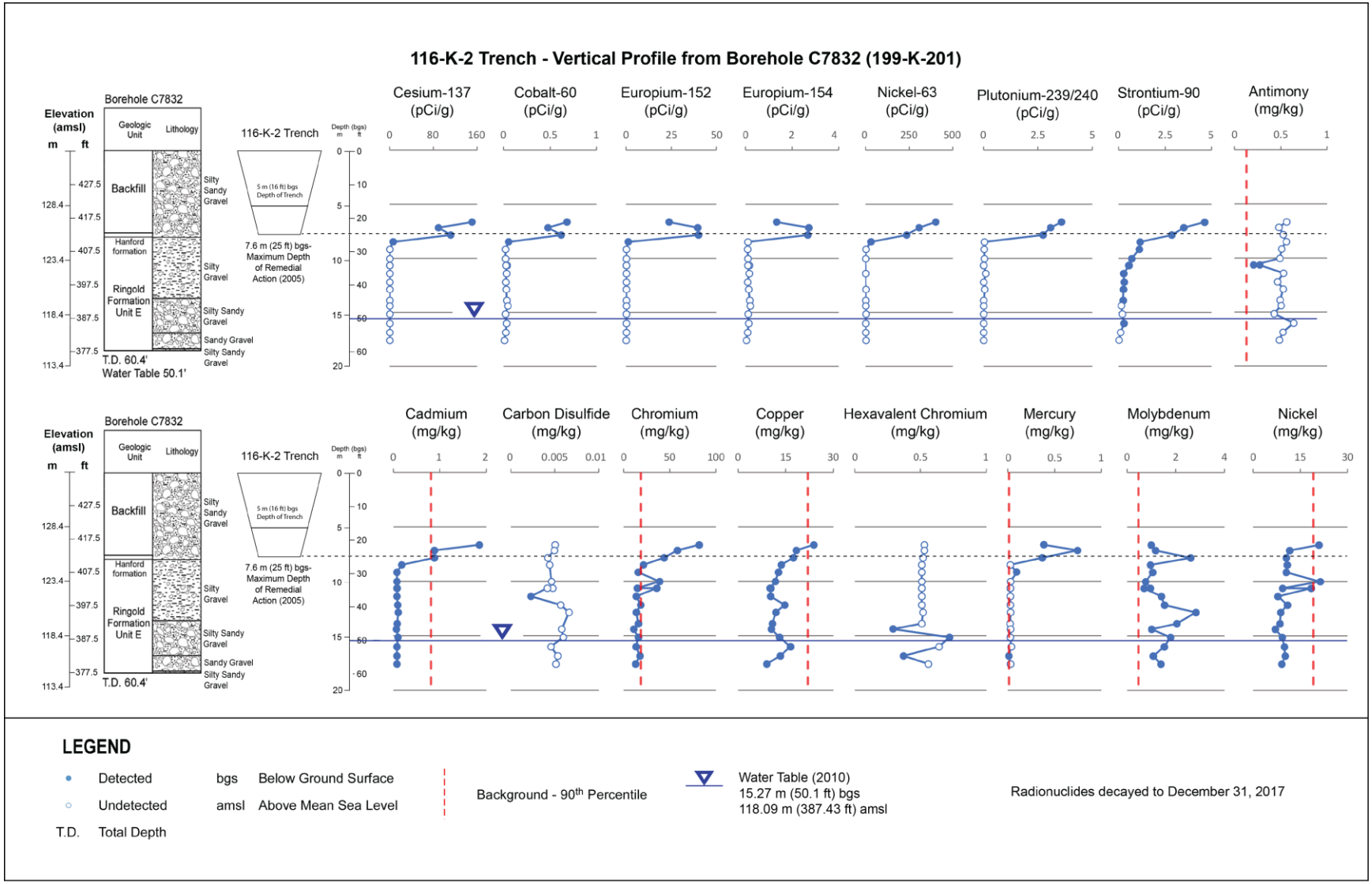


Figure 4-4. 116-K-2 Trench Vertical Profile from RI Borehole C7832 (199-K-201) (1 of 2)

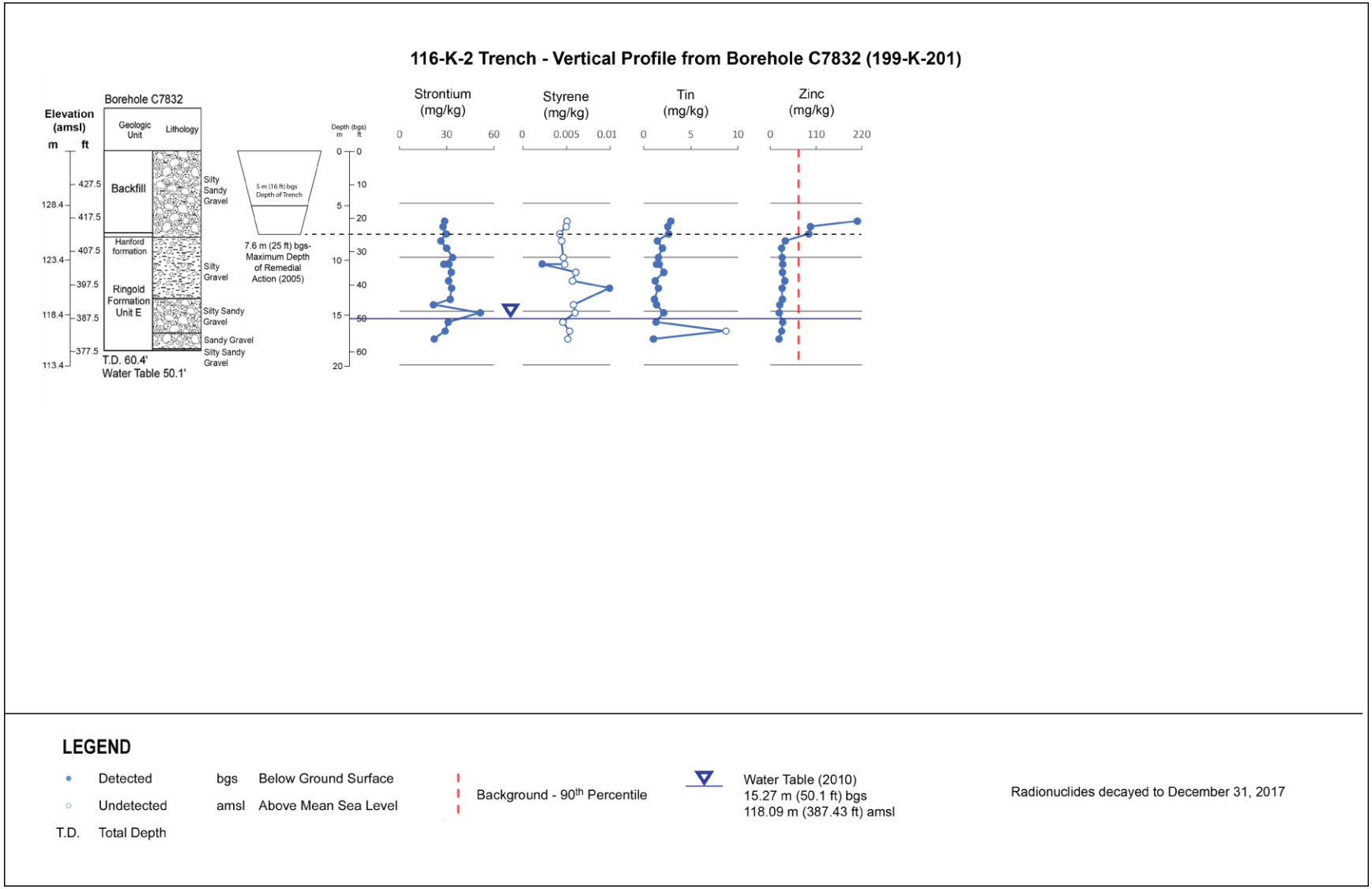


Figure 4-4. 116-K-2 Trench Vertical Profile from RI Borehole C7832 (199-K-201) (2 of 2)

4.2.2.2 Nature and Extent of Contamination—116-KE-3 Crib

The 116-KE-3 Crib was used for overflow disposal of an undetermined volume of sub-basin drainage from the KE FSB from 1955 to 1971. The crib consisted of subgrade coarse gravel overlain by a distribution drain field approximately 8.8 m (29 ft) bgs. A 20-cm (8-in.) steel reverse well also extended from the distribution piping to approximately 3 m (10 ft) below the water table.

Remediation was performed at the site and surrounding area between September 2009 and May 2012, consisting of excavation and disposal of piping, gravel, and contaminated soil to a maximum depth of 12.5 m (41 ft) bgs. Further remediation could not be completed at the location due to potential impacts to the structural integrity of the KE Reactor that would result from layback for a deeper excavation. The reverse well was capped and covered with a small concrete pad and the area was partially backfilled to prevent contamination spread and support additional site characterization activities. Radiological surveys of the completed excavation area near the crib before backfill measured contamination in excess of 1,000,000 dpm/100 cm^2. The uppermost borehole sampling interval from the supplemental characterization, discussed in the following paragraphs, did not substantiate this high radiological survey result.

The 116-KE-3 waste site was selected for additional supplemental characterization under the RI to address CSM uncertainties regarding contaminant distribution and mobility, as the site was suspected to be a secondary source of groundwater contamination. One borehole (C8796, well 199-K-221) was completed and sampled through the site in 2015. The borehole was placed in the partially backfilled site excavation, approximately 3 m (10 ft) below surrounding grade and extended to a total depth of 31.9 m (104.6 ft) bgs. The water table was encountered at 18.1 m (59.3 ft) bgs below the surface level at the borehole.

Figure 4-5 shows the original 116-KE-3 footprint, the remediation footprint around the KE FSB, and the location of the RI borehole. Table 4-7 summarizes the analytical data from the borehole. Figure 4-6 presents vertical profiles of analytes detected above background in the borehole.

Low activities of cesium-137, cobalt-60, europium-152, and europium-154 were detected only in the uppermost borehole sampling interval and were not detected at greater depth. Strontium-90 was detected throughout the vadose zone, with the highest activity levels coincident with the screened depth interval of the reverse well. Tritium and plutonium-239/240 were not detected in the upper sampling intervals but were detected in a portion of the sampling intervals coincident with the screened depth interval of the reverse well. Activity levels throughout the borehole were lower than the high activity levels noted in the radiological survey performed following remediation. Slightly elevated Cr(VI) was detected at the depth of the screened interval of the reverse well and at lower concentrations (<1 mg/kg) in other sampling intervals.

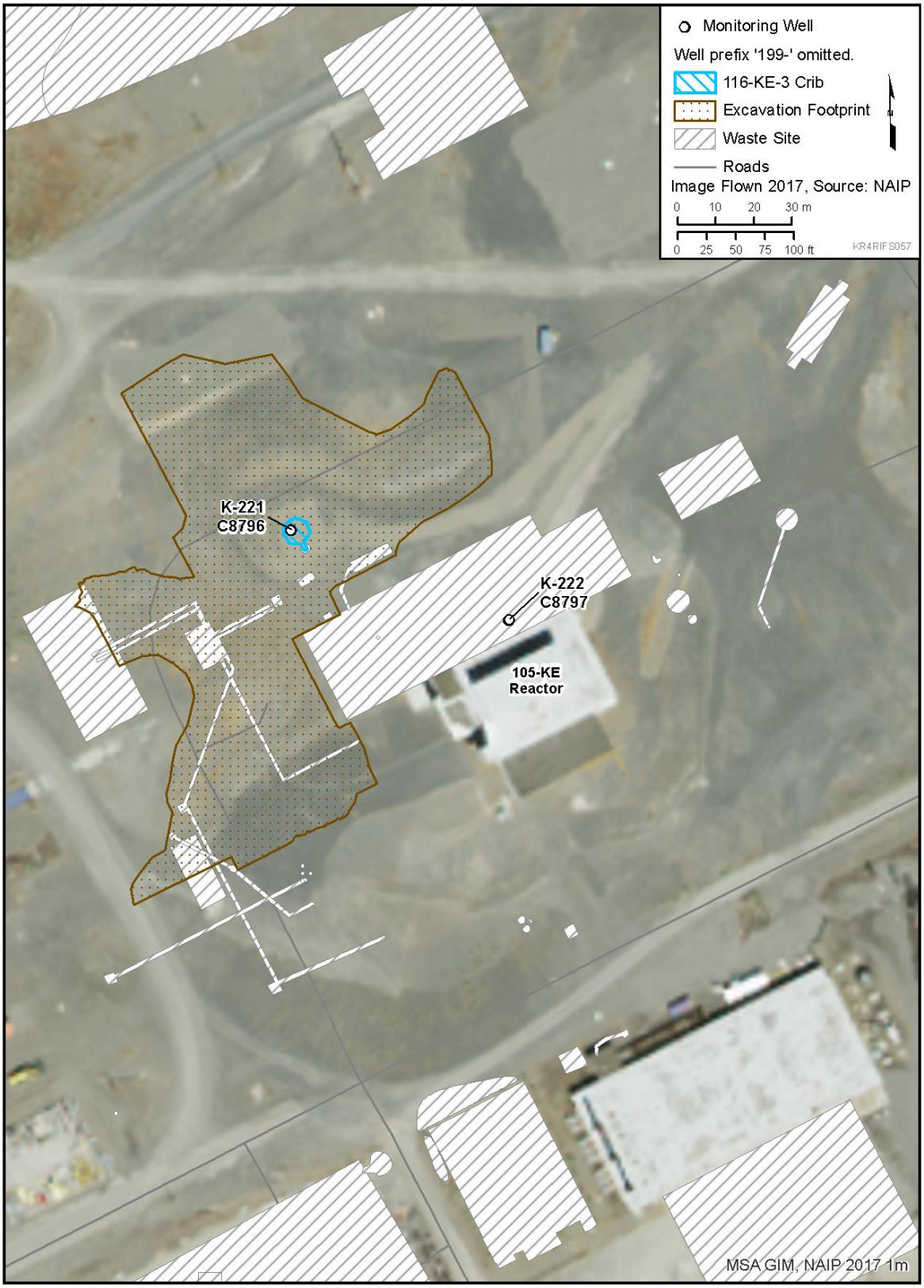


Figure 4-5. 116-KE-3 and UPR-100-K-1 Borehole Locations

Table 4-7. 116-KE-3 Crib—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Remedial Investigation Borehole C8796 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (31.9 m/104.6 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed [c]
Cesium-137	N/A	0.341 (8.4/27.5)	0.326	17.2/56.3	U	N/A
Cobalt-60	N/A	0.0766 (8.4/27.5)	0.0589	8.4/27.5	U	N/A
Europium-152	N/A	2.17 (8.4/27.5)	1.96	8.7/28.5	U	N/A
Europium-154	N/A	0.244 (8.4/27.5)	0.208	8.4/27.5	U	N/A
Plutonium-239/240	N/A	3.28 (17.2/56.3)	3.28	18.0/59.0	U	N/A
Strontium-90	N/A	90.0 (15.7/51.4)	85.8	18.0/59.0	U	N/A
Tritium	N/A	118 (16.1/52.8)	105	18.0/59.0	U	N/A
Nonradionuclides (mg/kg)						
Chromium	18.5	22.3 (15.4/50.5)		15.4/50.5	9.09	
Cr(VI)	N/A	2.04 (17.2/56.3)		26.3/86.3	U	

a. Data obtained from HEIS. Analytes that were not detected above background are not listed. The borehole was sited within an excavation, approximately 3 m (10 ft) below the surrounding surface level. The surface depth at the top of the borehole is used as the reference surface datum in this table.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 18.1 m (59.3 ft) bgs.

c. Decay-corrected to 2017.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

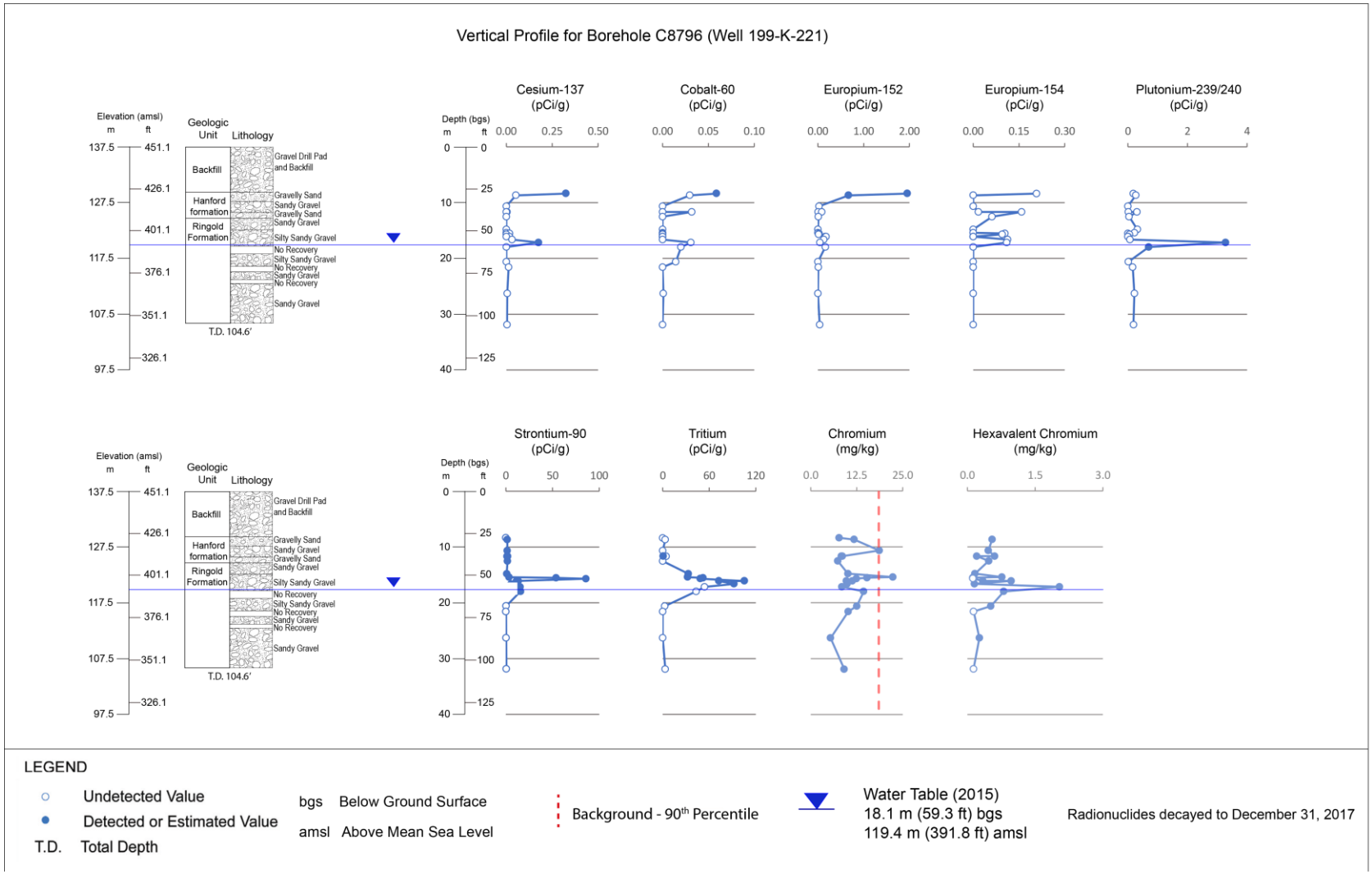


Figure 4-6. 116-KE-3 Site Vertical Profile from RI Borehole C8796 (199-K-221)

These data show that low levels of contamination remain in the deep vadose zone and saturated zone beneath the site. The highest contamination levels appear to be coincident with the screened depth of the reverse well, which is within the periodically rewetted zone and extends to below the water table.

4.2.2.3 Nature and Extent of Contamination—UPR-100-K-1 Site

The UPR-100-K-1 site addresses contaminated vadose zone soil resulting from contaminated water leakage beneath the KE FSB. Variable leakage rates, up to 49 L/min (13 gal/min) occurred from construction joints between the FSB and the main reactor building during the operational and post-operational period. The volume of water released in these leaks is unknown but could be as much as 100 million L (26 million gal).

The KE FSB was demolished from 2008 to 2009, and soil remediation was performed at the surrounding area between September 2009 and May 2012. Further remediation could not be performed at the UPR-100-K-1 site due to potential impacts to the structural integrity of the KE Reactor that would result from layback for a deeper excavation. Soil samples collected from beneath the former FSB showed elevated activities of cesium-137 (up to 22,100 pCi/g), strontium-90 (up to 18,100 pCi/g), americium-241 (up to 1,170 pCi/g), plutonium-238 (up to 237 pCi/g), and plutonium-239/240 (up to 1,770 pCi/g). The site area was partially backfilled to near-previous grade level to prevent contamination spread and support additional site characterization activities.

In 2011, 20 temporary borings were installed around the footprint of the former FSB using direct push technology to facilitate radiological logging of remaining subsurface soils. Seven of these borings were driven at approximately 45-degree slants beneath the KE Reactor. Radiological logging showed that the deepest and highest contamination was present under the reactor foundation between the northeast corner of the building and the eastern edge of the discharge chute to the FSB, with a maximum measured equivalent cesium-137 activity of 3,370,000 pCi/g. High activity levels were present throughout the FSB footprint areas investigated except for the north-central area of the former FSB.

The UPR-100-K-1 waste site was selected for additional supplemental characterization under the RI to address remaining CSM uncertainties regarding contaminant distribution and mobility, as the site was suspected to be a secondary source of groundwater contamination. One borehole (C8797, well 199-K-222) was completed and sampled through the site in 2015. The borehole extended to a total depth of 36.2 m (118.7 ft) bgs, and the water table was encountered at 22.5 m (73.9 ft) bgs.

Figure 4-5 shows the original 116-KE-3 footprint, the remediation footprint around the KE FSB, and the location of the RI borehole. Table 4-8 summarizes the analytical data from the borehole. Figure 4-7 presents vertical profiles of analytes detected above background in the borehole.

Table 4-8. UPR-100-K-1 Site—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Remedial Investigation Borehole C8797 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (35.9 m/117.8 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed [c]
Americium-241	N/A	3,220 (8.1/26.5)	3,210	22.9/75.1	U	N/A
Carbon-14	N/A	2.19 (8.1/26.5)	2.19	8.1/26.5	U	N/A
Cesium-137	N/A	35,100 (8.1/26.5)	33,500	23.1/76	U	N/A
Cobalt-60	N/A	7.07 (22.9/75.1)	5.44	22.9/75.1	U	N/A
Europium-154	N/A	9.71 (8.4/27.7)	8.26	10.6/34.8	U	N/A
Plutonium-238	N/A	502 (8.1/26.5)	494	22.9/75.1	U	N/A
Plutonium-239/ 240	N/A	3,460 (8.1/26.5)	3,460	22.9/75.1	U	N/A
Strontium-90	N/A	36,400 (8.1/26.5)	34,700	25.5/83.7	U	N/A
Technetium-99	N/A	3.4 (23.2/76.0)	3.4	24.5/80.4	U	N/A
Uranium-233/ 234	1.1	15.7 (8.1/26.5)	15.7	22.1/72.5	0.658 (<BG)	N/A
Uranium-235	0.109	0.929 (22.9/75.1)	0.929	22.9/75.1	U	N/A
Uranium-238	1.06	10.9 (8.1/26.5)	10.9	22.9/75.1	0.625 (<BG)	N/A
Nonradionuclides (mg/kg)						
Cr(VI)	N/A	1.34 (24.5/80.4)		31.5/103.3	U	

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 22.5 m (73.9 ft) bgs.

c. Decay-corrected to 2017.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

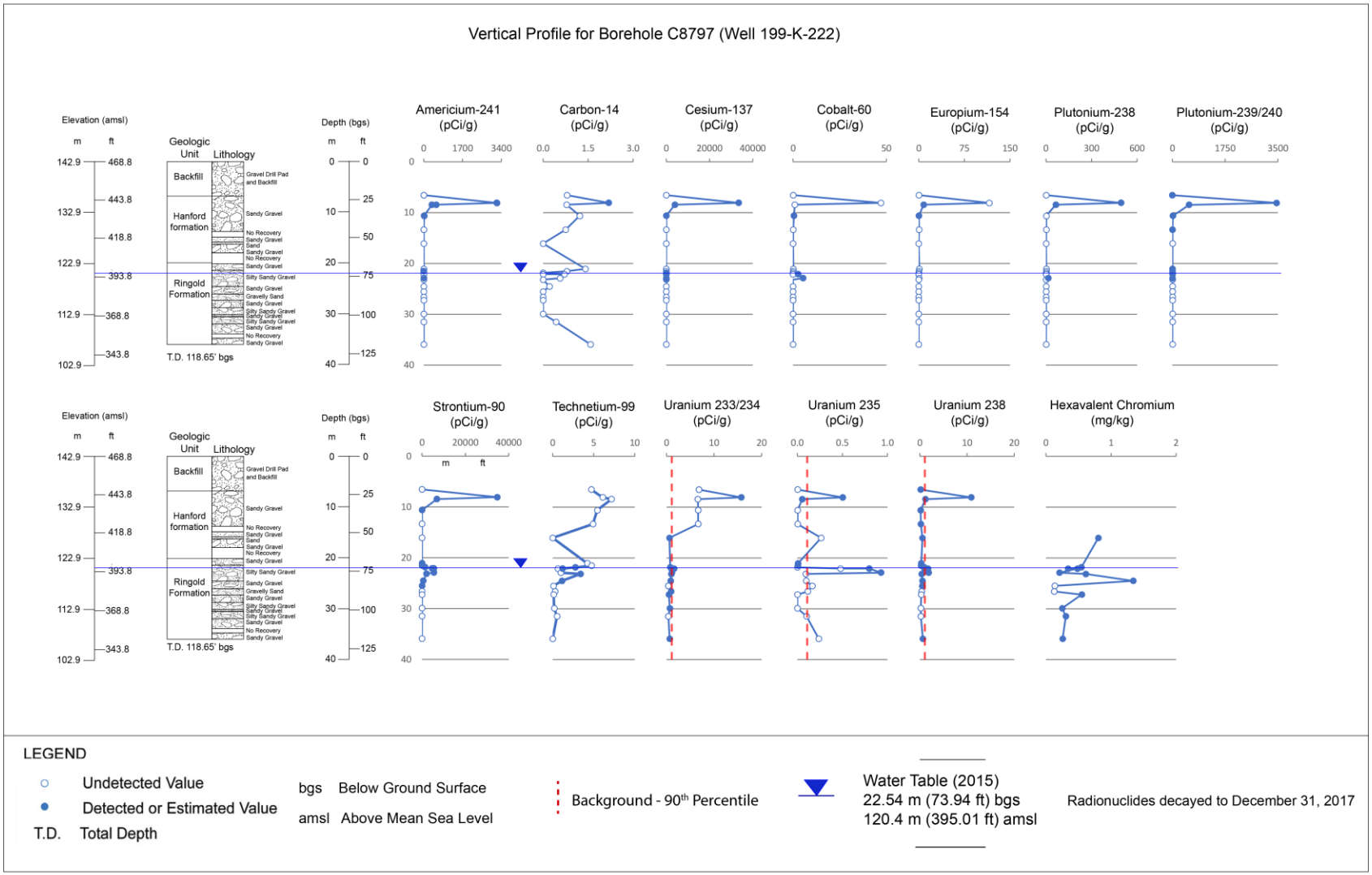


Figure 4-7. UPR-100-K-1 Site Vertical Profile from RI Borehole C8797 (199-K-222)

Results from the borehole showed high levels of americium-241, cesium-137, cobalt-60, plutonium-238, plutonium-239/240, strontium-90 uranium-233/234, and uranium-238 immediately below the depth of previous excavation. Radionuclides generally were not detected above background levels deeper in the vadose zone but were detected at low activities above background in the periodically rewetted zone, as shown in Figure 4-7. Strontium-90 activity levels increased more within the periodically rewetted zone and into the saturated zone, with measured activity levels up to 5,720 pCi/g at the groundwater interface. Low concentrations of Cr(VI) (<1 mg/kg) were observed in most of the vadose zone sampling intervals.

Collectively, the site data are consistent with the site history. The highest contaminant levels are present directly beneath the former release area, but elevated contamination is present directly beneath much of the former FSB footprint. Contamination has been driven deeper beneath the former release area, most notably strontium-90, which is more mobile than other fission products. Historical leaks and releases during operations, which are no longer occurring, were the driving forces for contaminant transport.

4.2.3 Characterization of Soil Samples from RI Monitoring Wells

To support the 100-K RI, nine wells were completed to characterize contamination in the unconfined aquifer and four additional wells were completed to characterize contaminants beneath the unconfined aquifer in the RUM, as described in the 100-K Work Plan (DOE/RL-2008-46-ADD2) and 100-K SAP (DOE/RL-2009-41). These wells are identified in Table 4-9, and well locations are shown in Figure 2-1 and Appendix A. Per the SAP, soil samples were collected during drilling for all wells at 4.6, 3.0, 1.5, and 0.61 m (15, 10, 5, and 2 ft) above the water table, at the water table, and 1.5 m (5 ft) below the water table. Additional soil samples were collected for some wells. Analytical results for soil above and below the groundwater table are presented in the following subsections.

Table 4-9. Identification of 100-K RI Wells

Well Identification	Borehole Identification	RI Well ID [a]
199-K-183	C7683	Well 1
199-K-184	C7684	RUM Well 1
199-K-185	C7685	Well 2
199-K-186	C7686	Well 9
199-K-187	C7687	Well 3
199-K-188	C7688	RUM Well 3
199-K-189	C7689	Well 5
199-K-190	C7690	Well 4
199-K-191	C7691	Well 6
199-K-192	C7692	RUM Well 2
199-K-193	C7693	Well 7
199-K-194	C7694	Well 8
199-K-195	C7695	RUM Well 4

Reference: DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units.*

a. Wells for the 100-K RI are identified and described in the 100-K Work Plan (DOE/RL-2008-46-ADD2).

RUM = Ringold Formation upper mud

4.2.3.1 199-K-183

Well 199-K-183 (RI Well 1) was located approximately 290 m (940 ft) west of the KW Reactor to define the upgradient extent of Cr(VI) in groundwater. During drilling, the water table was encountered at 19.6 m (64.2 ft) bgs. Table 4-10 summarizes the analytical data from the borehole. Figure 4-8 presents vertical profiles of analytes detected above background in the borehole.

Table 4-10. Well 199-K-183—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7683 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (23.6 m/77.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Antimony	0.130	4.68 (17.2/56.5)	23.6/77.5	1.19
Chromium	18.5	53.6 (17.2/56.5) [c]	20.2/66.3	12.7 (<BG)
Cr(VI)	N/A	0.28 (22.1/72.5)	23.6/77.5	0.10
Lead	10.2	185 (17.2/56.5)	23.6/77.5	38.7
Molybdenum	0.47	5.06 (17.2/56.5)	23.6/77.5	2.24
Nickel	19.1	30.4 (17.2/56.5) [c]	17.2/56.5	7.2 (<BG)
Strontium	N/A	31.4 (17.2/56.5)	23.6/77.5	13.0

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 19.6 m (64.2 ft) bgs.

c. Chromium and nickel concentrations in the duplicate sample collected at 17.2 m (56.5 ft) bgs are elevated and anomalous. Results in this duplicate sample are approximately two times that measured in the primary sample for chromium and nickel (27.0 and 18.2 mg/kg, respectively). Nickel results did not exceed background in any other samples from this borehole.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable

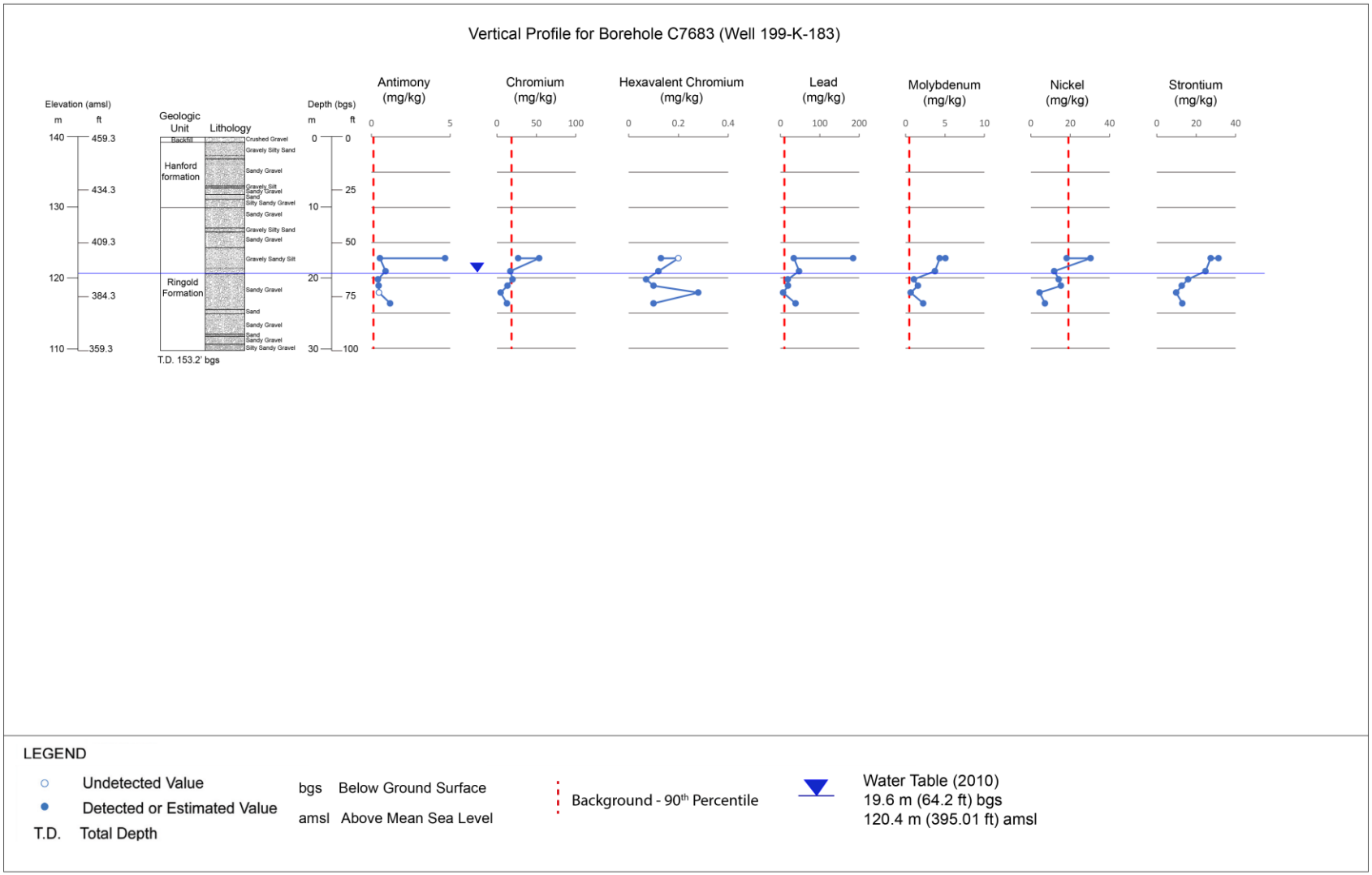


Figure 4-8. Vertical Profile from Well 199-K-183

No radionuclides were detected in the borehole samples. Cr(VI) was detected at low concentrations in all sample intervals. Elevated total chromium (53.6 mg/kg) and nickel (30.4 mg/kg) were detected in a duplicate sample at approximately two times the concentrations reported in the associated primary sample (27 and 18.2 mg/kg, respectively). Nickel was not detected above background in any other samples from this borehole. Molybdenum results were also elevated in both samples, and concentrations decrease in samples collected at greater depths. As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components. Concentrations of lead greater than background were measured in nearly all samples, with a maximum concentration of 185 mg/kg in the primary sample collected at 17.2 m (56.5 ft) bgs. Lead was elevated in the duplicate sample, but the concentration was lower (56.5 mg/kg). Samples from greater depth at 18.2 and 23.6 m (59.7 and 77.5 ft) bgs have similar concentrations of lead (47.6 and 38.7 mg/kg, respectively).

4.2.3.2 199-K-184

Well 199-K-184 (RI well R1) was sited downgradient of the 183-KW water treatment facility and upgradient of the KW Reactor. Samples were collected from about 2.4 to 25.6 m (8 to 84 ft) bgs. During drilling, the water table was encountered at 23.4 m (76.7 ft) bgs. Table 4-11 summarizes the analytical data from the borehole. Figure 4-9 presents vertical profiles of analytes detected above background in the borehole.

No radionuclides were detected in the borehole samples. Cr(VI) was detected at low concentrations in four of the sample intervals. The highest detection, 0.97 mg/kg, occurred in a duplicate sample collected at about 14.3 m (47 ft) bgs. Cr(VI) was not detected in the primary sample from this interval. Three other Cr(VI) detections up to 0.24 mg/kg occurred in C7684. Total chromium was slightly above background in samples collected at about 16.0 m (52.5 ft) bgs and above the water table (20.4 to 23.6 m [66.9 to 77.4 ft] bgs). Single detections of lead and copper, both at levels slightly above background, and an isolated detection of arsenic (11.5 mg/kg) at 6.2 m (20.3 ft) bgs were reported.

Table 4-11. Well 199-K-184—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7684 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (65.1 m/213.6 ft bgs) [b]
Nonradionuclides (mg/kg)				
Antimony	0.130	0.269 (13.0/42.5)	13.0/42.5	U
Chromium	18.5	26.9 (20.4/67.0)	23.6/77.3	11.4 (<BG)
Copper	22	24.5 (20.4/67.0)	20.4/67.0	12.3 (<BG)
Cr(VI)	N/A	0.97 (14.3/47.0)	17.6/57.7	U
Lead	10.2	12.7 (6.2/20.3)	6.2/20.3	0.73 (<BG)
Lithium	13.3	17.8 (6.1/20.3)	6.1/20.3	6.51 (<BG)
Molybdenum	0.47	4.13 (20.4/67.0)	25.5/83.6	1.30 [c]

Table 4-11. Well 199-K-184—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7684 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (65.1 m/213.6 ft bgs) [b]
Nickel	19.9	20.6 (57.0/186.9)	57.0/186.9	14.7 (<BG)
Selenium	0.78	1.45 (57.0/186.9)	65.1/213.6	U
Strontium	N/A	47.5 (14.3/47.0)	25.5/83.6	11.9 [c]
Tin	N/A	2.32 (23.6/77.3)	25.5/83.6	1.43 [c]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 23.4 m (76.7 ft) bgs.

c. Result at 25.5 m (83.6) ft depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

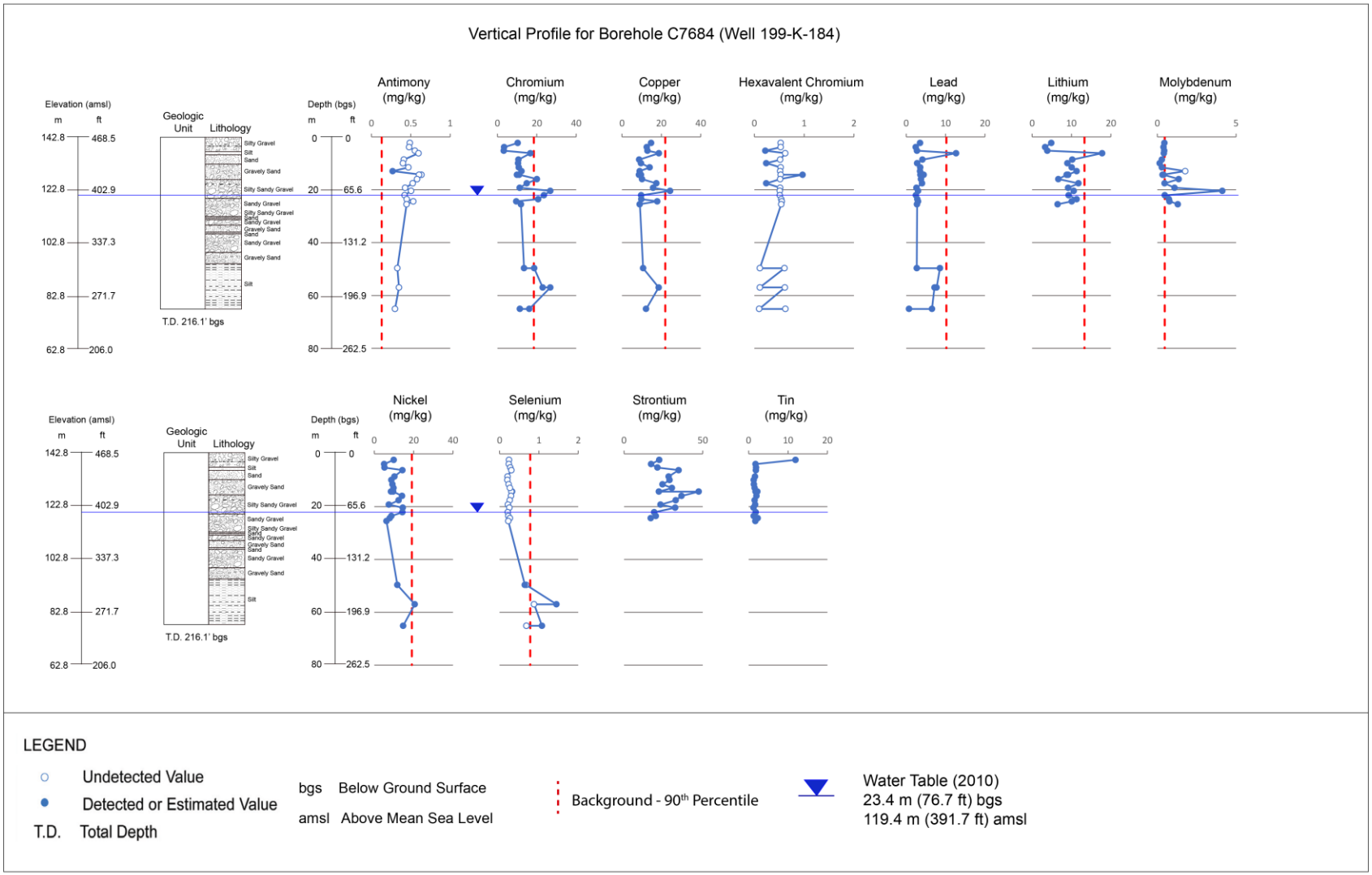


Figure 4-9. Vertical Profile from Well 199-K-184

4.2.3.3 199-K-185

Well 199-K-185 (RI well 2) was sited downgradient of the 116-KW-3 Retention Basin and KW Reactor area to define the extent of Cr(VI), carbon-14, trichloroethene, tritium, and strontium-90 in groundwater (Figure 2-1). Soil and sediment samples were collected from about 8.2 to 15.5 m (27 to 51 ft) bgs. During drilling, the water table was encountered at 14.2 m (46.7 ft) bgs. Table 4-12 summarizes the analytical data from the borehole. Figure 4-10 presents vertical profiles of analytes detected above background in the borehole.

Table 4-12. Well 199-K-185—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7685 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (15.6 m/51.2 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	21.2 (8.4/27.4)	8.4/27.4	8.16 (<BG)
Copper	22	23.6 (15.6/51.2)	15.6/51.2	23.6
Cr(VI)	N/A	0.18 (11.4/37.3)	15.6/51.2	0.15
Molybdenum	0.47	3.98 (11.4/37.3)	15.6/51.2	1.19
Strontium	N/A	34.6 (11.4/37.3)	15.6/51.2	26.0
Tin	N/A	2.12 (11.4/37.3)	15.6/51.2	1.68

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 14.2 m (46.7 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable

No radionuclides were detected in the borehole samples. Cr(VI) was detected at very low concentrations (up to 0.018 mg/kg) in all samples. Total chromium (21.2 mg/kg) and copper (23.6 mg/kg) were detected slightly above background in single intervals.

4.2.3.4 199-K-186

Well 199-K-186 (RI well 9) was sited just downgradient of the 165KE Power Control Building. Samples were collected from about 1.8 to 27.9 m (6 to 92 ft) bgs. During drilling, the water table was encountered at 24.9 m (81.8 ft) bgs. Table 4-13 summarizes the analytical data from the borehole. Figure 4-11 presents vertical profiles of analytes detected above background in the borehole.

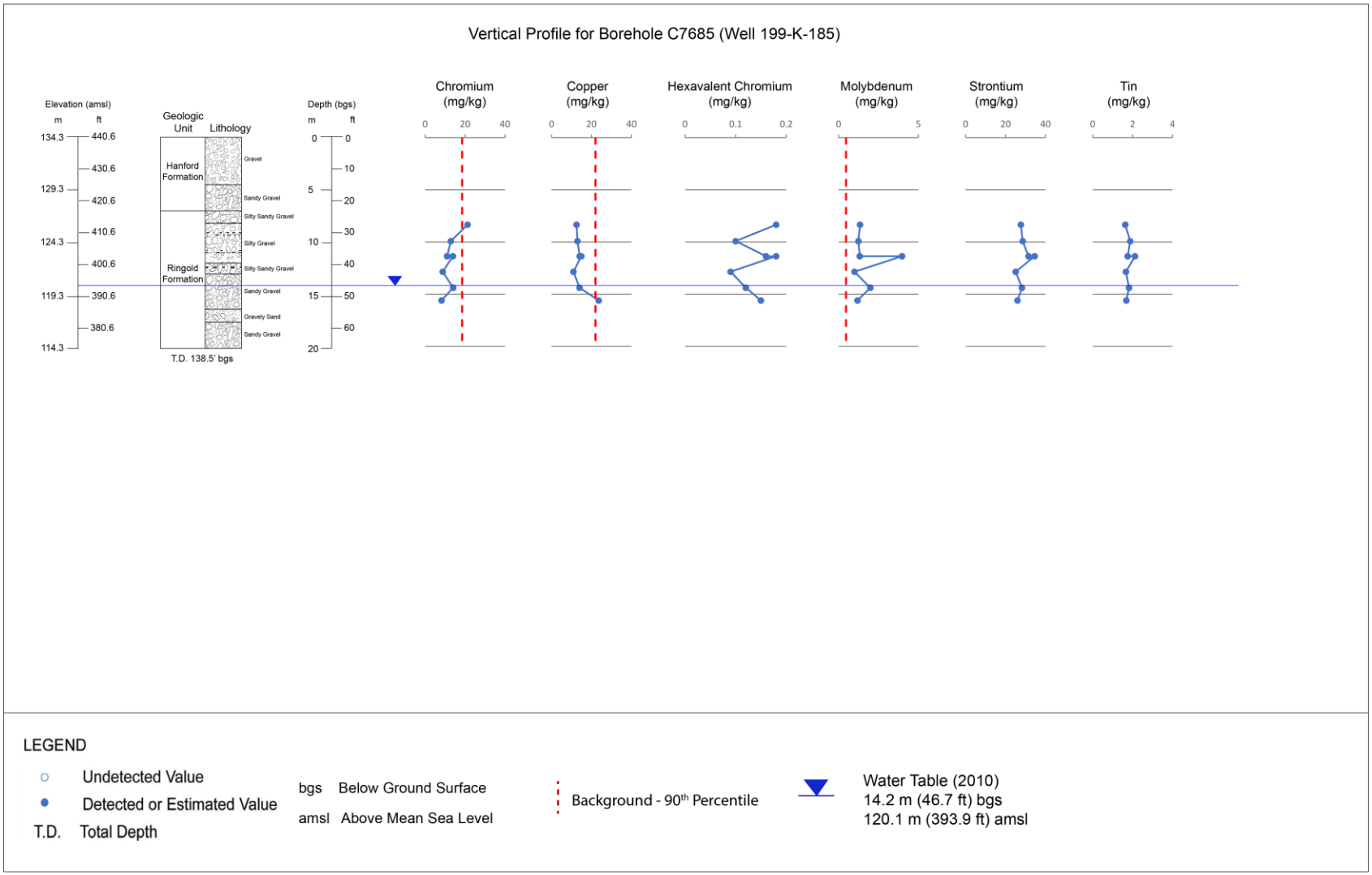


Figure 4-10. Vertical Profile from Well 199-K-185

Table 4-13. Well 199-K-186—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7686 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (49.5 m/162.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Antimony	0.130	0.246 (14.6/48)	14.6/48.0	U
Chromium	18.5	33.5 (20.4/66.8)	49.5/162.5	27.0
Cr(VI)	N/A	0.27 (25.9/84.9)	25.9/84.9	U
Molybdenum	0.47	2.28 (20.4/66.8)	27.9/91.5	0.795 [c]
Nickel	19.1	20.7 (1.8/6.0)	20.4/66.8	19.0 (<BG)
Strontium	N/A	75.8 (24.8/81.3)	27.9/91.5	24.5 [c]
Tin	N/A	4.10 (1.8/6.0)	27.9/91.5	2.08 [c]
Vanadium	85.1	90.4 (1.8/6)	11.4/37.5	28.7 (<BG)
TPH—diesel range	N/A	22,600 (14.6/48.0)	17.6/57.7	1.55 [d]
TPH—motor oil (high boiling)	N/A	22,500 (14.6/48.0)	17.6/57.7	5.10 [d]
Acenaphthene	N/A	0.599 (14.6/48.0)	16.2/53.0	U [d]
Acenaphthylene	N/A	5.07 (14.6/48.0)	15.4/50.4	U [d]
Anthracene	N/A	5.81 (14.6/48.0)	16.2/53.0	U [d]
Benzo(a)anthracene	N/A	1.42 (14.6/48.0)	14.6/48.0	U [d]
Benzo(a)pyrene	N/A	0.579 (14.6/48.0)	15.4/50.4	U [d]
Benzo(b)fluoranthene	N/A	3.77 (13.7/45.1)	15.4/50.4	U [d]
Benzo(ghi)perylene	N/A	0.690 (13.7/45.1)	14.6/48.0	U [d]
Benzo(k)fluoranthene	N/A	0.316 (14.6/48.0)	14.6/48.0	U [d]
Chrysene	N/A	10.2 (13.7/45.1)	16.2/53.0	U [d]
Dibenz(a,h)anthracene	N/A	0.280 (14.6/48.0)	14.6/48.0	U [d]
Fluoranthene	N/A	28.7 (14.6/48.0)	17.6/57.7	0.00327 [d]
Fluorene	N/A	7.17 (14.6/48.0)	16.2/53.0	U [d]
Indeno(1,2,3-cd)pyrene	N/A	0.370 (14.6/48.0)	15.4/50.4	U [d]
Naphthalene	N/A	4.92 (14.6/48.0)	15.4/50.4	U [d]

Table 4-13. Well 199-K-186—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7686 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (49.5 m/162.5 ft bgs) [b]
Phenanthrene	N/A	21.5 (14.6/48.0)	17.6/57.7	0.00261 [d]
Pyrene	N/A	8.72 (14.6/48.0)	16.2/53.0	U [d]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 24.9 m (81.8 ft) bgs.

c. Result at 27.9 m (91.5) ft depth; analyte not included in deeper sample intervals.

d. Samples for TPHs and semivolatile organic compound analyses were collected for samples collected between 13.8 and 17.6 m (45.1 and 57.7 ft) bgs. Maximum depth for organic sample results is 17.6 m (57.7 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
TPH = total petroleum hydrocarbons
U = undetected

No radionuclides were detected in the borehole samples. Cr(VI) was detected only once at 0.27 mg/kg in a sample collected at the water table. Total chromium was measured above background at 21.1 and 33.5 mg/kg from samples collected at 17.6 and 20.4 m (58 and 67 ft) bgs, respectively. Nickel was slightly above background at 20.7 and 19.4 mg/kg in samples collected at 1.8 and 20.4 m (6 and 67 ft) bgs, respectively. Concentrations of nonradiological analytes for which a background value is not available (i.e., strontium and tin) are consistent with concentrations measured in other 100-K RI samples.

At 13.7 m (45 ft) bgs, vadose soil from the borehole appeared to be contaminated with fuel oil. Additional samples for total petroleum hydrocarbons (TPH) and semivolatile organic compounds (SVOCs) were collected between 13.7 and 17.6 m (45 and 58 ft) bgs. Elevated concentrations of both diesel and motor oil range TPH were measured in most of these samples from this depth, with the highest concentrations (22,600 and 22,500 mg/kg, respectively) from samples collected from 14.6 m (48 ft) bgs. Concentrations decreased to 1.55 and 5.10 mg/kg, diesel and motor oil range, in the final TPH sample collected at 17.6 m (58 ft) bgs. Multiple polycyclic aromatic hydrocarbons (PAHs) were also measured in these samples. Benzo(a)pyrene was detected at 0.579 and 0.154 mg/kg in two samples collected at 14.6 and 15.2 m (48 and 50 ft) bgs. The borehole was approximately 24.7 m (81 ft) northeast of the 166-KE Oil Storage Tank, an underground fuel oil storage tank. It is probable that the oil-related contamination discovered at C7686 is the result of leaks from this underground storage tank.

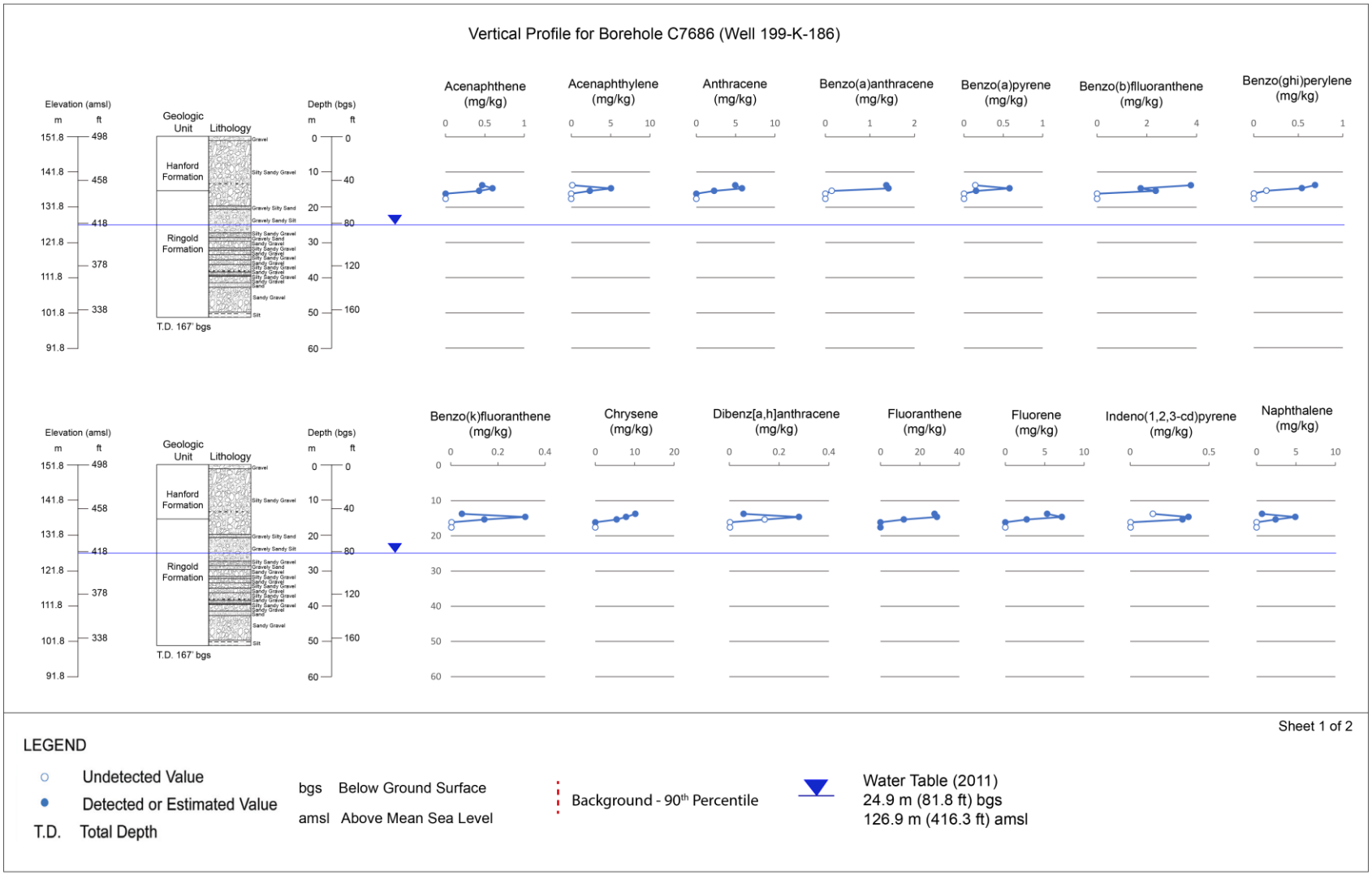


Figure 4-11. Vertical Profile from Well 199-K-186 (1 of 2)

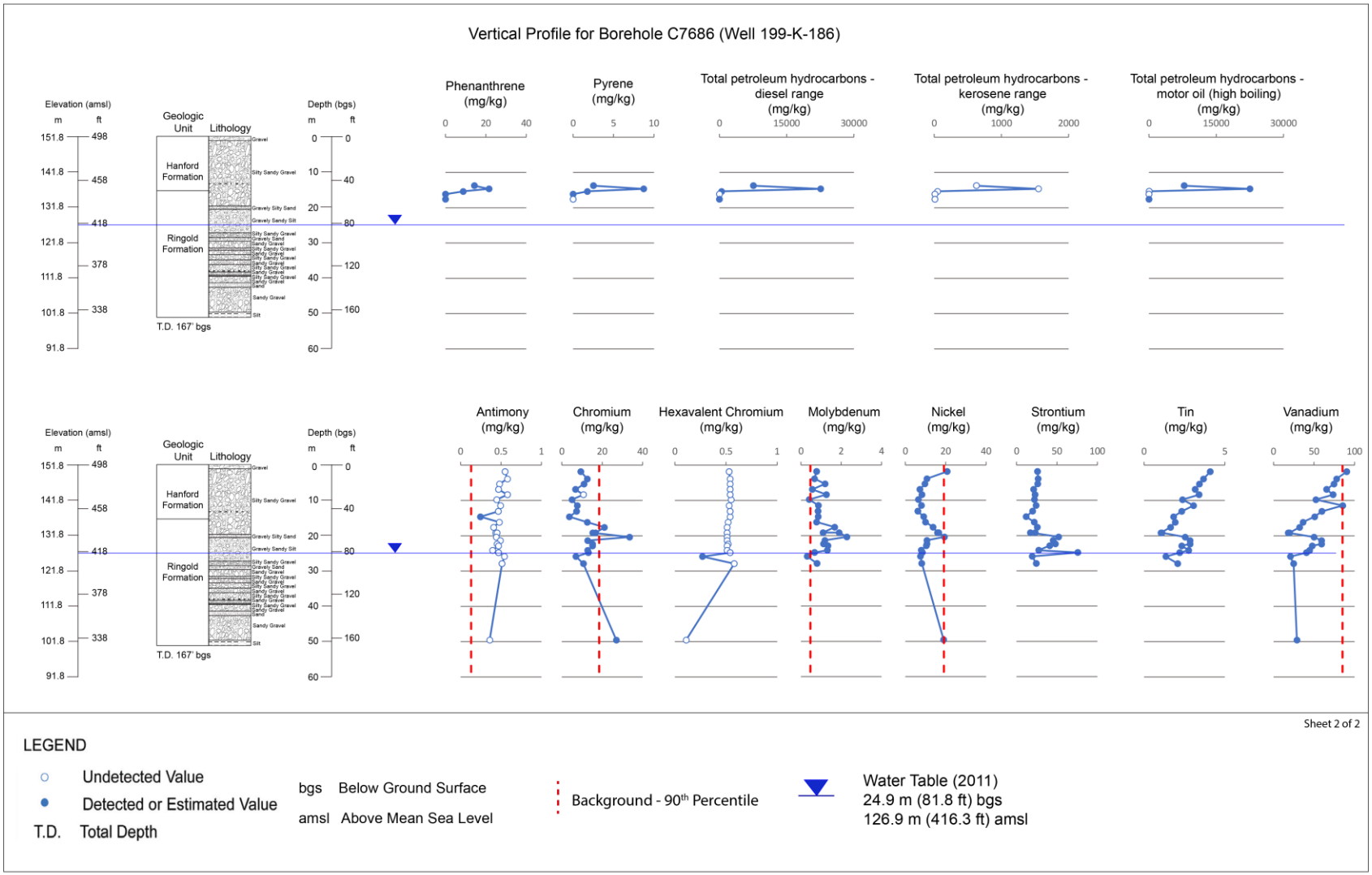


Figure 4-11. Vertical Profile from Well 199-K-186 (2 of 2)

4.2.3.5 199-K-187

Well 199-K-187 (RI well 3) was located approximately 325 m (1,070 ft) southeast of the 183.1KE Headhouse to define the upgradient extent of Cr(VI) in groundwater. Samples were collected from 30.5 to 36.6 m (100 to 120 ft) bgs. During drilling, the water table was encountered at 33.9 m (111.2 ft) bgs. Table 4-14 summarizes the analytical data from the borehole. Figure 4-12 presents vertical profiles of analytes detected above background in the borehole.

Table 4-14. Well 199-K-187—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7687 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (61.0 m/200.2 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	26.6 (32.1/105.3)	32.1/105.3	15.2 (<BG)
Copper	22	24.9 (30.4/99.6)	30.4/99.6	12.0 (<BG)
Cr(VI)	N/A	0.13 (32.1/105.3)	35.1/115	U
Molybdenum	0.47	4.92 (32.1/105.3)	36.7/120.3	0.632 [c]
Nickel	19.9	22.3 (61.0/200.2)	61.0/200.2	22.3
Selenium	0.78	1.0 (61.0/200.2)	61.0/200.2	1.0
Strontium	N/A	25.3 (32.1/105.3)	36.7/120.3	17.1 [c]
Tin	N/A	1.77 (32.1/105.3)	36.7/120.3	1.54 [c]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 33.9 m (111.2 ft) bgs.

c. Result at 36.7 m (120.3 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

No radionuclides were detected in the borehole samples. Low concentrations of Cr(VI) (up to 0.13 mg/kg) were detected in samples collected just above and at the water table. Total chromium was slightly above background (26.6 mg/kg) in a sample collected at 32.1 m (105 ft) bgs. A single detection of copper slightly above background was measured in the shallowest sample.

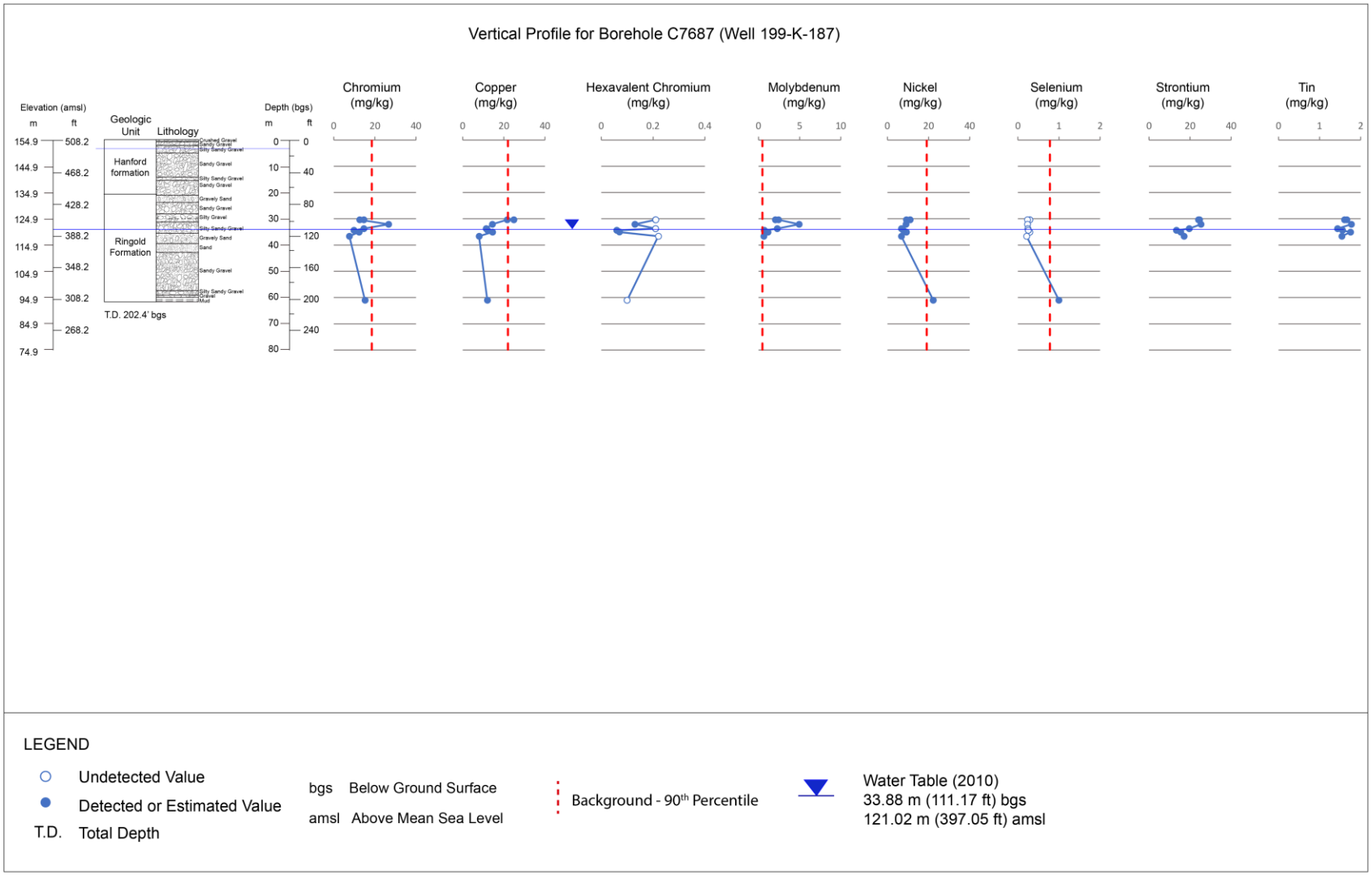


Figure 4-12. Vertical Profile from Well 199-K-187

4.2.3.6 199-K-188

Well 199-K-188 (RI well R3) was sited near the location of the former 120-KE-6 Sodium Dichromate Storage Tank. Soil and sediment samples were collected from 1.8 and 32.8 m (6 and 108 ft) bgs to evaluate contamination through the vadose zone to the water table. During drilling, the water table was encountered at 30.0 m (98.4 ft) bgs. Table 4-15 summarizes the analytical data from the borehole. Figure 4-13 presents vertical profiles of analytes detected above background in the borehole.

Table 4-15. Well 199-K-188—Summary of Soil Contaminant Data

Analyte	Background	Concentration and Distribution				
		Remedial Investigation C7688 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (71.6 m/235.0 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed
Cesium-137	N/A	0.116 (1.9/6.3)	0.099	1.9/6.3	U	N/A
Nonradionuclides (mg/kg)						
Antimony	0.13	1.96 (14.2/46.7)		32.8/107.5	U	
Arsenic	6.47	9.11 (71.6/235.0)		71.6/235.0	9.11	
Chromium	18.5	108 (14.2/46.7) [d]		71.6/235.0	19.4	
Cr(VI)	N/A	1.6 (1.9/6.3)		32.8/107.5	U	
Lead	10.2	37.7 (1.9/6.3)		71.6/235.0	12.9	
Manganese	512	714 (71.6/235.0)		71.6/235.0	714	
Mercury	0.0131	0.628 (1.9/6.3)		27.4/90.0	U	
Molybdenum	0.47	2.74 (19.6/64.2)		32.8/107.5	1.42 [e]	
Nickel	19.1	64.6 (14.2/46.7) [d]		71.6/235.0	19.8	
Selenium	0.78	2.46 (71.6/235.0)		71.6/235.0	2.46	
Strontium	N/A	93.2 (30.9/101.5)		32.8/107.5	17.9 [e]	
Thallium	0.185	0.213 (1.9/6.3)		1.9/6.3	U	
Tin	N/A	5.21 (6.9/22.7)		32.8/107.5	1.63 [e]	
Vanadium	85.1	107 (14.2/46.7)		14.2/46.7	32.7 (<BG)	

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 30.0 m (98.4 ft) bgs.

c. Decay-corrected to 2017.

d. Chromium and nickel concentrations in the sample collected at 14.2 m (46.7 ft) bgs are elevated and anomalous. The maximum values of chromium and nickel from the borehole excluding this sample are 26.4 and 16.2 mg/kg, respectively, at 27.4 m (89.9 ft) bgs.

e. Result at 32.8 m (107.5 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

Cesium-137 was detected at 0.116 pCi/g in the uppermost sample, at a depth of 1.8 m (6 ft) bgs. No other radionuclides were detected throughout the borehole. This uppermost sample interval also contained antimony, chromium, lead, and mercury above background levels as well as Cr(VI) at 1.6 mg/kg. No other detections above background were reported for lead or mercury in samples from the borehole. Cr(VI) was detected at lower concentrations (maximum of 0.60 mg/kg) in several intervals through the vadose zone and below the water table. Elevated total chromium and nickel concentrations are observed in the sample collected approximately 14.2 m (47 ft) bgs. Total chromium was detected slightly above background (maximum concentration of 26.4 mg/kg) at about 22.3, 23.2, and 27 m (73, 76, and 90 ft). As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components.

4.2.3.7 199-K-189

Well 199-K-189 (RI well 5) was drilled as replacement for a previous groundwater monitoring well, located downgradient of the KE Reactor. Samples were collected from 2.4 to 24.1 m (8 to 79 ft) bgs. During drilling, the water table was encountered at 22.5 m (73.8 ft) bgs. Table 4-16 summarizes the analytical data from the borehole. Figure 4-14 presents vertical profiles of analytes detected above background in the borehole.

No radionuclides were detected in the borehole samples. Cr(VI) was detected in all borehole samples at low concentrations (up to 0.79 mg/kg). Concentrations of lead were above background in samples collected from about 12.9 and 22.1 m (43 and 72 ft) bgs and again in the deepest sample collected beneath the water table at 24.2 m (79 ft) bgs. Elevated total chromium and nickel concentrations (211 and 110 mg/kg, respectively) were observed in the sample collected at 13.0 m (42.5 ft) bgs. Concentrations of chromium and nickel were less than background in the samples collected above and below this sample. As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components.

4.2.3.8 199-K-190

Well 199-K-190 (RI well 4) was sited to define the extent of anomalous elevated Cr(VI) and strontium-90 in groundwater. Samples were collected from 4.9 to 18.6 m (16 to 61 ft) bgs. During drilling, the water table was encountered at 17.1 m (56.2 ft) bgs. Table 4-17 summarizes the analytical data from the borehole. Figure 4-15 presents vertical profiles of analytes detected above background in the borehole.

No radionuclides were detected in the borehole samples. Cr(VI) was detected at low concentrations (up to 0.18 mg/kg) in all borehole samples including those from the aquifer. Elevated total chromium and nickel concentrations (90 and 45.7 mg/kg, respectively) were observed in the sample collected at 16.8 m (55.0 ft) bgs. Concentrations of chromium and nickel were less than background in the samples collected above and below this sample. Total chromium was also detected above background at 11.1 and 12.3 m (37 and 41 ft) bgs (21.8 and 29.1 mg/kg, respectively). As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components. A single detection of lead above background (15.7 mg/kg) was reported at about 15.8 m (52 ft) bgs.

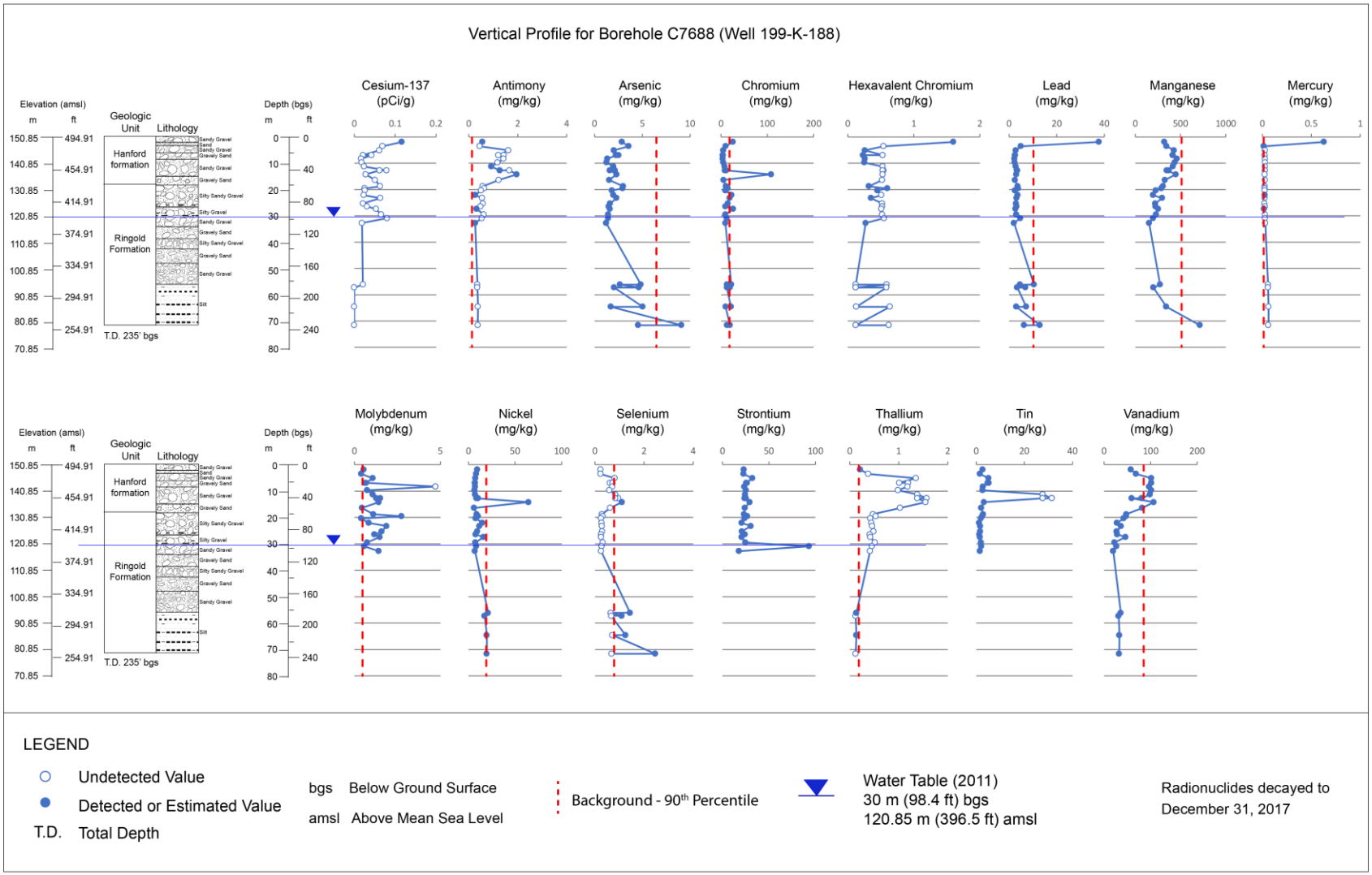


Figure 4-13. Vertical Profile from Well 199-K-188

Table 4-16. Well 199-K-189—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7689 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (47.1 m/154.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Antimony	0.130	4.97 (13/42.5)	24.2/79.3	U
Arsenic	6.47	14.3 (22.5/73.7)	22.5/73.7	1.80 (<BG)
Chromium	18.5	211 (13.0/42.5) [c]	16.0/52.5	9.28 (<BG)
Cr(VI)	N/A	0.79 (3.9/12.7)	24.2/79.3	U
Lead	10.2	182 (13.0/42.5)	24.2/79.3	9.45 (<BG)
Molybdenum	0.47	7.04 (6.9/22.0)	24.2/79.3	0.504 [d]
Nickel	19.1	110 (13.0/42.5) [c]	13.0/42.5	13.2 (<BG)
Strontium	N/A	51.1 (16.0/52.5)	24.2/79.3	26.6 [d]
Tin	N/A	1.45 (22.1/72.4)	22.5/73.7	U [d]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 22.5 (73.8 ft) bgs.

c. Chromium and nickel concentrations in the sample collected at 13.0 m (42.5 ft) bgs are elevated and anomalous. Concentrations of chromium and nickel are less than background in the samples collected above and below this sample. The maximum values of chromium and nickel from the borehole excluding this sample are 21.9 and 14.5 mg/kg, respectively, at 16.0 m (52.5 ft) bgs.

d. Result at 24.2 m (79.3 ft) depth; analyte not included in deeper sample intervals.

BG = background

bgs = below ground surface

Cr(VI) = hexavalent chromium

HEIS = Hanford Environmental Information System

N/A = not applicable

U = undetected

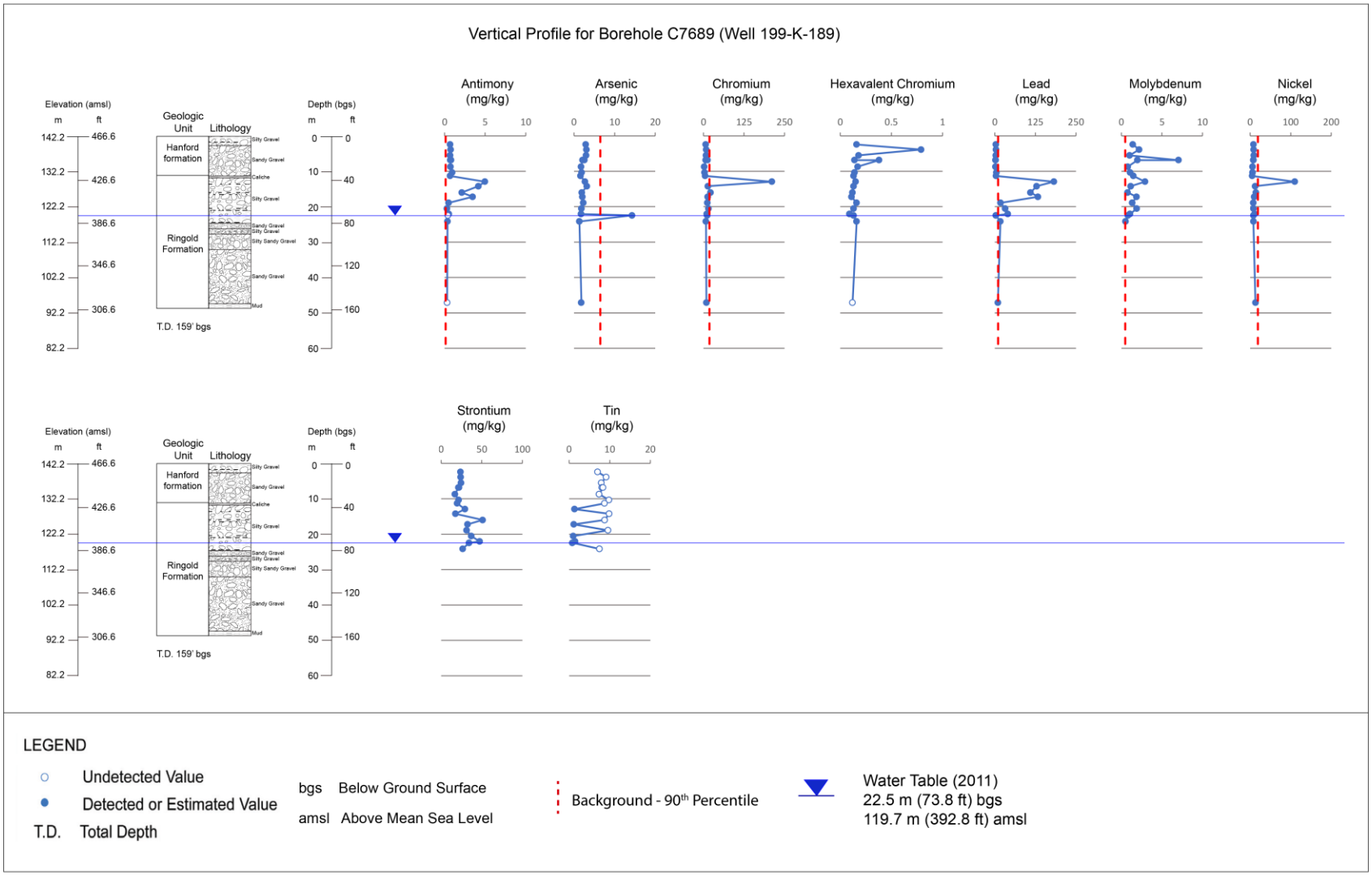


Figure 4-14. Vertical Profile from Well 199-K-189

Table 4-17. Well 199-K-190—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7690 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (46.3 m/152.0 ft bgs) [b]
Nonradionuclides (mg/kg)				
Antimony	0.13	0.738 (15.8/52)	18.6/61.1	U
Chromium	18.5	90.0 (16.8/55.0) [c]	16.8/55.0	16.7 (<BG)
Cr(VI)	N/A	0.18 (14.8/48.5)	18.6/61.1	U
Lead	10.2	15.7 (15.8/52.0)	15.8/52.0	6.32 (<BG)
Molybdenum	0.47	1.94 (11.1/36.5)	18.6/61.1	1.77 [d]
Nickel	19.1	45.7 (16.8/55.0) [c]	16.8/55.0	15.8 (<BG)
Strontium	N/A	30.6 (6.6/21.5)	18.6/61.1	16.0 [d]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 17.1 m (56.2 ft) bgs.

c. Chromium and nickel concentrations in the sample collected at 16.8 m (55.0 ft) bgs are elevated and anomalous. Concentrations of chromium and nickel are less than background in the samples collected above and below this sample. The maximum values of chromium and nickel from the borehole excluding this sample are 29.1 and 19.0 mg/kg, respectively, at 12.3 m (40.5 ft) bgs.

d. Result at 18.6 m (61.1 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

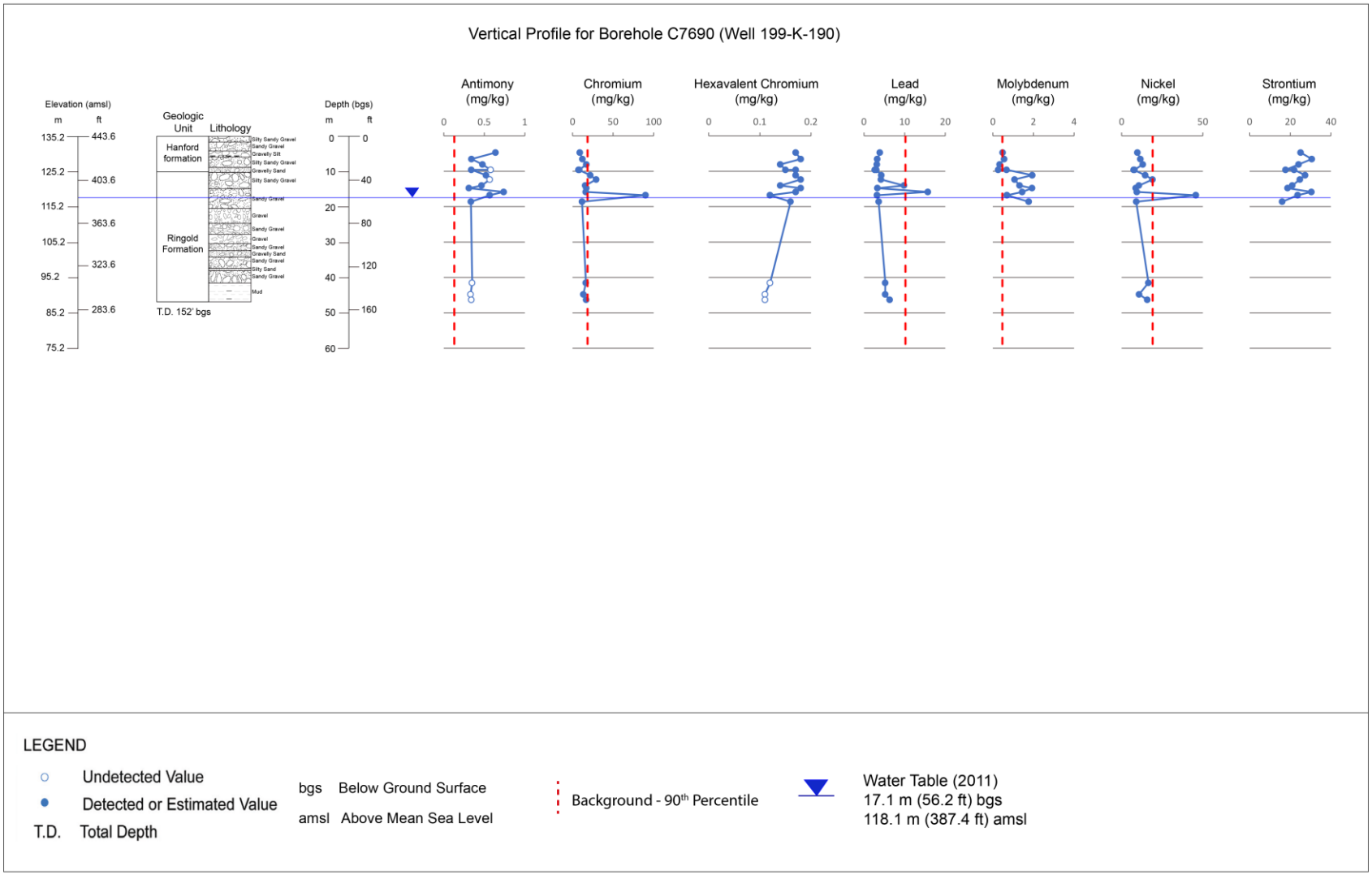


Figure 4-15. Vertical Profile from Well 199-K-190

4.2.3.9 199-K-191

Well 199-K-191 (RI well 6) was one of three wells drilled to define the Cr(VI) groundwater plume upgradient of the 116-K-2 Trench. Samples were collected from 18.5 to 24.5 m (61 to 81 ft) bgs. During drilling, the water table was encountered at 22.1 m (72.4 ft) bgs. Table 4-18 summarizes the analytical data from the borehole. Figure 4-16 presents vertical profiles of analytes detected above background in the borehole.

Table 4-18. Well 199-K-191—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7691 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (24.5 m/80.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Antimony	0.130	4.11 (21.9/72)	24.5/80.5	U
Chromium	18.5	38.7 (18.5/60.7)	21.9/72.0	8.68 (<BG)
Copper	22	23.6 (21.9/72.0)	21.9/72.0	8.66 (<BG)
Cr(VI)	N/A	0.19 (21.9/72.0)	24.5/80.5	0.17
Lead	10.2	229 (21.9/72.0)	24.5/80.5	10.9
Molybdenum	0.47	7.34 (21.9/72.0)	24.5/80.5	1.65
Nickel	19.1	25.8 (18.5/60.7)	18.5/60.7	6.39 (<BG)
Strontium	N/A	39.9 (21.9/72.0)	24.5/80.5	22.8
Tin	N/A	2.98 (21.2/69.5)	24.5/80.5	1.67

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 22.1 m (72.4 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

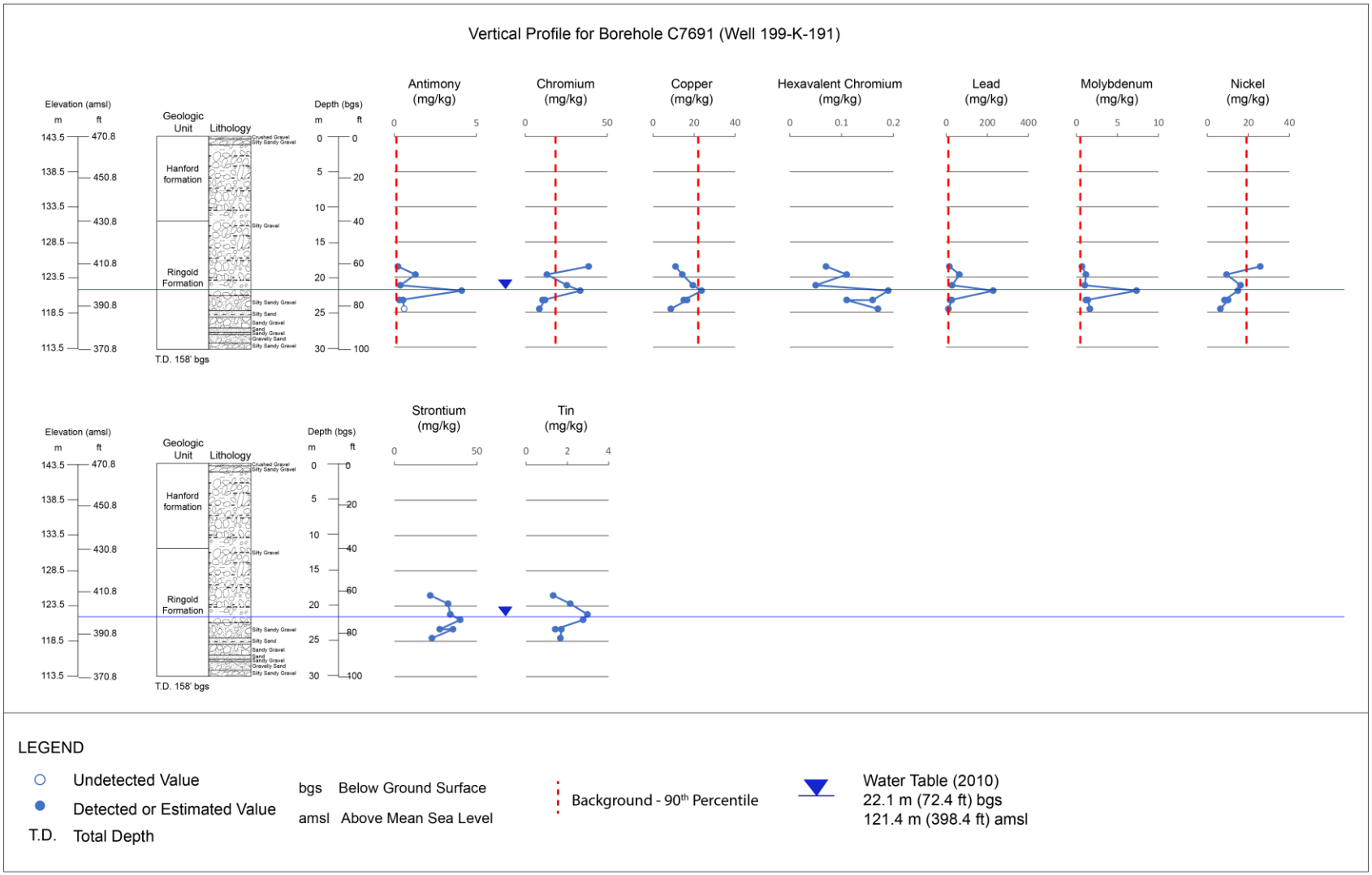


Figure 4-16. Vertical Profile from Well 199-K-191

No radionuclides were detected in the borehole samples. Cr(VI) was detected at low concentrations (up to 0.19 mg/kg) in all borehole samples. Total chromium was detected above background (maximum concentration of 38.7 mg/kg) in multiple samples. Concentrations of lead were above background in all but the deepest sample, with the highest concentration (229 mg/kg) measured just above the water table. Lead in the samples immediately above and below this sample are an order of magnitude lower at 28.7 and 26.9 mg/kg, respectively. A single detection of copper slightly above background (23.6 mg/kg) was measured at 21.9 m (72 ft) bgs, while nickel above background (25.8 mg/kg) was measured at 18.8 m (61 ft) bgs.

4.2.3.10 199-K-192

Well 199-K-192 (RI well 2) was sited downgradient from the inlet end of the 116-K-2 Trench. Soil and sediment samples were collected from 11.4 to 17.5 m (37 to 57 ft) bgs. During drilling, the water table was encountered at 15.0 m (49.1 ft) bgs. Table 4-19 summarizes the analytical data from the borehole. Figure 4-17 presents vertical profiles of analytes detected above background in the borehole.

Table 4-19. Well 199-K-192—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Remedial Investigation Borehole C7692 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (43.4 m/142.4 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed [c]
Strontium-90	N/A	0.282 (17.5/57.3)	0.239	17.5/57.3	U	N/A
Nonradionuclides (mg/kg)						
Antimony	0.13	0.619 (11.4/37.4)		12.9/42.4	U	
Chromium	18.5	56.0 (14.6/47.8) [d]		51.7/169.5	4.57 (<BG)	
Copper	22	25.9 (58.4/191.5)		58.4/191.5	8.21 (<BG)	
Cr(VI)	N/A	0.147 (58.4/191.5)		58.4/191.5	U	
Lead	10.2	23.3 (11.4/37.4)		58.4/191.5	1.45 (<BG)	
Molybdenum	0.47	1.31 (11.4/37.4)		17.5/57.3	0.327 [e] (<BG)	
Nickel	19.1	28.9 (14.6/47.8) [d]		14.6/47.8	10.1 (<BG)	
Selenium	0.78	1.37 (58.4/191.5)		58.4/191.5	0.951	
Strontium	N/A	27.1 (12.9/42.4)		17.5/57.3	25.6 [e]	
Tin	N/A	0.882 (15.2/50.0)		15.2/50.0	U [e]	

Table 4-19. Well 199-K-192—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7692 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (43.4 m/142.4 ft bgs) [b]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 15.0 m (49.1 ft) bgs.

c. Decay-corrected to 2017.

d. Chromium and nickel concentrations in the sample collected at 14.6 m (47.8 ft) bgs are elevated and anomalous. Concentrations of chromium and nickel are less than background in all other sample intervals.

e. Result at 17.5 m (57.3 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

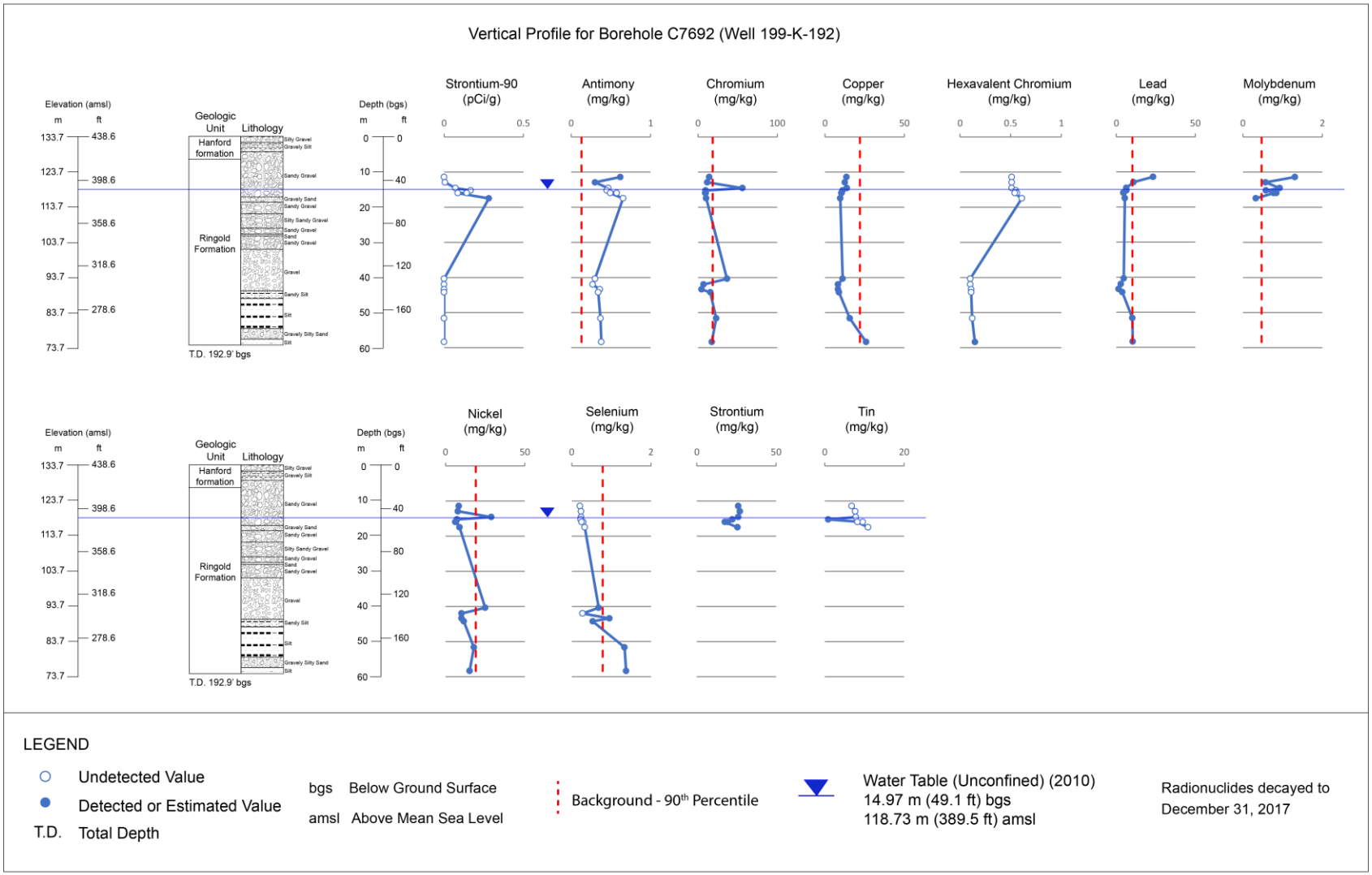


Figure 4-17. Vertical Profile from Well 199-K-192

Strontium-90 was detected at 0.282 pCi/g in the deepest sample, which was collected below the water table. No other radionuclides were detected in the borehole. Cr(VI) was not detected in any borehole samples. Elevated total chromium and nickel concentrations (56.0 and 28.9 mg/kg, respectively) were observed in the sample collected at 14.6 m (48 ft) bgs. Concentrations of chromium and nickel were less than background in the samples collected above and below this sample. As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components. Lead was measured above background at 11.4 and 12.9 m (37 and 42 ft) bgs at concentrations of 23.3 and 10.9 mg/kg, respectively.

4.2.3.11 199-K-193

Well 199-K-193 (RI well 7) was one of three wells drilled to define the Cr(VI) groundwater plume upgradient of the 116-K-2 Trench. Samples were collected from 18.2 to 25.9 m (60 to 85 ft) bgs. During drilling, the water table was encountered at 23.5 m (77.2 ft) bgs. Table 4-20 summarizes the analytical data from the borehole. Figure 4-18 presents vertical profiles of analytes detected above background in the borehole.

Table 4-20. Well 199-K-193—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7693 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (49.2 m/161.4 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	57.8 (20.3/66.5) [c]	24.5/80.3	10.9 (<BG)
Molybdenum	0.47	2.90 (18.2/59.8)	25.9/85.0	2.01 [d]
Nickel	19.1	32.1 (20.3/66.5) [c]	20.3/66.5	8.65 (<BG)
Strontium	N/A	79.7 (23.2/76.0)	25.9/85.0	25.8 [d]
Thallium	0.185	0.24 (21.7/71.2)	21.7/71.2	U
Tin	N/A	3.70 (20.3/66.5)	25.9/85.0	1.02 [d]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 23.5 m (77.2 ft) bgs.

c. Chromium and nickel concentrations in the samples collected at 20.3 and 23.2 m (66.5 and 76.0 ft) bgs are elevated and anomalous. Concentrations of chromium and nickel are at or below background in all other sample intervals.

d. Result at 25.9 m (85.0 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

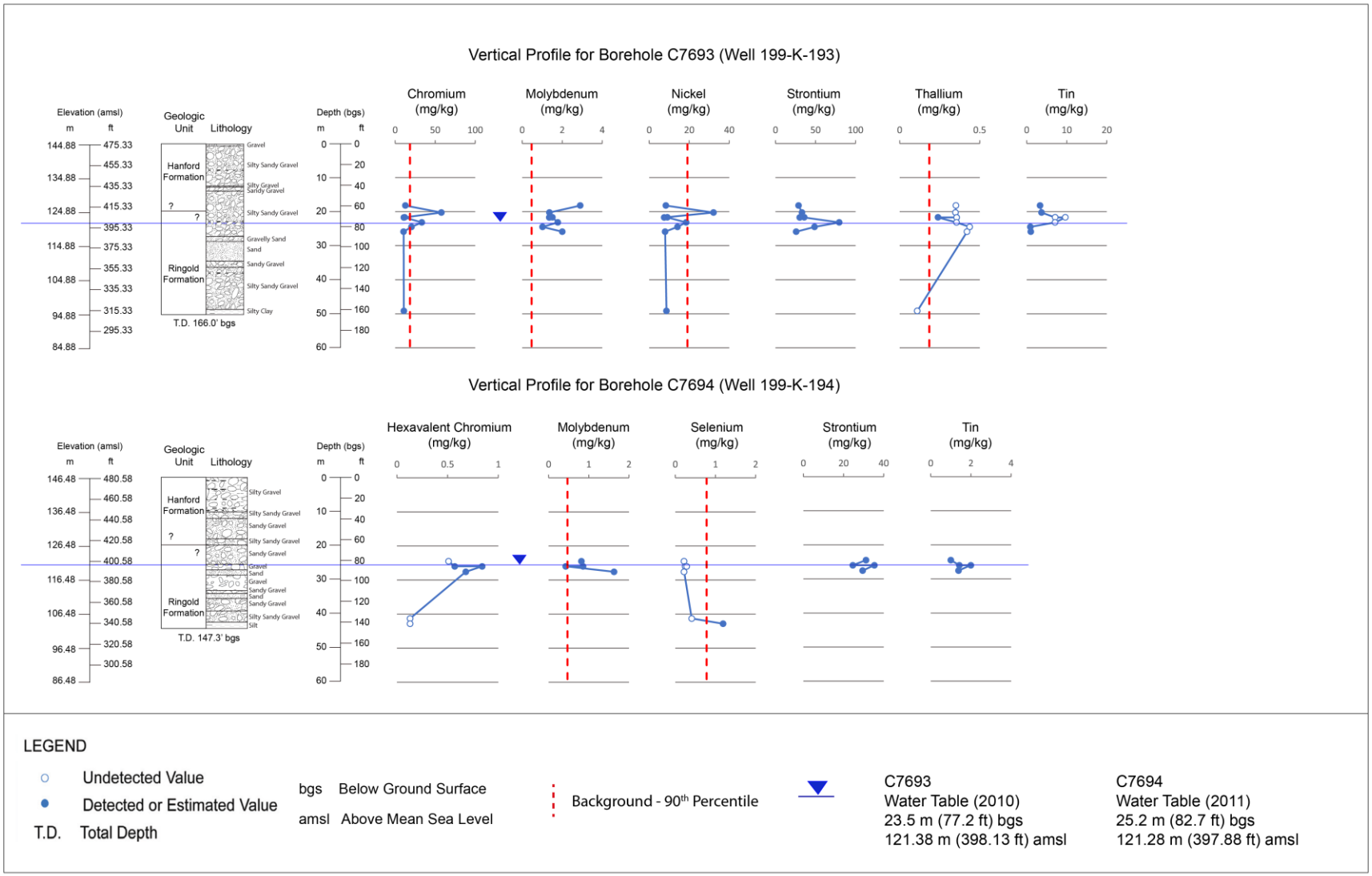


Figure 4-18. Vertical Profile from Wells 199-K-193 and 199-K-194

Neither radionuclides nor Cr(VI) were detected in the borehole samples. Total chromium was measured above background at 33.4 and 20.4 mg/kg from samples collected just above and at the water table (23.2 and 24.5 m [76 and 80 ft] bgs). Nickel concentrations were correspondingly elevated in the same intervals (up to 32.1 mg/kg). Concentrations of chromium and nickel were at or less than background in all other sample intervals. As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components.

4.2.3.12 199-K-194

Well 199-K-194 (RI well 8) was one of three wells drilled to define the Cr(VI) groundwater plume upgradient of the 116-K-2 Trench. Samples were collected from 24.5 to 27.6 m (80 to 91 ft) bgs. During drilling, the water table was encountered at 25.2 m (82.7 ft) bgs. Table 4-21 summarizes the analytical data from the borehole. Figure 4-18 presents vertical profiles of analytes detected above background in the borehole.

No radionuclides were detected in the borehole samples. Cr(VI) was detected in samples collected at and below the water table between 0.57 and 0.68 mg/kg. No other metals with an established background value were detected above background.

Table 4-21. Well 199-K-194—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7694 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (42.8 m/140.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Cr(VI)	N/A	0.84 (26.0/85.2)	27.6/90.5	U
Molybdenum	0.47	1.63 (27.6/90.5)	27.6/90.5	1.63 [c]
Selenium	0.78	1.19 (42.8/140.5)	42.8/140.5	1.19
Strontium	N/A	35.3 (26.0/85.2)	27.6/90.5	29.5 [c]
Tin	N/A	1.99 (26.0/85.2)	27.6/90.5	1.38 [c]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 25.2 m (82.7 ft) bgs.

c. Result at 27.6 m (90.5 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

4.2.3.13 199-K-195

Well 199-K-195 (RI well R4) was drilled through the 100-K-97 French Drain and Rail Spur Unplanned Release waste site, located near the former 120-KW-5 Sodium Dichromate Storage Tank, to evaluate potential contamination release to groundwater. Before the RI sampling, the 100-K-97 waste site had been excavated to a depth of 4.5 m (14.8 ft) bgs, and drilling was conducted at the bottom of the excavation. Samples were collected from 1.5 to 70.3 m (4.8 to 230.5 ft) below the depth of remedial excavation. During drilling, the water table was encountered at 26.0 m (85.3 ft) below the depth of the excavation. Table 4-22 summarizes the analytical data from the borehole. Figure 4-19 presents vertical profiles of analytes detected above background in the borehole.

Table 4-22. Well 199-K-195—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Remedial Investigation Borehole C7695 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (70.3 m/230.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	3,560 (23.6/77.3) [c]	62.6/205.5	17.9 (<BG)
Cobalt	15.7	20.4 (23.6/77.3) [c]	23.6/77.3	9.93 (<BG)
Copper	22	44.1 (23.6/77.3) [c]	23.6/77.3	17.2 (<BG)
Cr(VI)	N/A	0.42 (14.5/47.5)	22.0/72.0	U
Manganese	512	603 (23.6/77.3) [c]	23.6/77.3	370 (<BG)
Mercury	0.0131	0.0691 (70.3/230.5)	70.3/230.5	0.0691
Molybdenum	0.47	36.6 (23.6/77.3) [c]	28.0/92.0	1.32 [d]
Nickel	19.1	2,100 (23.6/77.3) [c]	70.3/230.5	23.8
Selenium	0.78	1.04 (62.6/205.5)	62.6/205.5	0.672 (<BG)
Strontium	N/A	29.3 (23.6/77.3)	28.0/92.0	19.9 [d]
Tin	N/A	3.36 (23.6/77.3)	26.3/86.2	U [d]

a. Data obtained from HEIS. Analytes that were not detected above background are not listed. Borehole C7695 was sited within the 100-K-97 excavation at approximately 4.5 m (15 ft) below the surrounding surface level. The surface depth at the top of the borehole is used as the reference surface datum in this table.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 26.0 m (85.3 ft) bgs.

c. Chromium, nickel, molybdenum, cobalt, copper, and manganese concentrations in the sample collected at 23.6 m (77.3 ft) bgs are elevated and anomalous. Chromium, nickel, and molybdenum concentrations in the next deepest sample (collected at 25.2 m [82.7 ft] bgs) are also elevated and anomalous. Concentrations of chromium, nickel, copper, cobalt, and manganese are at or below background in all other sample intervals.

d. Result at 28.0 m (92.0 ft) depth; analyte not included in deeper sample intervals.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

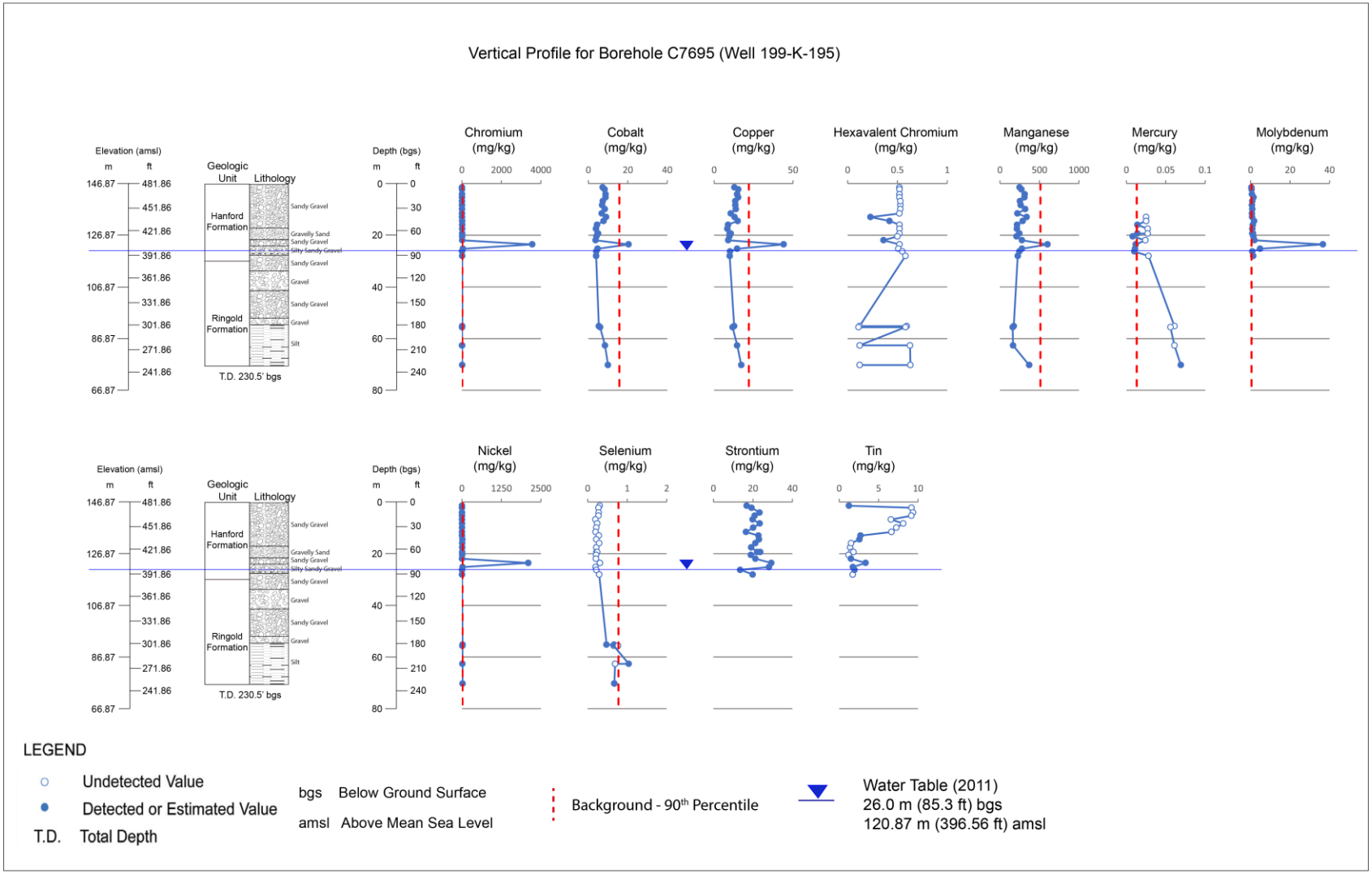


Figure 4-19. Vertical Profile from Well 199-K-195

No radionuclides were detected in the borehole samples. Low concentrations of Cr(VI) were detected in only in samples collected between 13.0 and 14.5 m (42.6 and 47.5 ft) bgs and again at 22.0 m (72 ft) bgs, with a maximum concentration of 0.42 mg/kg. Total chromium, nickel, molybdenum, cobalt, copper, and manganese concentrations were anomalously elevated in the sample collected from 23.6 m (77.3 ft) bgs. Total chromium, nickel, and molybdenum concentrations were also elevated in the next deepest sample, from 25.2 m (82.7 ft) bgs, though at lower concentrations (approximately two orders of magnitude lower for chromium and nickel). Concentrations of these metals were at or below background in all other sample intervals. As described in Section 4.2.2, these anomalous results are likely attributable to impacts from the use of steel drilling components.

4.2.4 Characterization of Soil Samples from Post-RI Monitoring Wells

In addition to the soil and sediment data collected during construction of RI monitoring wells (Section 4.2.3), soil contaminant data have also been collected from 15 additional wells constructed since the initiation of RI field data collection activities. These wells are identified in Table 4-23, and well locations are shown on Figure 2-8 and Appendix A. Soil data were collected in accordance with addenda to DOE/RL-2013-36, *100-KR-4 Groundwater Operable Unit Well Installation Sampling and Analysis Plan*, and results are discussed in the following subsections.

Table 4-23. Identification of 100-K Post-RI Wells with Soil/Sediment Data

Well Identification	Borehole Identification	Location
199-K-202	C8289	Northwest of the KE Reactor and 116-KE-3 Crib
199-K-203	C8290	North of the KE Reactor and 116-KE-1 Crib
199-K-204	C8291	North of the KW Reactor and 116-KW-1 Crib, within the 116-KW-4 Heat Recovery Station site footprint
199-K-205	C8292	At the former 183.1KW Headhouse area
199-K-207	C8294	Within the northern portion of the 118-K-1 Burial Ground footprint
199-K-210	C8297	In the river embankment north of the 116-KE-4 Retention Basin site; within the 100-K-64 site
199-K-220	C8795	At the former 183-KE Flocculation and Sedimentation Basins area
199-K-223	C9595	At the former 183-KW Flocculation and Sedimentation Basins area
199-K-224	C9596	At the former 183-KW Flocculation and Sedimentation Basins area, northwest of Well 199-K-223
199-K-225	C9597	At the former 183-KE Flocculation and Sedimentation Basins area, northwest of Well 199-K-220
199-K-226	C9598	At the northeastern corner of the 100-K operational area, within the 116-KE-4 Retention Basin site footprint

Table 4-23. Identification of 100-K Post-RI Wells with Soil/Sediment Data

Well Identification	Borehole Identification	Location
199-K-227	C9711	Within the southeastern portion of the 118-K-1 Burial Ground footprint, at the 100-K-132 site
199-K-228	C9712	East of the KE Reactor and southwest of the 118-K-1 Burial Ground site
199-K-229	C9713	North of the northwestern corner of the former 183-KW Flocculation and Sedimentation Basins area
199-K-230	C9714	Northeast of the 116-KE-3 Retention Basin site

4.2.4.1 199-K-202

Well 199-K-202 was located approximately 73 m (240 ft) northwest of the former KE Reactor FSB to provide monitoring within the area of the highest predicted strontium-90 concentrations downgradient from the FSB. During drilling, the water table was encountered at 22.3 m (73.1 ft) bgs. One primary/duplicate soil sample pair was collected from the periodically rewetted zone at 21.2 m (69.6 ft) bgs and analyzed for strontium-90. Strontium-90 was not detected in the primary sample, but was detected in the duplicate at 1.0 pCi/g (0.91 pCi/g with decay-correction to 2017). No additional soil constituent analyses were performed for this well.

4.2.4.2 199-K-203

Well 199-K-203 was located approximately 102 m (335 ft) north of the 116-KE-1 Gas Condensate Crib to provide monitoring within the area of the highest predicted carbon-14 concentrations downgradient from the crib. During drilling, the water table was encountered at 22.0 m (72.1 ft) bgs. Sediment samples were collected from the top, midpoint, and bottom of the unconfined aquifer and analyzed for carbon-14, tritium, Cr(VI), and nitrate. Cr(VI) was the only analyte detected above background, up to 0.518 mg/kg. Table 4-24 summarizes the analytical data from the borehole. Figure 4-20 presents vertical profiles of analytes detected above background in the borehole.

4.2.4.3 199-K-204

Well 199-K-204 was located approximately 95 m (310 ft) north of the KW Reactor, downgradient from the 116-KW-1 Gas Condensate Crib and within the remediation footprint of the 116-KW-4 Heat Recovery Station site. This well was sited to provide monitoring within the area of the highest predicted carbon-14 concentrations downgradient from the crib. During drilling, the water table was encountered at 23.3 m (76.3 ft) bgs. Sediment samples were collected from the top, midpoint, and bottom of the unconfined aquifer and analyzed for carbon-14, tritium, Cr(VI), and nitrate. Carbon-14 was the only analyte detected above background, with a single detection of 24.5 pCi/g at the top of the aquifer. Table 4-25 summarizes the analytical data from the borehole. Figure 4-20 presents vertical profiles of analytes detected above background in the borehole.

Table 4-24. Well 199-K-203—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C8290 a		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (46.7 m/153.2 ft bgs) b
Nonradionuclides (mg/kg)				
Cr(VI)	N/A	0.518 (24.6/80.8)	46.7/153.2	0.256

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 22.0 m (72.1 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable

4.2.4.4 199-K-205

Well 199-K-205 was located approximately 380 m (1,250 ft) southeast of the KW Reactor, at the former 183.1KW Headhouse area, to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 26.5 m (87.1 ft) bgs. Soil samples were collected from approximately 3 m (10 ft) intervals below backfill material and analyzed for multiple metals (including total chromium and mercury), Cr(VI), fluoride, nitrate, and nitrite. Table 4-26 summarizes the analytical data from the borehole. Figure 4-20 presents vertical profiles of analytes detected above background in the borehole.

Chromium and selenium were the only analytes detected above background. Chromium was detected nominally above background in only one sample interval. The concentration of nickel in this interval was also elevated relative to concentrations in other intervals (14.5 mg/kg relative to 4.01 – 5.94 mg/kg), though still below background. As described in Section 4.2.2, these isolated slightly elevated results may be attributable to impacts from the use of steel drilling components.

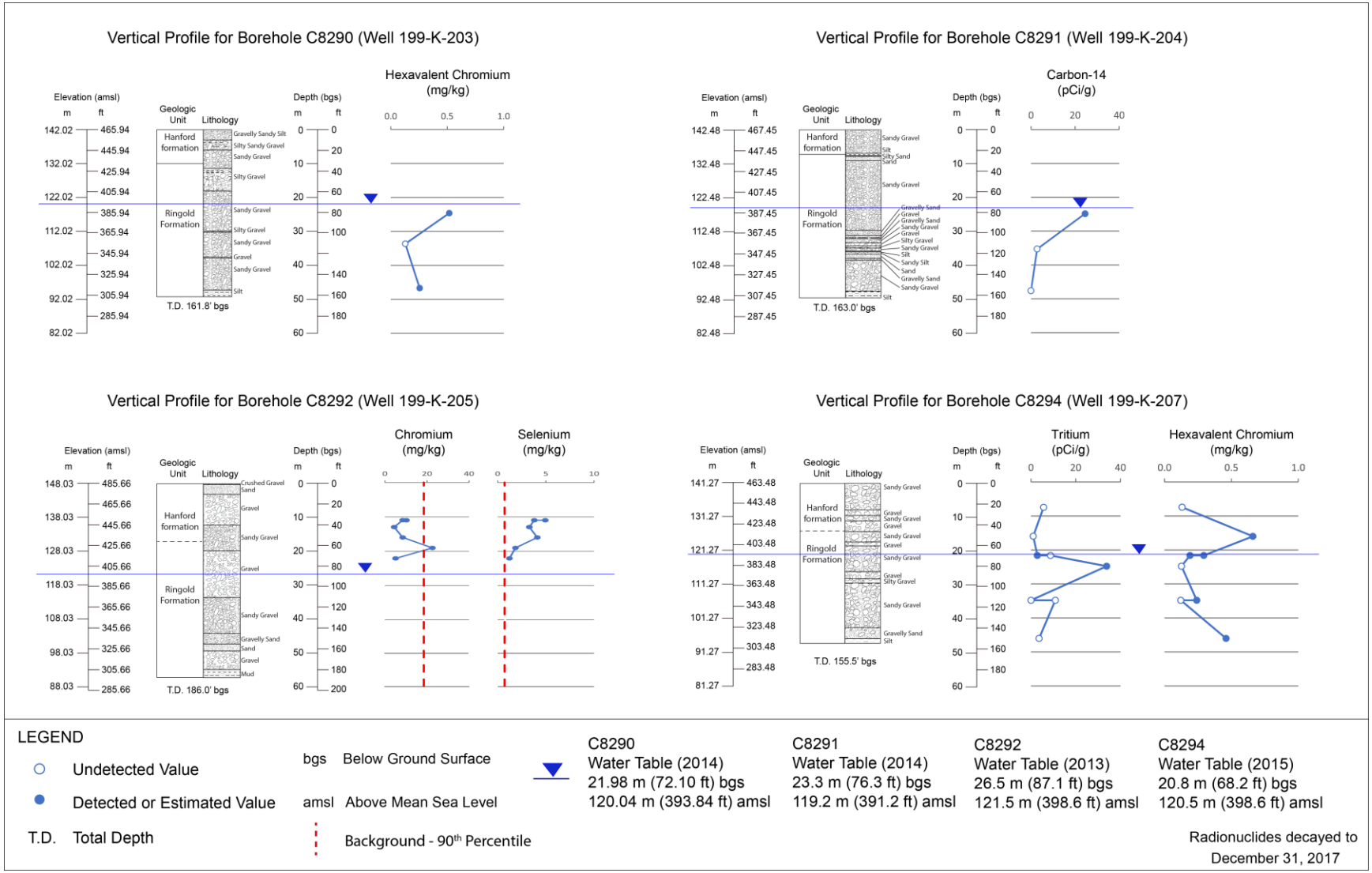


Figure 4-20. Vertical Profiles from Wells 199-K-203, 199-K-204, 199-K-205, and 199-K-207

Table 4-25. Well 199-K-204—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Borehole C8291 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (47.6 m/156.2 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed [c]
Carbon-14	N/A	24.5 (24.8/81.5)	24.5	24.8/81.5	U	N/A

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 22.8 m (74.9 ft) bgs.

c. Decay-corrected to 2017.

BG = background
bgs = below ground surface
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

Table 4-26. Well 199-K-205—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C8292 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (22.1 m/72.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	22.6 (19.1/62.5)	19.1/62.5	5.04 (<BG)
Selenium	0.78	4.95 (11.0/36.0)	22.1/72.5	1.22

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. All soil samples were collected above the water table, which was encountered at 26.5 m (87.1 ft) bgs.

BG = background
bgs = below ground surface
HEIS = Hanford Environmental Information System

4.2.4.5 199-K-207

Well 199-K-207 was located approximately 310 m (1,020 ft) northeast of the KE Reactor, within the northern end of the 118-K-1 Burial Ground remediation footprint, and downgradient from former waste caissons within the burial ground. This well was sited to provide additional data on potential residual tritium in the vadose zone and to provide additional monitoring for tritium contamination in groundwater. During drilling, the water table was encountered at 20.8 m (68.2 ft) bgs. Soil and sediment samples were collected from multiple intervals in the vadose zone and within the aquifer and analyzed for tritium and Cr(VI). Tritium was not detected in vadose zone soil at the location but was detected in the saturated zone. Table 4-27 summarizes the analytical data from the borehole. Figure 4-20 presents vertical profiles of analytes detected above background in the borehole.

Table 4-27. Well 199-K-207—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Remedial Investigation Borehole C8294 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (46.0 m/151.0 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed [c]
Tritium	N/A	40.1 (24.8/81.3)	33.9	24.8/81.3	U	N/A
Nonradionuclides (mg/kg)						
Cr(VI)	N/A	0.661 (16.0/52.4)		46.0/151.0	0.460	

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 20.8 m (68.2 ft) bgs.

c. Decay-corrected to 2017.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

4.2.4.6 199-K-210

Well 199-K-210 was located approximately 420 m (1,380 ft) north of the KE Reactor, within the river embankment and the 100-K-64 waste site to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 6.4 m (21.0 ft) bgs. Organic vapors were detected by field instrumentation-screening of sediment from 26.6 m (87.2 ft) bgs, and a sample was analyzed for volatile and semivolatile organic compounds. No organic contaminants were detected and no further soil constituent analyses were performed for this well.

4.2.4.7 199-K-220

Well 199-K-220 was located approximately 210 m (690 ft) southeast of the KE Reactor, within the former 183-KE Flocculation and Sedimentation Basins footprint, to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 24.3 m (79.8 ft) bgs. One primary and duplicate soil sample pair was collected from the historic high water table elevation at 21.5 m (70.4 ft) bgs and analyzed for Cr(VI), which was not detected in either sample. No additional soil constituent analyses were performed for this well.

4.2.4.8 199-K-223

Well 199-K-223 was located approximately 290 m (950 ft) south of the KW Reactor, within the former 183-KW Flocculation and Sedimentation Basins footprint, to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 24.0 m (78.7 ft) bgs. Soil samples were collected from multiple intervals in the vadose zone and at the groundwater table and analyzed for multiple metals (including total chromium and mercury) and Cr(VI). Table 4-28 summarizes the analytical data from the borehole. Figure 4-21 presents vertical profiles of analytes detected above background in the borehole.

Table 4-28. Well 199-K-223—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C9595 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (41.9 m/137.4 ft bgs) [b]
Nonradionuclides (mg/kg)				
Copper	22	110 (23.7/77.6)	41.9/137.4	41
Selenium	0.78	0.94 (3.0/10.0)	3.0/10.0	0.15 (<BG)
Vanadium	85.1	86 (1.5/5)	1.5/5	11 (<BG)
Zinc	67.8	85 (23.7/77.6)	23.7/77.6	47 (<BG)

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 24.0 m (78.7 ft) bgs.

BG = background
bgs = below ground surface
HEIS = Hanford Environmental Information System

4.2.4.9 199-K-224

Well 199-K-224 was located approximately 220 m (720 ft) south of the KW Reactor, within the former 183-KW Flocculation and Sedimentation Basins footprint, to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 25.4 m (83.3 ft) bgs. Soil samples were collected from multiple intervals in the vadose zone and at the groundwater table and analyzed for multiple metals (including total chromium and mercury) and Cr(VI). Table 4-29 summarizes the analytical data from the borehole. Figure 4-21 presents vertical profiles of analytes detected above background in the borehole.

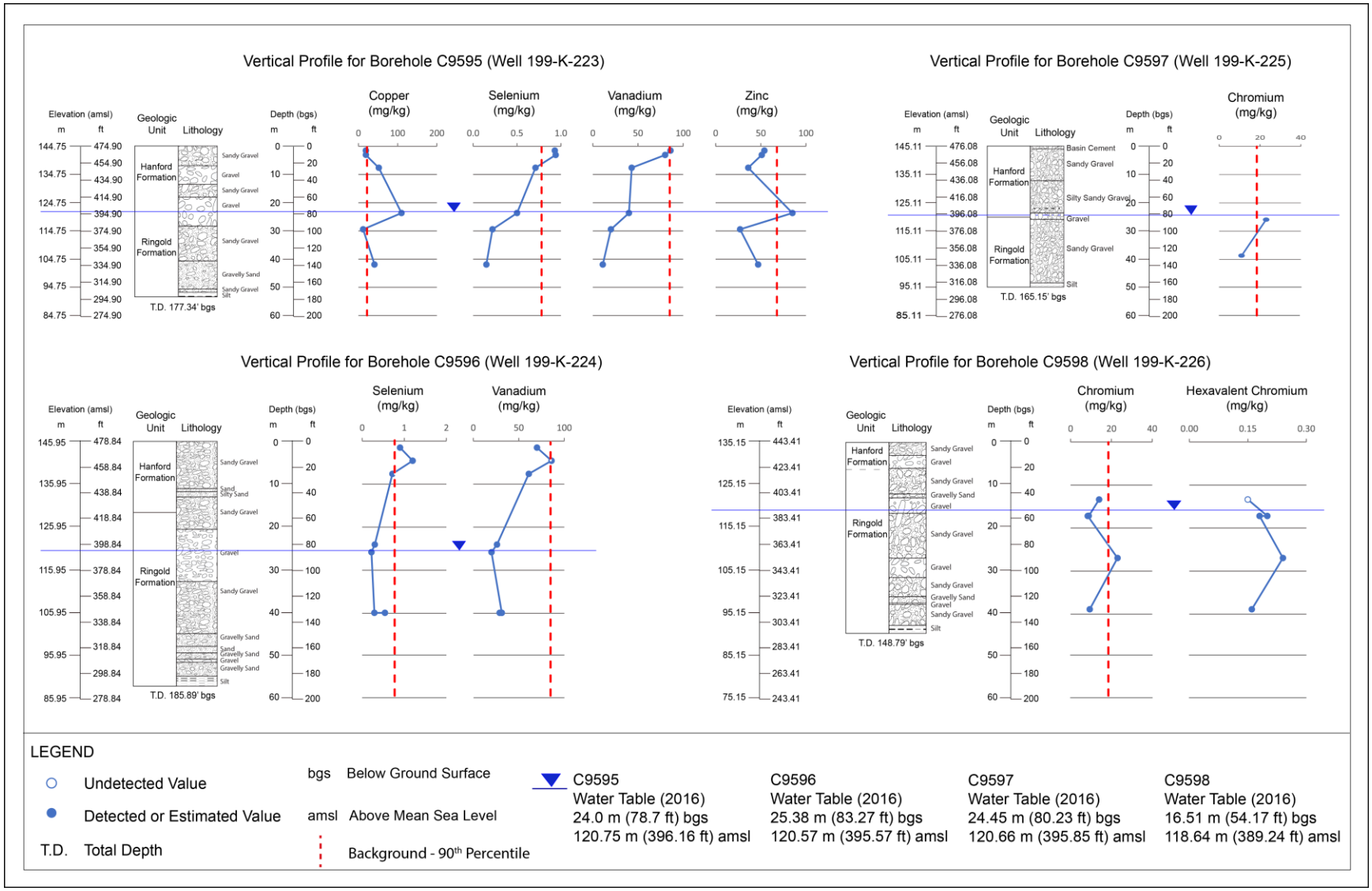


Figure 4-21. Vertical Profiles from Wells 199-K-223, 199-K-224, 199-K-225, and 199-K-226

Table 4-29. Well 199-K-224—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C9596 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (39.9 m/130.9 ft bgs) [b]
Nonradionuclides (mg/kg)				
Selenium	0.78	1.2 (4.6/15.0)	4.6/15.0	0.29 (<BG)
Vanadium	85.1	86 (4.6/15.0)	4.6/15.0	29 (<BG)

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 25.4 m (83.3 ft) bgs.

BG = background

bgs = below ground surface

HEIS = Hanford Environmental Information System

4.2.4.10 199-K-225

Well 199-K-225 was located approximately 250 m (820 ft) south of the KE Reactor, within the former 183-KE Flocculation and Sedimentation Basins footprint, to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 24.5 m (80.2 ft) bgs. Soil samples were collected at the water table and the bottom of the unconfined aquifer and analyzed for total chromium and Cr(VI). Cr(VI) was not detected in either sample. Table 4-30 summarizes the total chromium analytical data from the borehole, and Figure 4-21 presents the corresponding vertical profile.

Table 4-30. Well 199-K-225—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C9597 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (38.7 m/126.9 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	23.0 (4.6/15.0)	25.9/85.1	11.0 (<BG)

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 24.5 m (80.2 ft) bgs.

BG = background

bgs = below ground surface

HEIS = Hanford Environmental Information System

4.2.4.11 199-K-226

Well 199-K-226 was located approximately 280 m (920 ft) north of the KE Reactor, within the remediation footprint of the 116-KE-4 Retention Basins site, to serve as an extraction well for Cr(VI) groundwater contamination in the area. During drilling, the water table was encountered at 16.5 m (54.2 ft) bgs. Soil samples were collected at the water table, the midpoint of the unconfined aquifer, and the bottom of the unconfined aquifer and analyzed for total chromium and Cr(VI). Table 4-31 summarizes the total chromium analytical data from the borehole, and Figure 4-21 presents the corresponding vertical profile.

Table 4-31. Well 199-K-226—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C9598 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (38.9 m/127.5 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	23.0 (27.0/88.4)	27.0/88.4	9.4 (<BG)
Cr(VI)	N/A	0.24 (27.0/88.4)	38.9/127.5	0.16

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 16.5 m (54.2 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable

4.2.4.12 199-K-227

Well 199-K-227 was located approximately 360 m (1,180 ft) east of the KE Reactor, within the remediation footprint of the 118-K-1 Burial Ground, at the 100-K-132 deep vadose zone contamination site. This well was sited to provide additional characterization of deep vadose zone soil and to provide groundwater monitoring to enhance plume definition for tritium and Cr(VI). During drilling, the water table was encountered at 21.4 m (70.3 ft) bgs. Soil samples were collected at 1.5-m (5-ft) intervals from the deep vadose zone beneath the former base of remediation, at the water table, at the midpoint of the unconfined aquifer, and at the bottom of the unconfined aquifer. Soil samples were analyzed for multiple metals (including chromium), Cr(VI), tritium, strontium-90, technetium-99, uranium-233/234, uranium-235, and uranium-238. Table 4-32 summarizes the analytical data from the borehole. Figure 4-22 presents vertical profiles of analytes detected above background in the borehole.

Table 4-32. Well 199-K-227—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution					
	Background	Remedial Investigation Borehole C9711 [a]				
		Maximum Result with Corresponding Depth (m/ft bgs)		Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (46.2 m/151.6 ft bgs) [b]	
Radionuclides (Original and Decayed Concentrations) (pCi/g)						
		Original	Decayed [c]		Original	Decayed [c]
Tritium	N/A	6,040 (22.7/74.5)	6,040	46.2/151.6	251	251
Uranium-233/234	1.1	1.37 (18.3/60.0)	1.37	18.3/60.0	U	N/A
Uranium-235	0.109	1.09 (19.8/65.0)	1.09	19.8/65.0	U	N/A
Uranium-238	1.06	1.81 (18.3/60.0)	1.81	21.9/72.0	U	N/A
Nonradionuclides (mg/kg)						
Antimony	0.13	0.522 (19.8/65.0)		19.8/65.0	U	
Chromium	18.5	27.4 (30.0/98.3)		30.0/98.3	15.9 (<BG)	
Cr(VI)	N/A	0.536 (18.3/60.0)		22.9/75.2	U	

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

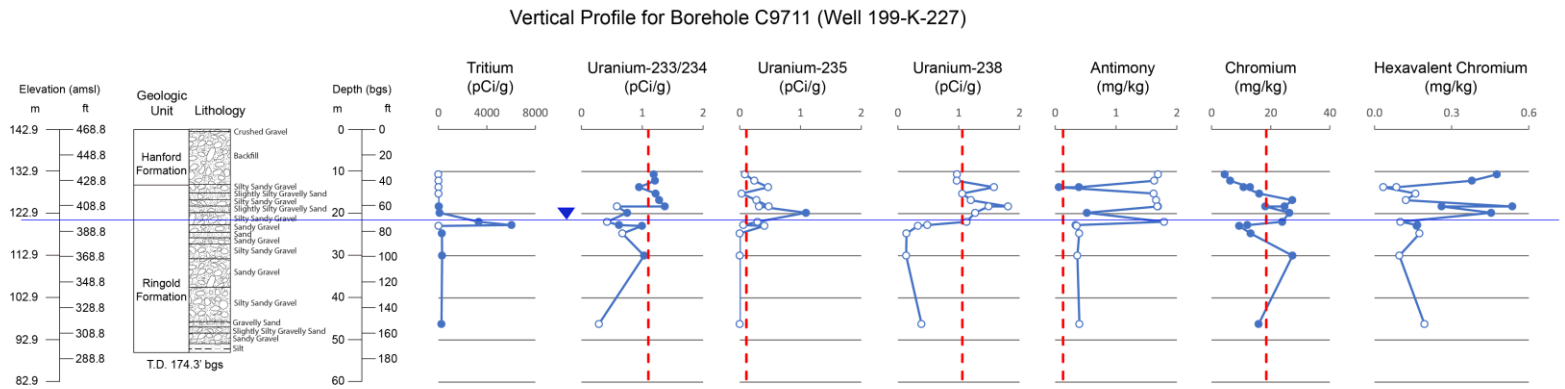
b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 21.4 m (70.3 ft) bgs.

c. Data collected in 2017; no decay-correction applied.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable
U = undetected

4.2.4.13 199-K-228

Well 199-K-228 was located approximately 220 m (660 ft) east of the KE Reactor, to provide groundwater monitoring to enhance plume definition for Cr(VI). During drilling, the water table was encountered at 21.3 m (70.0 ft) bgs. Soil samples were collected at the water table, the midpoint of the unconfined aquifer, and the bottom of the unconfined aquifer and analyzed for metals (including chromium) and Cr(VI). No analyte was detected above background, except for a single detection of antimony in the primary sample from the bottom of the unconfined aquifer (49.1 m [161.2 ft] bgs), quantified at 0.522 mg/kg (relative to a background value of 0.13 mg/kg). Antimony was not detected in any of the other soil samples collected, including the duplicate sample collected from the same depth. Figure 4-23 presents the corresponding vertical profile for antimony.



LEGEND

- ○ Undetected Value
- ● Detected or Estimated Value
- T.D. Total Depth
- bgs Below Ground Surface
- amsl Above Mean Sea Level
- Background - 90th Percentile
- C9711 Water Table (2014) 21.4 m (70.3 ft) bgs 121.5 m (398.5 ft) amsl

Radionuclides decayed to December 31, 2017

Figure 4-22. Vertical Profile from Well 199-K-227

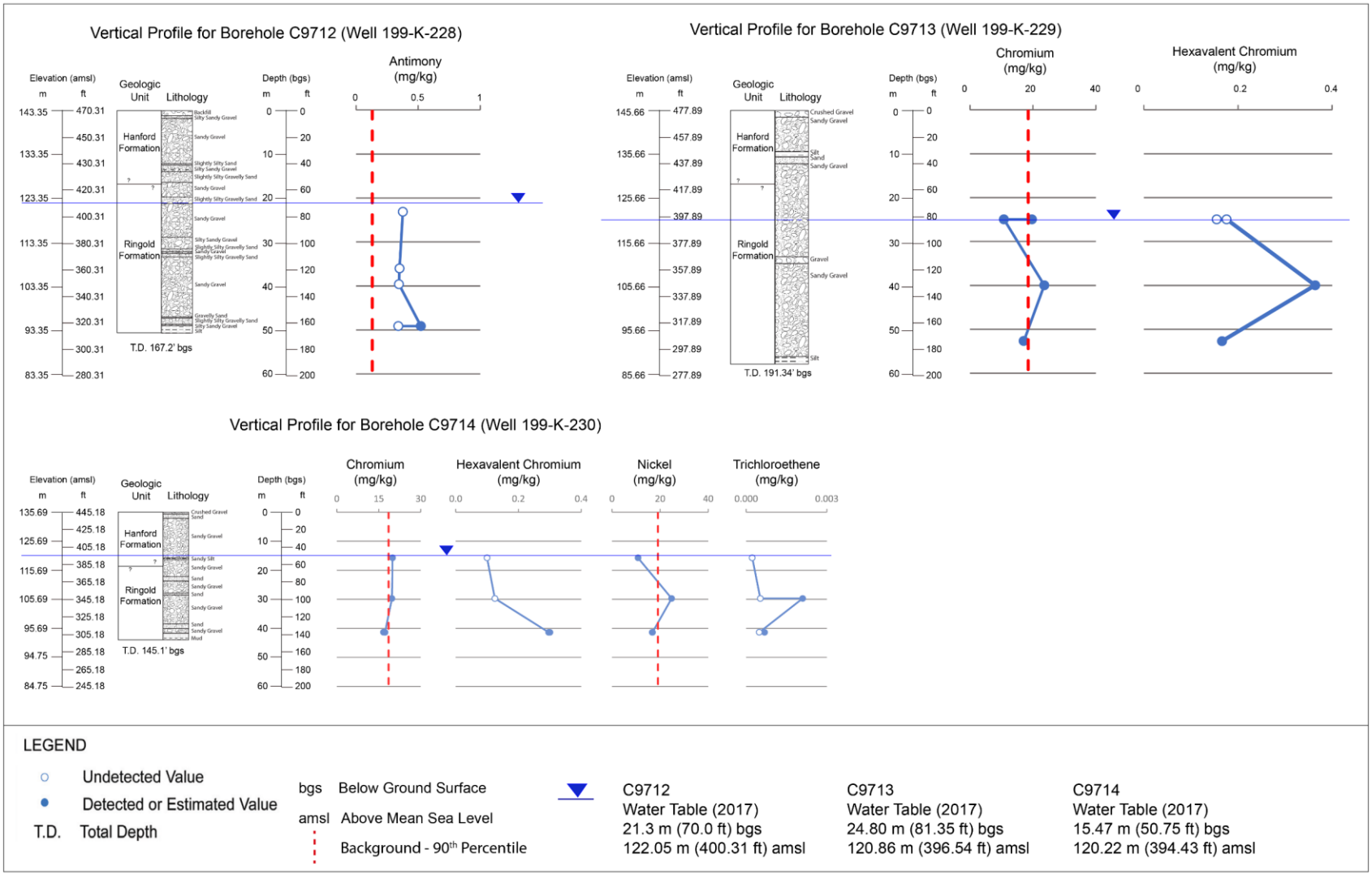


Figure 4-23. Vertical Profiles from Wells 199-K-228, 199-K-229, and 199-K-230

4.2.4.14 199-K-229

Well 199-K-229 was located approximately 210 m (690 ft) southeast of the KW Reactor, near the northwestern corner of the former 183-KW Flocculation and Sedimentation Basins. This well was sited based on modeling for P&T operations to provide groundwater monitoring for Cr(VI). During drilling, the water table was encountered at 24.8 m (81.4 ft) bgs. Soil samples were collected at the water table, the midpoint of the unconfined aquifer, and the bottom of the unconfined aquifer and analyzed for total chromium and Cr(VI). Table 4-33 summarizes the total chromium analytical data from the borehole, and Figure 4-23 presents the corresponding vertical profile.

Table 4-33. Well 199-K-229—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C9713 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection above BG (m/ft bgs)	Result at Maximum Sample Depth (52.7 m/172.9 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	23.6 (52.7/172.9)	52.7/172.9	23.6
Cr(VI)	N/A	0.364 (40.0/131.1)	52.7/172.9	0.166

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 24.8 m (81.4 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable

4.2.4.15 199-K-230

Well 199-K-230 was located approximately 290 m (950 ft) north of the KW Reactor, immediately northeast of the 116-KE-3 Retention Basins site. This well was sited to provide groundwater monitoring for Cr(VI) in a previously unmonitored area that was a potential flow path for contamination from the western portion of 100-K. During drilling, the water table was encountered at 15.5 m (50.8 ft) bgs. Soil samples were collected at the water table, the midpoint of the unconfined aquifer, and the bottom of the unconfined aquifer and analyzed for multiple metals (including chromium), Cr(VI), nitrate, and trichloroethene. Table 4-34 summarizes the total chromium analytical data from the borehole, and Figure 4-23 presents the corresponding vertical profile.

4.2.5 Other Vadose Zone Nature and Extent Data

The verification and RI data described in the preceding sections represent the largest and broadest analytical data sets describing the nature and extent of residual contamination in the vadose zone following completion of interim remedial actions and other removal activities. Additional site-specific data sets were also considered, when available, to provide a more comprehensive understanding of conditions at particular waste sites.

Table 4-34. Well 199-K-230—Summary of Soil Contaminant Data

Analyte	Concentration and Distribution			
	Background	Borehole C9714 [a]		
		Maximum Result with Corresponding Depth (m/ft bgs)	Extent of Detection Above BG (m/ft bgs)	Result at Maximum Sample Depth (41.4 m/135.7 ft bgs) [b]
Nonradionuclides (mg/kg)				
Chromium	18.5	19.9 (15.7/51.6)	29.7/97.5	16.7 (<BG)
Cr(VI)	N/A	0.300 (41.4/135.7)	41.4/135.7	0.300
Nickel	19.1	24.8 (29.7/97.5)	29.7/97.5	16.8 (<BG)
Trichloroethene	N/A	0.000683 (41.4/135.7)	41.4/135.7	0.000683

a. Data obtained from HEIS. Analytes that were not detected above background are not listed.

b. The maximum depth from which samples were collected is below the water table. The water table was encountered at 15.5 m (50.8 ft) bgs.

BG = background
bgs = below ground surface
Cr(VI) = hexavalent chromium
HEIS = Hanford Environmental Information System
N/A = not applicable

4.2.5.1 River Effluent Pipelines Data

The 100-K-80, 100-K-96, 100-K-113, and 100-K-114 sites address the two river effluent pipelines extending from the 1908K outfall structure into the Columbia River channel. Information about studies of the river pipelines is presented in Chapter 1 (Section 1.2.3.9). The data and conclusions from these investigations are considered further in Chapter 6 (Section 6.4.3).

4.2.5.2 Floodplain Soil Investigation

The 100-K-64 and 100-K-111 sites encompass a floodplain area on the downriver side of the 100-K operational area. The 100-K-64 site includes the shoreline embankment and adjacent floodplain area adjacent to the former 107-KE Retention Basins and upriver (southwest) of the 116-K-1 Crib. A simple collection ditch system within the 100-K-64 site is identified as the separate 100-K-57 waste site. During operations, process water effluent leakage from the 107-KE Retention Basins flowed to the 100-K-64 embankment area. The 100-K-57 ditches were excavated to collect and channel the leakage towards the river and reduce erosion of the embankment.

The 100-K-111 site includes the floodplain area downriver (northeast) of the former 116-K-1 Crib and adjacent to the head end of the former 116-K-2 Trench. The 116-K-1 Crib was briefly used for disposal of diverted contaminated cooling water before a portion of the crib washed out. The crib was repaired, but subsequently replaced by the 116-K-2 Trench, which was an unlined trench that provided the primary disposal for diverted process water. The 100-K-111 site was identified to address potential soil contamination from seepage from the 116-K-1 or 116-K-2 sites or lateral contaminant migration from the 100-K-64 site.

Soil samples were collected from these sites to characterize residual contaminant concentrations. Systematic random and focused samples were collected within the 100-K-64 and 100-K-111 footprints, including focused samples within the 100-K-57 ditches. The sampling area also included the shoreline area between the 116-K-2 Trench and the ordinary high water mark, along the entire length of the trench, as well as riparian sampling locations (Figure 4-24). Soil samples were also collected from a portion of the 100-K-83 emergency overflow spillway located within the 100-K-64 site footprint. Results from sampling are presented and evaluated in Appendix H.

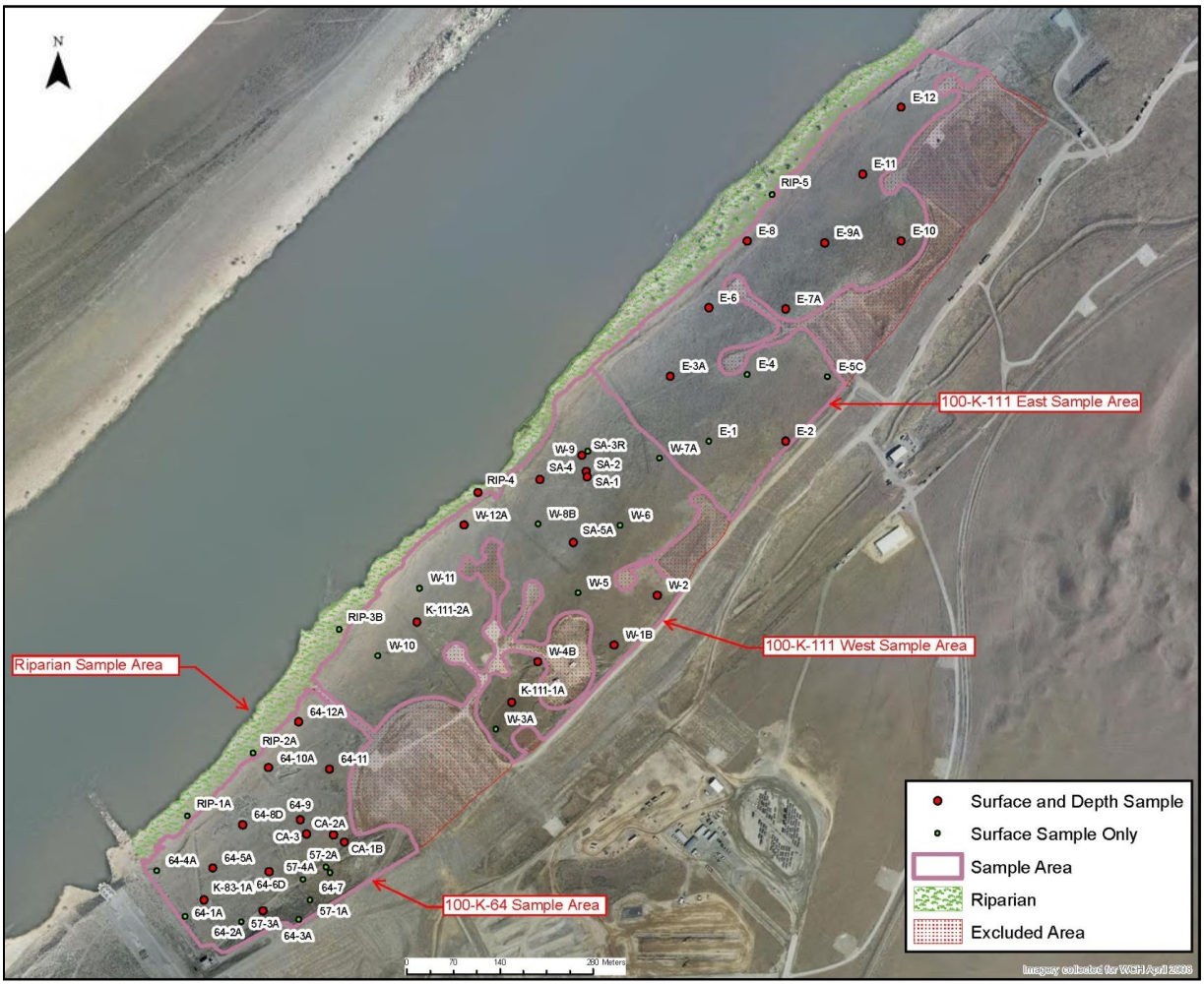


Figure 4-24. 100-K-64 and 100-K-111 Sampling Locations

4.2.5.3 100-K-132 Waste Site Characterization

The 100-K-132 waste site addresses tritium contamination in the deep vadose zone underlying the southern portion of the former 118-K-1 Burial Ground. Remediation in the southern portion of the burial ground extended up to 12.2 m (40 ft) bgs. A characterization test pit was excavated to approximately 5 m (16 ft) below this depth and identified elevated tritium activities in the soil column, ranging between 181 and 372 pCi/g (CVP-2013-00002, *Cleanup Verification Package for the 118-K-1 Burial Ground*). Remediation in the southeastern portion of the burial ground extended up to 15.6 m (51 ft) bgs. A characterization test pit was also excavated in this area to approximately 4.6 m (15 ft) below the depth of remediation. Elevated tritium activities were also identified in this soil column, ranging between 8,520 and 13,400 pCi/g (CVP-2013-00002). After the 118-K-1 remedial excavation was backfilled, a

monitoring well (199-K-227) was completed in the southeastern portion of the burial ground footprint, downgradient from the characterization test pit location (Section 4.2.4.12).

4.2.5.4 116-KE-1 and 116-KW-1 Cribs Characterization

The 116-KE-1 and 116-KW-1 Cribs were used to discharge liquid effluent wastes from the 115-KE and 115-KW Gas Recirculation Facilities, respectively. Both cribs primarily received condensate from the reactor gas purification system. The sites were remediated to a depth of approximately 9 m (30 ft) bgs in 2004 (BHI-01737, *Cleanup Status Report for the 116-KE-1 and 116-KW-1 Cribs*). Characterization samples collected following remediation indicated that interim remedial action objectives were not attained, but further remediation was not performed due to the close proximity of facilities, including the 105-KE and 105-KW Reactors, and the apparent extent of contaminated soil remaining at the sites.

Characterization of the residual soil at the 116-KE-1 site identified multiple elevated radionuclide activities, particularly carbon-14 (up to 7,600 pCi/g) and tritium (up to 851 pCi/g). Low levels of residual mixed fission products were also identified, including cesium-137 (up to 8.69 pCi/g) and strontium-90 (up to 0.946 pCi/g). Elevated results were limited to characterization samples collected below 4.6 m (15 ft) bgs.

Soil characterization results for the 116-KW-1 site generally identified more elevated activities of residual contamination. Carbon-14 and tritium were detected up to 45,000 pCi/g and 162 pCi/g, respectively, and cesium-137 and strontium-90 were detected up to 36.8 pCi/g and 4.61 pCi/g, respectively. The highest activity levels were measured in samples collected below 4.6 m (15 ft) bgs, but carbon-14 and tritium contamination were also detected in shallower soil sidewalls.

Additional soil remediation was performed around the 116-KE-1 site from 2010 to 2011 during remediation of the proximal 100-K-6, 100-K-46, 100-K-62, and 132-KE-1 sites (DOE/RL-2012-38, *Remaining Sites Verification Package for the 100-KR-2 Operable Unit Waste Sites: 100-K-6, 100-K-46, 100-K-62, and 132-KE-1*). Remediation in the vicinity of the 116-KE-1 Crib did not extend below the 2004 remedial action depth. Elevated carbon-14 (up to 65.5 pCi/g) was detected in verification samples and attributed to residual contamination associated with the 116-KE-1 Crib.

4.2.5.5 Ongoing Interim Remedial Action

Interim remedial action is ongoing at 100-K and will continue during development of a final action ROD. Table 4-35 provides a site listing with planned interim remedial actions that had not been completed by April 30, 2017, as well as the interim action decision document for each site. These sites will be carried into the FS as sites requiring remedial action. Additional information for these sites is provided in Appendix E.

Table 4-35. Wastes Sites with Ongoing Interim Action Planning

Site	Interim Action Decision Document	Site	Interim Action Decision Document
100-K-1	Liquid Effluent Waste Site ROD Amendment [a]	100-K-98	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-5	2009 ESD for the Remaining Sites ROD [b]	100-K-99	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-13	Remaining Sites ROD [c]	100-K-101	2010 Fact Sheet for the Remaining Sites ROD [e]

Table 4-35. Wastes Sites with Ongoing Interim Action Planning

Site	Interim Action Decision Document	Site	Interim Action Decision Document
100-K-25	2009 ESD for the Remaining Sites ROD [b]	100-K-103	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-27	2009 ESD for the Remaining Sites ROD [b]	100-K-104	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-35	Remaining Sites ROD [c]	100-K-107	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-43	Remaining Sites ROD [c]	100-K-108	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-47	2009 ESD for the Remaining Sites ROD [b]	116-K-3	Remaining Sites ROD [c]
100-K-48	Remaining Sites ROD [c]	116-KE-1	Liquid Effluent Waste Site ROD Amendment [a]
100-K-49	Remaining Sites ROD [c]	116-KE-2	Liquid Effluent Waste Site ROD Amendment [a]
100-K-54	Remaining Sites ROD [c]	116-KE-3	Liquid Effluent Waste Site ROD Amendment [a]
100-K-55:2	Liquid Effluent Waste Site ROD Amendment [a]	116-KW-1	Liquid Effluent Waste Site ROD Amendment [a]
100-K-56:2	Liquid Effluent Waste Site ROD Amendment [a]	116-KW-2	Liquid Effluent Waste Site ROD Amendment [a]
100-K-56:3	Liquid Effluent Waste Site ROD Amendment [a]	120-KE-1	Remaining Sites ROD [c]
100-K-60	2004 ESD for the Remaining Sites ROD [d]	120-KE-2	Remaining Sites ROD [c]
100-K-72	2009 ESD for the Remaining Sites ROD [b]	120-KE-3	Remaining Sites ROD [c]
100-K-73	2009 ESD for the Remaining Sites ROD [b]	120-KE-4	2009 ESD for the Remaining Sites ROD [b]
100-K-74	2009 ESD for the Remaining Sites ROD [b]	120-KE-5	2009 ESD for the Remaining Sites ROD [b]
100-K-75	2009 ESD for the Remaining Sites ROD [b]	120-KE-6	Remaining Sites ROD [c]
100-K-79:3	2004 ESD for the Remaining Sites ROD [d]	120-KE-8	2009 ESD for the Remaining Sites ROD [b]
100-K-79:4	2004 ESD for the Remaining Sites ROD [d]	120-KE-9	2009 ESD for the Remaining Sites ROD [b]
100-K-79:5	2004 ESD for the Remaining Sites ROD [d]	120-KW-6	2009 ESD for the Remaining Sites ROD [b]

Table 4-35. Wastes Sites with Ongoing Interim Action Planning

Site	Interim Action Decision Document	Site	Interim Action Decision Document
100-K-79:6	2004 ESD for the Remaining Sites ROD [d]	130-K-2	Remaining Sites ROD [c]
100-K-79:7	2004 ESD for the Remaining Sites ROD [d]	130-KE-2	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-79:8	2004 ESD for the Remaining Sites ROD [d]	130-KW-1	Remaining Sites ROD [c]
100-K-79:9	2004 ESD for the Remaining Sites ROD [d]	130-KW-2	2010 Fact Sheet for the Remaining Sites ROD [e]
100-K-81	2009 ESD for the Remaining Sites ROD [b]	1607-K1	2009 ESD for the Remaining Sites ROD [b]
100-K-82	2009 ESD for the Remaining Sites ROD [b]	1607-K5	2009 ESD for the Remaining Sites ROD [b]
100-K-83	2009 ESD for the Remaining Sites ROD [b]	1607-K6	2009 ESD for the Remaining Sites ROD [b]
100-K-94	2010 Fact Sheet for the Remaining Sites ROD [e]	UPR-100-K-1	Remaining Sites ROD [c]

References: EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision*.

EPA, Ecology, and DOE, 2009a, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision: Hanford Site Benton County, Washington.*

EPA, Ecology, and DOE, 2011, *100 Area "Plug-In" and Candidate Waste Sites for Fiscal Year 2010*.

EPA/AMD/R10-97/044, *Amendment to the Interim Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.*

EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.*

a. EPA/AMD/R10-97/044.

b. EPA et al., 2009a.

c. EPA/ROD/R10-99/039.

d. EPA et al., 2004.

e. EPA et al., 2011.

ESD = explanation of significant differences

ROD = record of decision

4.3 Groundwater Contamination

To better define the nature and extent of groundwater contamination at 100-K, the 100-K Work Plan (DOE/RL-2008-46-ADD2) identified several data needs requiring additional sampling and analysis. Data gaps 5, 7, 10, and 13 on Table 2-2 required additional groundwater data collection. These efforts focused on the need to define the extent of groundwater contamination for COPCs in the unconfined aquifer (Data Gap 5) and in the uppermost confined aquifer in the RUM (Data Gap 7). Results from groundwater samples collected in the PRZ above the unconfined aquifer and within the RUM unit were evaluated with soil results to identify mechanisms for Cr(VI) persistence (Data Gap 10). Groundwater data were collected during the RI from 18 wells to define the spatial and temporal distribution of groundwater contamination (Data Gap 13).

The RI data and additional data collected from October 2009 through April 2017 were used to evaluate the nature and extent of contamination. These include groundwater monitoring data from the interim RA and Hanford Site programs and are considered representative of current groundwater conditions.

Following the data evaluation described in Section 4.5, data are discussed for Cr(VI), nitrate, tritium, carbon 14, strontium 90, and trichloroethene in Section 4.6. These six COPCs have consistent concentrations greater than regulatory limits. Summary statistics and plume maps are based on groundwater data from 2009 through 2017. Groundwater data are available via the Hanford Environmental Dashboard application (https://ehs.hanford.gov/eda/) and included in Appendix D.

4.3.1 Groundwater Data Collected for Spatial and Temporal Analysis

As a result of the uncertainties identified in the RCBRA (DOE/RL-2007-21), the Integrated Work Plan (DOE/RL-2008-46) added activities to help reduce uncertainties, verify HHRA conclusions presented in the RCBRA (DOE/RL-2007-21, Volume II), and ensure contaminants were not inadvertently overlooked based on using the existing (2008) groundwater data set. Section 3.6.5.1 of the Integrated Work Plan (DOE/RL-2008-46) identified the following activities to reduce uncertainties:

- Identify existing and/or install new monitoring wells spatially representative of the groundwater. This set of wells will represent locations where a receptor potentially could contact groundwater.
- Conduct multiple sampling rounds to obtain temporal representation of the unconfined aquifer from influence of river stage. Additional sampling rounds at spatially representative monitoring wells will represent current groundwater conditions and capture the influence of river fluctuations on COPC concentrations.
- Analyze all spatially representative monitoring wells for a focused list of groundwater COPCs identified for each round of sampling. Analyzing the monitoring wells for COPCs will provide a data set representative of potential releases to the groundwater.
- Evaluate sample results from characterization activities to support final remedial action decisions for groundwater.

To address Data Gap 13 in Table 2-2, groundwater monitoring wells were sampled and results analyzed to provide spatial and temporal distribution of COPCs. Samples were collected during three distinct river stage periods.

The Historical Groundwater Evaluation in Section 4.5.2 describes the process to identify and select COPCs for the spatial and temporal analysis. Eighteen monitoring wells were selected to represent the 100-KR-4 OU spatially, with three sampling rounds collected from each location for COPC analyses. Sampling rounds for the RI spatial and temporal analysis were collected at low, transitional, and high

river stage to represent the temporal variability in aquifer constituent concentrations during the year. Figure 4-25 shows the 18 wells sampled in October 2009 (low river stage), March 2010 (transitional river stage), and June 2010 (high river stage). These sampling intervals are evaluated with respect to the temporal changes in the aquifer, and the degree to which the intervals reflect varying aquifer conditions related to fluctuations in the Columbia River elevations.

Seasonal variations in Columbia River elevation affect aquifer conditions by causing temporary changes in the water table. River elevation effects on groundwater generally diminish with increasing distance from the river. The effects include alterations in flow direction and velocity, which can result in local changes in contaminant concentrations. For example, during high river stage, river water may extend inland to some degree and mix with the aquifer, resulting in lower measured contaminant concentration in the nearshore locations. Within the aquifer, a high river stage is experienced inland as a pressure pulse, causing the water table to rise. As a result, the higher water table may extend into the overlying vadose zone. When contaminant source material is in the PRZ, the contaminants may mobilize, causing an increase in contaminant concentrations in nearby and downgradient monitoring wells. During low river stage, contaminants may be sorbed to vadose zone soil greater than the water table in the PRZ and not contribute to aquifer contamination. The RI spatial and temporal sampling was conducted during periods when the river elevation and water table were high, low, and transitional to characterize the dynamic groundwater conditions and associated contaminant levels.

River stage elevation at 100-K typically fluctuates 3 to 4 m (10 to 13 ft) during a year. Examples of the seasonal river elevation changes are shown in Figure 3-5. The daily average elevations depict a cyclical variation in river stage from year to year. These periodic or cyclic changes are engineered by upstream dams and reservoirs used for flood control, hydroelectric production, and salmon spawning programs. For any given year, the highest river elevations occur from May through June, and the lowest levels from September through October, possibly extending to mid-November. The transitional periods between the maximum and minimum river elevations occur from approximately December through April and July through August. The change from low to high elevations occurs gradually over about 4 months, when levels are increasing from the fall low to the May to June maximum. The change from high to low levels is faster, generally occurring between July and August.

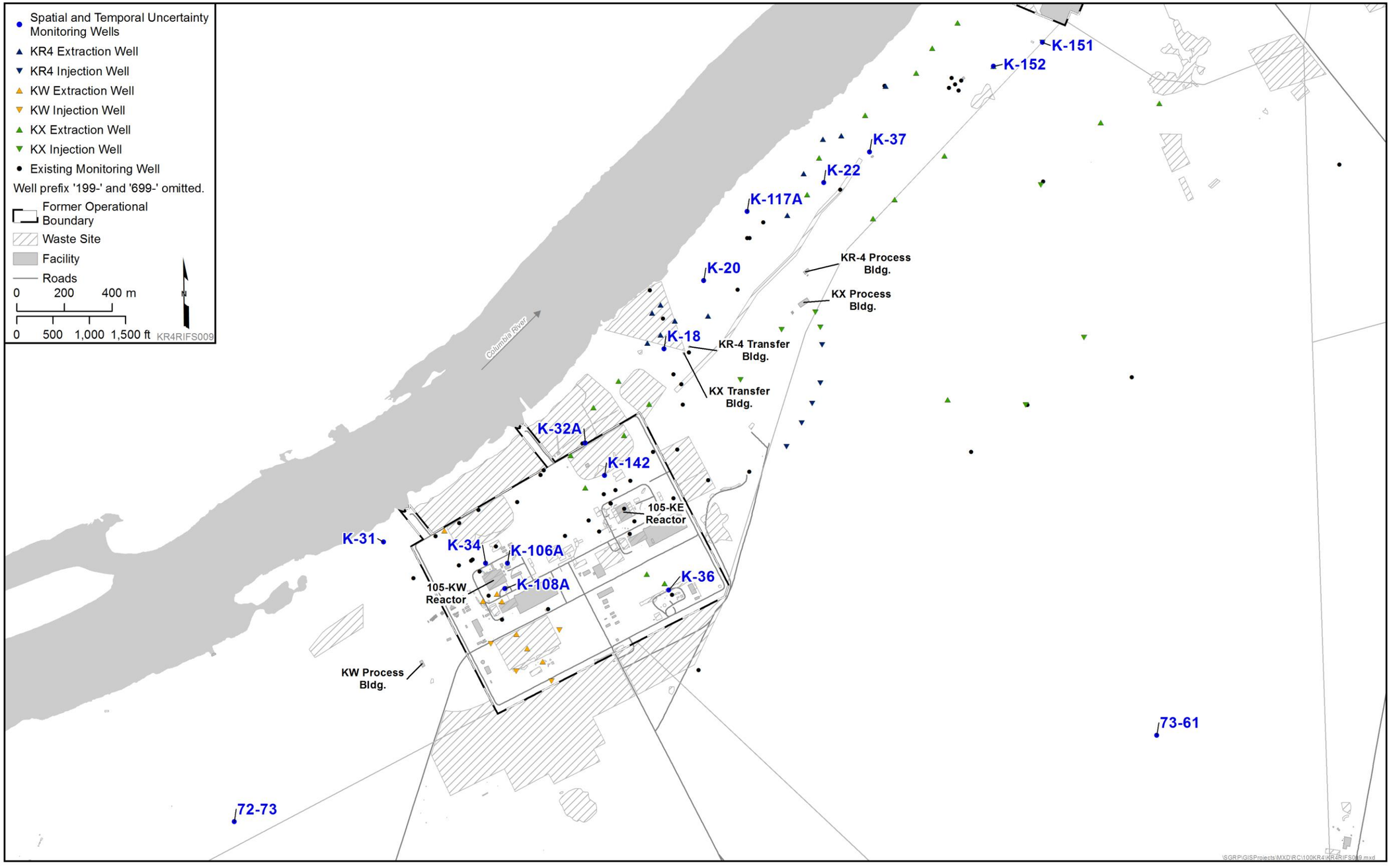


Figure 4-25. RI Spatial and Temporal Groundwater Sampling Locations

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To illustrate the maximum and minimum river elevations are predictable and useful for setting the 100-KR-4 OU risk assessment sampling schedule, trends of daily averaged elevation measurements covering the same 360-day period from September through August are superimposed in Figure 4-26. The comparison illustrates the cyclical seasonal variations, allowing the timing of river fluctuations to schedule the 100-KR-4 OU RI groundwater sampling. This schedule, as discussed in the Integrated Work Plan (DOE/RL-2008-46) and outlined in the 100-K SAP (DOE/RL-2009-41), began in October 2009 and was completed in June 2010.

Each sampling event was completed within the predetermined periods for low water table from mid-September to mid-November, transitional aquifer conditions occurring from December 2009 through April 2010, and maximum aquifer levels from May through June 2010. However, an extremely high river stage occurred in July 2010**.** This anomaly resulted from unusual snowfall and temperatures, and could not have been predicted. Each sampling event was completed within 30 days, minimizing sample effects from dynamic river fluctuations. Based on the previous discussion, the analytical data from groundwater collected during these three sampling events represent the dynamic groundwater conditions at the 100-KR-4 OU.

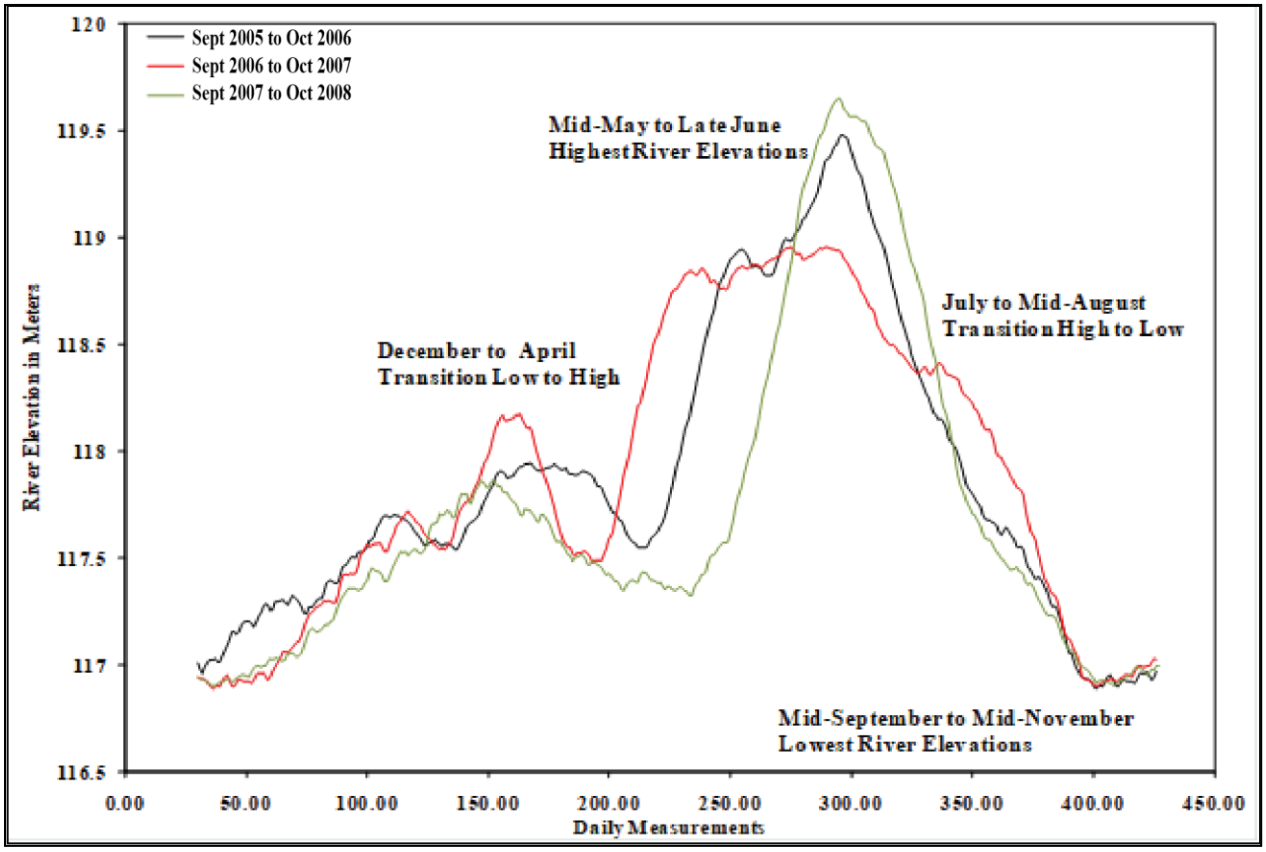

Figure 4-26. Annual Trends in River Elevations at a Single Location

Figure 4-27 shows hydrographs for the 100-K river gauge and wells screened in the unconfined aquifer. Groundwater levels in wells 199-K-18, 199-K-32A, 199-K-108A, and 199-K-117A track relatively closely to changes in river stage elevation. However, due to the extensive network of extraction and injections wells, most of the 100-KR-4 OU groundwater is under the P&T systems influence. Wells closer to the river track more closely to the river response and the river inflections in the aquifer can be measured relatively far inland.

The analytical data are presented in Appendix D, incorporated into the historical summary statistics, and included in the contaminant distribution discussions in Sections 4.4.1 to 4.4.8. Further evaluations, including the COPCs, are presented in Chapter 6, Human Health Risk Assessment.

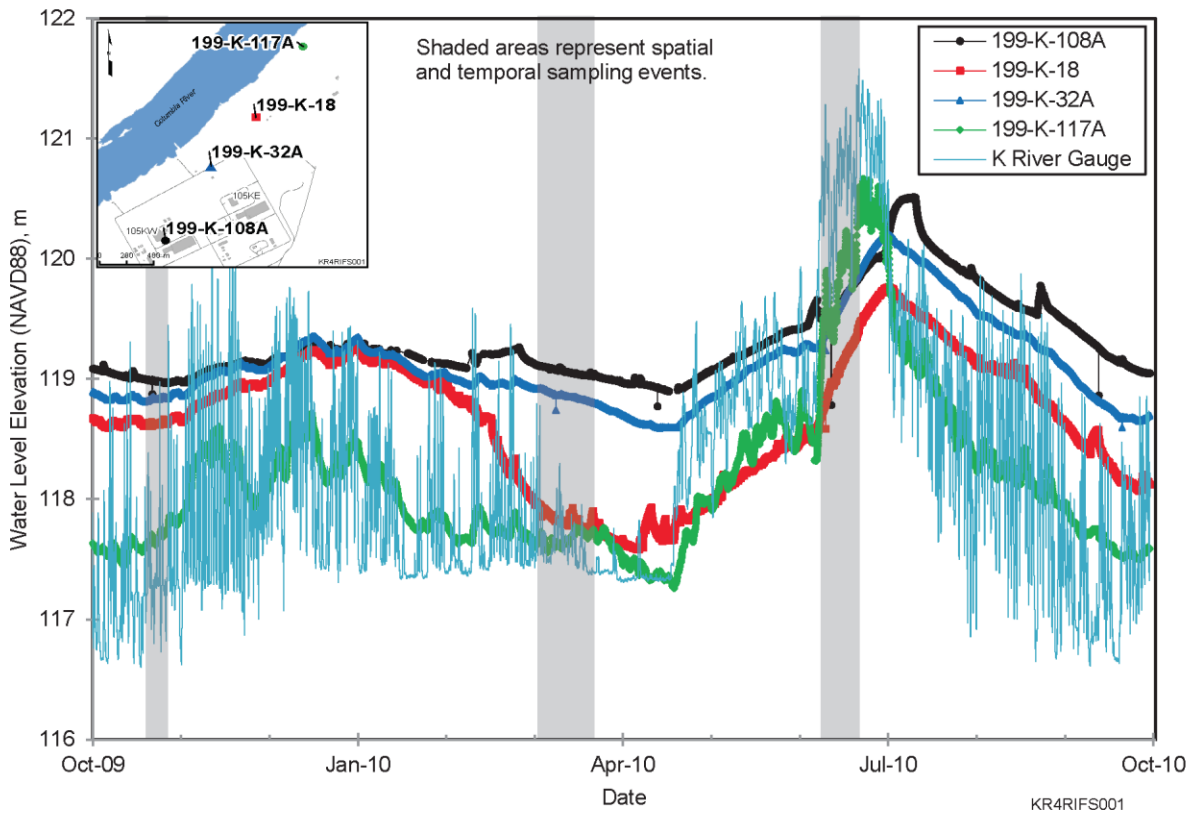

Figure 4-27. Hydrographs of the Columbia River at 100-K and Groundwater Levels in Select Monitoring Wells

4.3.2 Historical Groundwater Evaluation

As a result of the uncertainties identified in the RCBRA (DOE/RL-2007-21, Volume II), a rigorous groundwater data analysis was performed to identify COPCs, as described and reported in the 100-K Work Plan (DOE/RL-2008-46-ADD2). Table 1-3 in the 100-K SAP (DOE/RL-2009-41) lists the 34 groundwater COPCs identified in the assessment. Analytical data used for the screening level assessment were collected to fulfill a variety of state and federal regulations including the *Atomic Energy Act of 1954* (AEA), RCRA, CERCLA, and Section 173 of the *Washington Administrative Code*. While the monitoring data can be used for risk assessment purposes, there are uncertainties associated with its use. Specifically, target analytes, sampling frequencies, and MDLs (or reporting limits) are different between programs because the information is used to meet different requirements.

The groundwater data set used for COPC identification included sampling and analysis data collected from 57 monitoring wells in the 100-KR-4 OU. The data were collected between January 23, 1992, and December 8, 2008, and included the four consecutive quarterly rounds collected during 1992 and 1993 to support the 100-KR-4 LFI (DOE/RL-93-79). These LFI data were also used for the ecological component of the qualitative risk assessment (WHC-SD-EN-RA-010).

The analytical performance requirements are listed in the 100-K SAP (DOE/RL-2009-41, Table 2-4) and were intended to meet Data Gap 13. The action level is listed to ensure the reporting limits were adequate to confirm COPC presence or absence. Spatial and temporal data, discussed in Section 4.5.1, were included for the groundwater risk assessment. The data set used for the groundwater risk assessment (Section 6.3) consists of sampling and analysis data from 82 monitoring and extraction wells. This data set is discussed in Section 4.5.3.

4.3.3 Evaluation of Groundwater Contaminants of Potential Concern

Data Gap 13 (Table 2-2), stated, "Data are needed to better define the spatial and temporal distribution of groundwater contamination." To fill this data gap, wells were sampled for all groundwater COPCs. These data also fill Data Gap 5, "The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been defined in select areas."

This section summarizes results of COPC sampling and comparisons of results to applicable water quality standards. Appendix D discusses this evaluation in greater detail, and Chapter 6 presents the results of the groundwater risk assessment and determination of final COPCs.

This evaluation of the nature and extent of contamination in groundwater was based on data from wells and aquifer tubes sampled between October 2009 and April 2017. Figure 4-27 illustrates the spatial and temporal sampling periods in relation to river stage. The following groundwater sampling occurred between October 2009 and April 2017:

- Three rounds of spatial and temporal sampling at 18 wells in 2010, as specified in the 100-K Work Plan (DOE/RL-2008-46-ADD2)
- Additional groundwater sampling (existing wells and wells installed after 2010) per DOE/RL-2009-41
- Groundwater sampling under DOE/RL-2013-29
- Aquifer tube sampling under DOE/RL-2000-59

Figure 4-28 shows the wells included in the RI groundwater evaluation. Groundwater data for 100-K were compiled and statistically analyzed, and the results are summarized in Table 4-36. Appendix D presents detailed results, including the summary statistics for each analyte identified as a COPC in the work plan, lists the background concentrations in Hanford Site groundwater (DOE/RL-96-61) where available, and lists the action level for each analyte.

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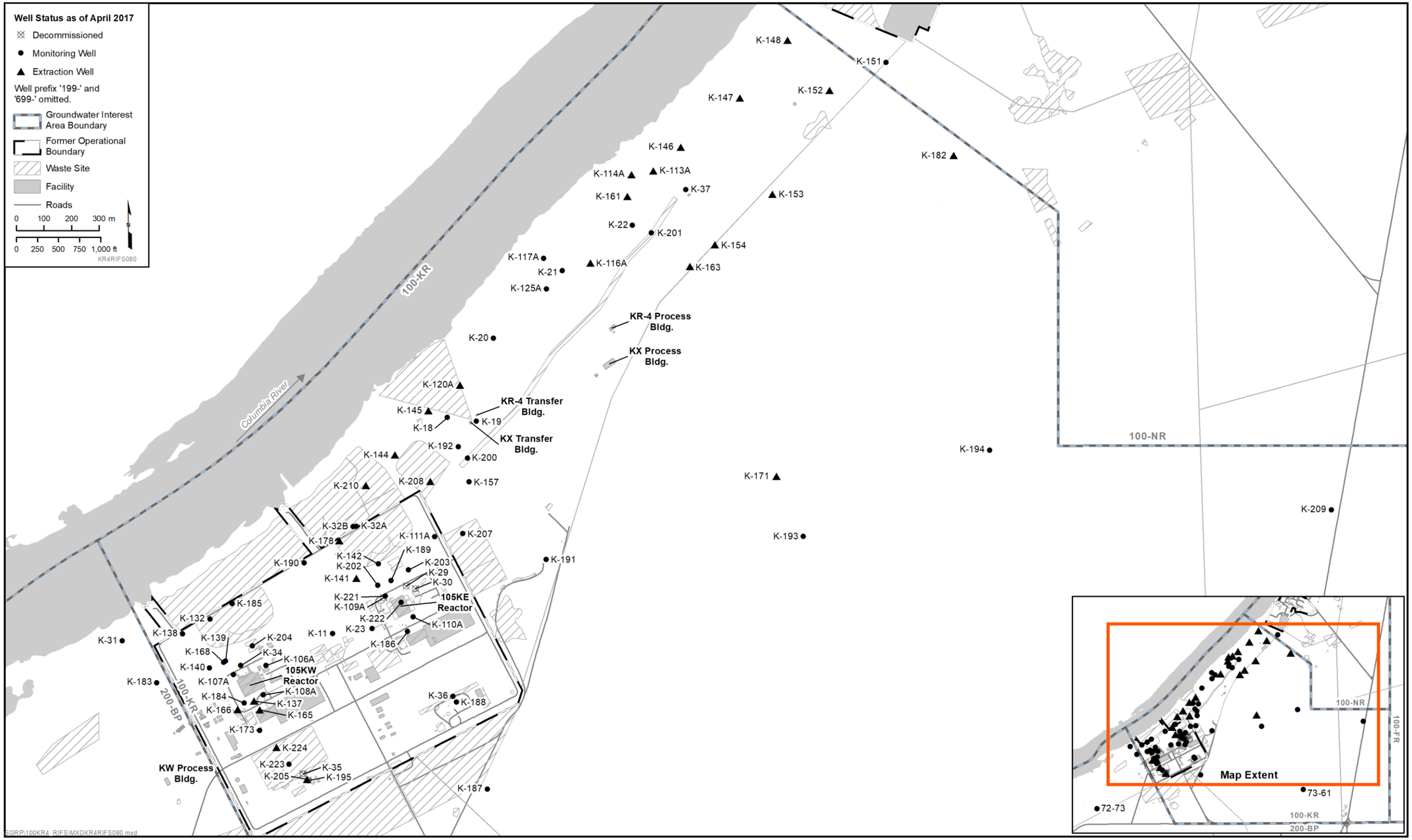

Figure 4-28. Wells for RI Groundwater Sampling

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Table 4-36. Groundwater Summary Statistics for Analytes Detected Above Background and Action Levels

Analyte	Units	Number of Results	Percent Detects	Maximum Detection	Background	Percent > Background	Action Level	Actin Level Basis	Percent > Action Level	Comments
Wells Screened in Top of Unconfined Aquifer										
Comparison to Human Health DWSs and Criteria										
Carbon-14	pCi/L	308	89	40,100	N/A	N/A	2,000	DWS	21	COPC
Strontium-90	pCi/L	276	53	251	0.0146	53	8	DWS	39	COPC
Tritium	pCi/L	383	89	379,000	119	89	20,000	DWS	14	COPC
Trichloroethene	µg/L	161	68	7.4	N/A	N/A	0.54 4	MTCA Adj MCL	64 22	See note[c] COPC
Chromium [a]	µg/L	366	98	764	2.4	98	100	DWS	14	COPC
Cr(VI)[a]	µg/L	438	92	571	N/A	N/A	48	MTCA	18	COPC
Nitrate	mg/L	409	100	100,900	26.9	64	45	DWS	19	COPC
Comparison to Surface Water Standards										
Chromium [b]	µg/L	369	94	541	2.4	92	65	CWA	17	COPC
Cr(VI)[a]	µg/L	438	92	571	N/A	N/A	10	AWQC	54	COPC
Well Screened in Upper Unconfined Aquifer										
Comparison to Human Health DWSs and Criteria										
Carbon-14	pCi/L	408	65	26,600	N/A	N/A	2,000	DWS	4.6	COPC
Strontium-90	pCi/L	399	37	152	0.0146	37	8	DWS	15	COPC
Tritium	pCi/L	431	77	58,000	119	77	20,000	DWS	1.6	COPC

Table 4-36. Groundwater Summary Statistics for Analytes Detected Above Background and Action Levels

Analyte	Units	Number of Results	Percent Detects	Maximum Detection	Background	Percent > Background	Action Level	Actin Level Basis	Percent > Action Level	Comments
Trichloroethene	µg/L	173	69	6	N/A	N/A	0.54 4	MTCA Adj MCL	69 24	See note[c] COPC
Chromium [a]	µg/L	508	94	3,250	2.4	90	100	DWS	8.1	COPC
Cr(VI) [a]	µg/L	562	82	3,310	N/A	N/A	48	MTCA	13	COPC
Nitrate	mg/L	466	100	87,700	26.9	9.4	45	DWS	0.9	COPC
Comparison to Surface Water Standards										
Chromium [b]	µg/L	511	92	5,220	2.4	84	65	CWA	9.4	COPC
Cr(VI)[a]	µg/L	562	82	3,310	N/A	N/A	10	AWQC	48	COPC
Wells Screened through the Entire Unconfined Aquifer										
Comparison to Human Health DWSs and Criteria										
Carbon-14	pCi/L	208	72	6,140	N/A	N/A	2,000	DWS	7.7	COPC
Strontium-90	pCi/L	168	27	8.1	0.0146	12	8	DWS	0.5	COPC
Tritium	pCi/L	267	96	935,000	119	96	20,000	DWS	16	COPC
Trichloroethene	µg/L	96	67	9.5	N/A	N/A	0.54 4	MTCA Adj MCL	65 48	See note[c] COPC
Chromium[a]	µg/L	294	97	261	2.4	96	100	DWS	4.4	COPC
Cr(VI)[a]	µg/L	349	97	353	N/A	N/A	48	MTCA	21	COPC
Nitrate	mg/L	291	100	75,300	26.9	11	45	DWS	2.1	COPC

Table 4-36. Groundwater Summary Statistics for Analytes Detected Above Background and Action Levels

Analyte	Units	Number of Results	Percent Detects	Maximum Detection	Background	Percent > Background	Action Level	Actin Level Basis	Percent > Action Level	Comments
Comparison to Surface Water Standards										
Chromium [b]	µg/L	294	97	255	2.4	95	65	CWA	8.2	COPC
Cr(VI) [a]	µg/L	349	97	353	N/A	N/A	10	AWQC	56	COPC
Wells Screened in the Lower Unconfined Aquifer										
Comparison to Human Health DWSs and Criteria										
Trichloroethene	µg/L	51	100	6.5	N/A	N/A	0.54 4	MTCA Adj MCL	100 49	See note[c] COPC
Cr(VI) [a]	µg/L	79	100	95	N/A	N/A	48	MTCA	6.3	COPC
Comparison to Surface Water Standards										
Chromium[b]	µg/L	75	100	68	2.4	100	65	CWA	1.3	COPC
Cr(VI) [a]	µg/L	79	100	95	N/A	N/A	10	AWQC	68	COPC
Wells Screened in the Upper and Lower Unconfined Aquifer										
Comparison to Human Health DWSs and Criteria										
None	--	--	--	--	--	--	--	--	--	
Comparison to Surface Water Standards										
Cr(VI)[a]	µg/L	23	100	33	N/A	N/A	10	AWQC	91	COPC
Wells Screened in Ringold Upper Mud										
Comparison to Human Health DWSs and Criteria										
None	--	--	--	--	--	--	--	--	--	

Table 4-36. Groundwater Summary Statistics for Analytes Detected Above Background and Action Levels

Analyte	Units	Number of Results	Percent Detects	Maximum Detection	Background	Percent > Background	Action Level	Actin Level Basis	Percent > Action Level	Comments
Comparison to Surface Water Standards										
None	--	--	--	--	--	--	--	--	--	
Aquifer Sampling Tubes										
Comparison to Human Health DWSs and Criteria										
Strontium-90	pCi/L	173	18	8.8	0.0146	18	8	DWS	0.6	Isolated exceedance; not COPC
Trichloroethene	pCi/L	113	33	1	N/A	N/A	0.54 4	MTCA Adj MCL	20 0	Not a COPC
Cr(VI)[a]	µg/L	370	41	50	N/A	N/A	48	MTCA	0.3	Isolated exceedance; not COPC
Comparison to Surface Water Standards and Criteria										
Cr(VI)[a]	µg/L	370	41	50	N/A	N/A	10	AWQC	6.8	COPC

Note: Based on data collected 2009 through 2017 with at least one value exceeding the action level and background concentration; full summary is in Appendix D.

a. Unfiltered samples.

b. Filtered samples.

c. Trichloroethene concentrations in several wells were greater than the MTCA (WAC-173-340-720) groundwater cleanup level. The trichloroethene concentrations measured in wells 199-K-11, 199-K-31, 199-K-34, 199-K-106A, 199-K-107A, 199-K-108A, 199-K-132, 199-K-137, 199-K-138, 199-K-139, 199-K-140, 199-K-165, 199-K-166, 199-K-168, 199-K-173, 199-K-183, 199-K-184, 199-K-185, 199-K-190, 199-K-204, 199-K-223, 199-K-224, were greater than the 4 µg/L adjusted MCL, and trichloroethene is identified as a COPC. Appendix D provides specific information.

AWQC = ambient water quality criteria
COPC = contaminant of potential concern
Cr(VI) = hexavalent chromium
CWA = Clean Water Act (*Federal Water Pollution Control Act*)
DWS = drinking water standard
MCL = maximum contaminant level
MTCA = "Model Toxics Control Act—Cleanup"
N/A = not applicable

4.4 Distribution of Groundwater Contaminants

Data were collected to better describe the nature and extent of contamination in the various stratigraphic units and enhance plume understanding. Data from monitoring wells and remediation wells were included in the evaluation. Table 4-37 summarizes the approximate areal extent of plume areas exceeding standards in 2016.

Table 4-37. Approximate Areal Extent of 100-K Plumes in 2016

Contaminant	Standard	Total (km^2 [mi^2])
Cr(VI)	10 µg/L [a]	1.5 (0.58)
Cr(VI)	48 µg/L [b]	0.11 (0.04)
Nitrate	45 mg/L [c]	0.05 (0.02)
Tritium	20,000 pCi/L [d]	0.12 (0.05)
Carbon-14	2,000 pCi/L [d]	0.05 (0.02)
Strontium-90	8 pCi/L [d]	0.03 (0.01)
Trichloroethene	5 µg/L [e]	0.10 (0.04)

Note: Values are based on the extent of contaminants in 2016 (DOE/RL-2016-67).

a. WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington." This standard only applies to groundwater that discharges to surface water at the interface.

b. WAC 173-340-720(4)(b)(iii), "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

c. 40 CFR 141.62, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Inorganic Contaminants" (modified, 10,000 µg/L×1/0.226).

d. 40 CFR 141.66, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Radionuclides."

e. 40 CFR 141.61, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Organic Contaminants."

Cr(VI) = hexavalent chromium

The extent of the Cr(VI) plumes greater than the state surface water quality standard of 10 µg/L had not been defined in several areas. This included the eastern boundary of the KW Reactor plume, upgradient of the KE and KW Reactors, and upgradient from the 116-K-2 Trench plume. Carbon-14, tritium, and trichloroethene have been detected on the downgradient edge of the 107-KW waste site at concentrations greater than DWSs, and their extent was not defined. Tritium at more than 10 times the DWS has been detected upgradient of the southwest portion of the 116-K-2 Trench. The extent of tritium contamination was not defined upgradient of the southwest portion of the 116-K-2 Trench. To address Data Gap 5, nine new monitoring wells and one new aquifer tube cluster were installed and sampled (Table 2-2).

4.4.1 Hexavalent Chromium

Investigation and remediation of Cr(VI) has been ongoing since the mid-1990s. The annual groundwater monitoring reports provide contaminant summaries, and the annual P&T reports describe RA performance.

Remedial process optimization (RPO) for the groundwater Cr(VI) interim RA installs wells and realigns the P&T extraction and injection configuration to enhance performance. The enhancements are prioritized to meet the RAO for river protection and to improve mass removal and decrease plume size. Table 2-10 lists RPO wells installed through 2016, which are included on Figure 4-28. Changes to the RA since 2016 are described in the annual reports.

The two main influences on contaminant distribution in groundwater at 100-K are the P&T systems and the Columbia River. There were three operating P&T systems at 100-K, referred to as KR-4, KW, and KX (Figure 4-29), at the end of 2016. These systems are operated under the 1996 Interim Action ROD (100-HR-3 and 100-KR-4 OU ROD [EPA/ROD/R10 96/134]) and EPA et al., 2009b. The original KR-4 system focused on a Cr(VI) plume near the 116-K-2 Trench, and began operations in 1997, with a design capacity of 1,136 L/min (300 gal/min). The KW system began operations in January 2007 with a design capacity of 757 L/min (200 gal/min) and treats groundwater near the KW Reactor. The KX system became fully operational in February 2009 with a design capacity of 2,271 L/min (600 gal/min) and treats groundwater in the KE Reactor area and groundwater contaminated by the 116-K-2 Trench that migrated east. As part of ongoing RPO activities, the three systems have undergone various upgrades and realignments since installation, which has resulted in increased treatment capacity. The KW (1,249 L/min [330 gal/min]), KX (3,407 L/min [900 gal/min]), and KR-4 (1,249 L/min [330 gal/min]) P&T systems provided a total combined capacity of 5,905 L/min (1,560 gal/min) at the end of 2016.

The 100-K Cr(VI) plumes are discussed for geographic areas, designated as K West, K East, K North (KN), K-N boundary, and 100-N based on the groundwater distribution (Figures 4-30 and 4-31). In general, the K West plume originates near the 183.1KW Headhouse and extends downgradient toward the Columbia River. The K East plume originates near the 183.1KE Headhouse and extends downgradient toward the Columbia River. One part of the K East plume is downgradient and west of the process facilities centerline, while another part diverges to the northeast and combines with the Cr(VI) at the southwestern end of the 116-K-2 Trench. The KN plume encompasses the northern portion of the 116-K-2 Trench and an inland area. Because the 100-KR-4 OU is identified through contaminant releases from the 100-KR-1 and 100-KR-2 OUs, the Cr(VI) plumes at the 100-K and 100-N areas boundary (wells 199-K-182 and 199-N-189) and in the 100-N Area (wells 699-84-59 and 199-N-74) (Figure 4-30) are included for 100-K characterization. These plumes are discussed as the K-N boundary plume and 100-N plume. Isolated wells east and northeast of the 100-K Area with Cr(VI) concentrations >10 µg/L include 699-83-47, 699-87-55, and 699-77-54.

The plume areas have been reshaped through groundwater P&T systems operation. Groundwater injection upgradient of the plume areas has increased groundwater elevation, especially notable in the arc on injections wells that includes 199-K-169 through 199-K-124A (Figure 4-29). Downgradient extraction results in water table depression along the river, providing hydraulic containment and river protection. The result has been a change in hydraulic control of contaminant migration, and subsequent reshaping of the plumes directing Cr(VI) plumes towards extraction points. Aquifer tube sampling and near-river well sampling results show the Cr(VI) extent at the river shore decreasing. In addition, the P&T system has targeted higher concentration Cr(VI) plume areas for extraction, reducing groundwater Cr(VI) concentrations and mass.

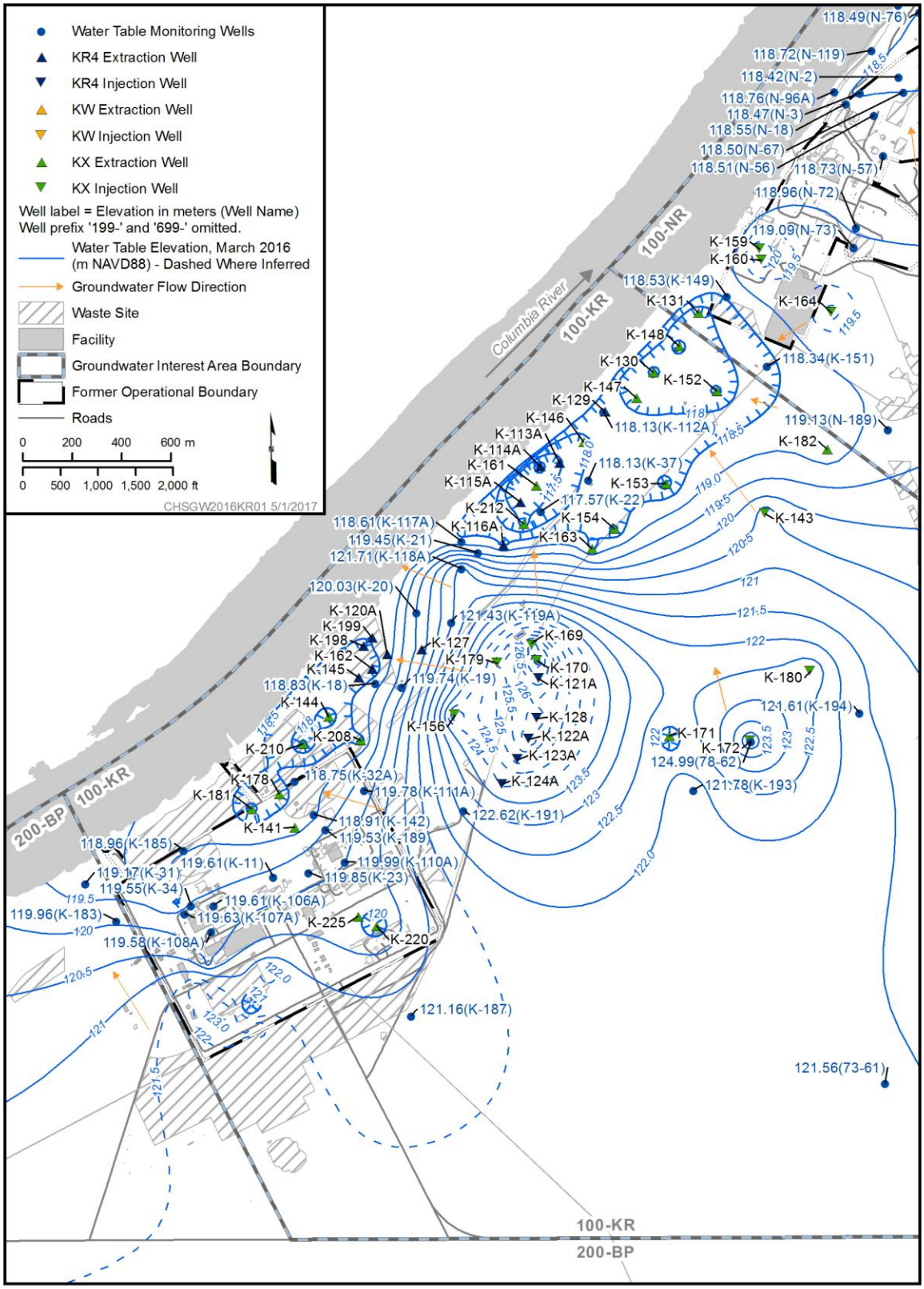
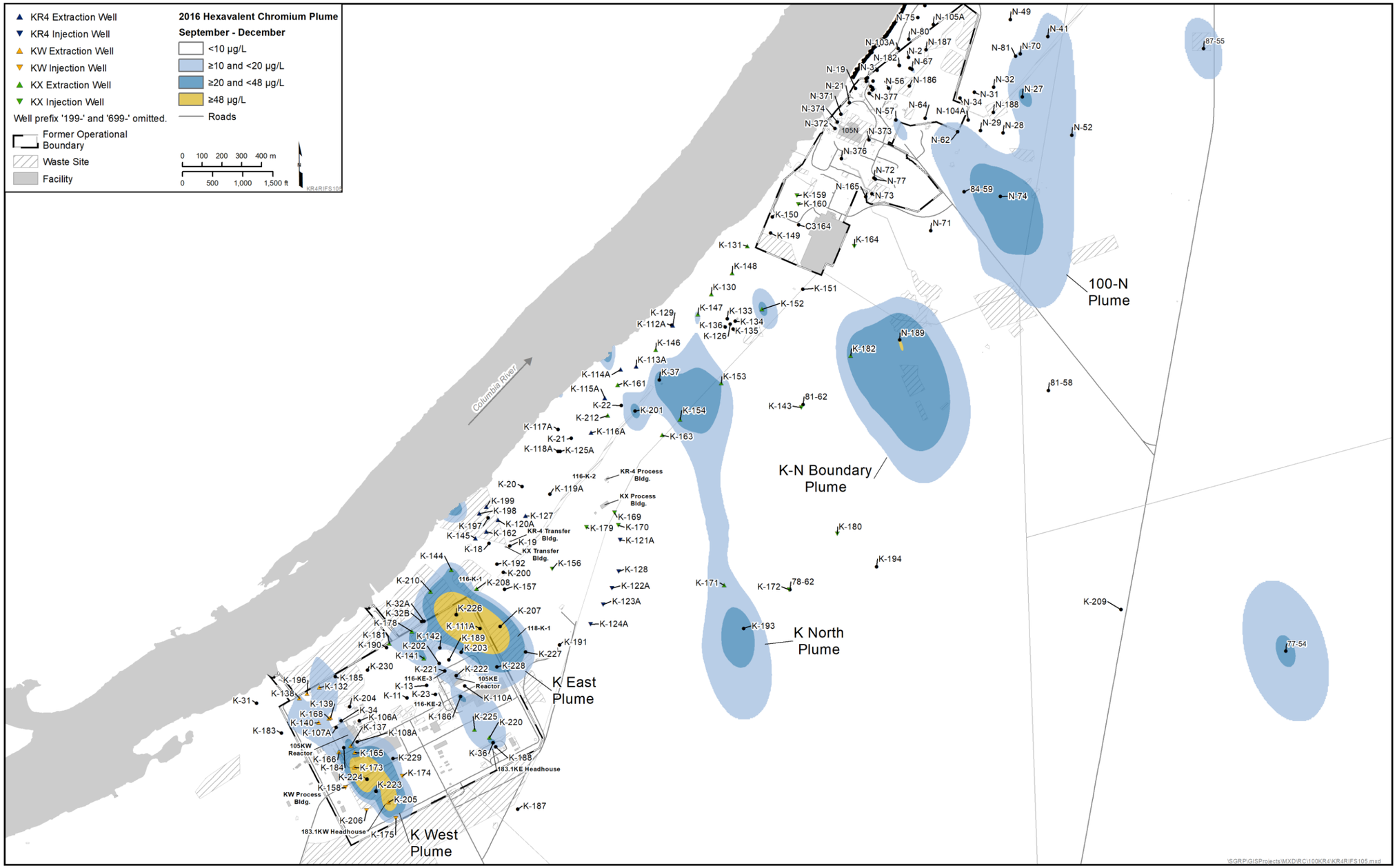


Figure 4-29. KR-4, KW, and KX Pump and Treat Systems in 2016

The second main influence on contaminant distribution within 100-K is the Columbia River, which is a discharge boundary for groundwater beneath the 100-K Area. When river stage is low, groundwater flows toward the river and discharges into the river through areas of interaction in the hyporheic zone where the aquifer meets the surface water. During high river stage, the groundwater elevation increases in response to the change in boundary conditions, and the gradient toward the river decreases. The low river stage period has been selected for collecting water samples from the 100-K aquifer tubes. This sampling period is intended to capture conditions when the highest contaminant concentrations are present along the shoreline. During 2016, six aquifer tube locations exceeded the 10 µg/L state surface water quality standard. The inferred 2016 distribution of Cr(VI) at 100-K during the low river stage period is shown on Figure 4-30, with the high river stage shown on Figure 4-31.

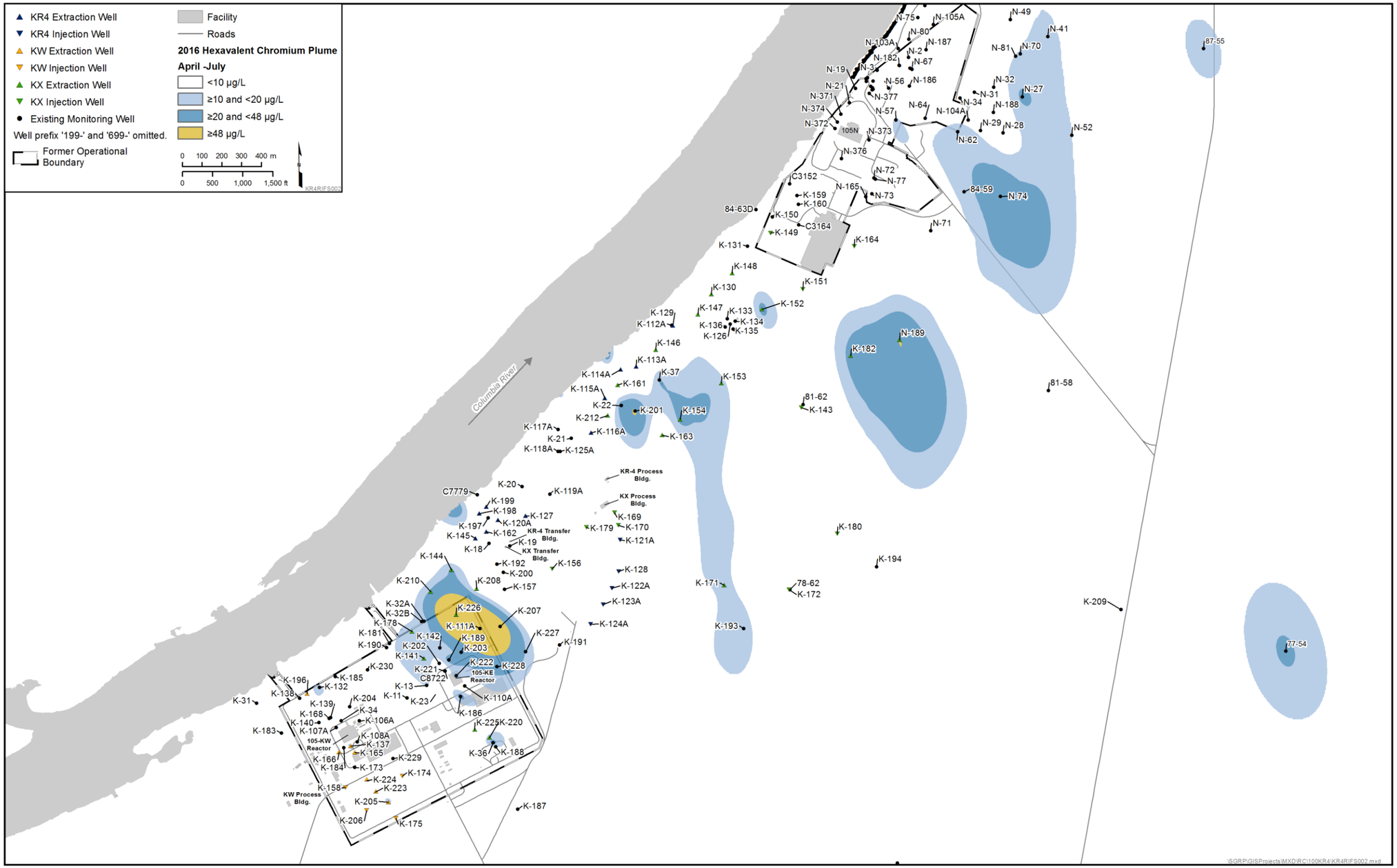
K West Plume. The initial monitoring well network in K West was limited to a small area near the KW Reactor, with Cr(VI) concentrations reaching a high of 606 µg/L in well 199-K-107A (April 1999). As the K West plume was investigated and drilling activities moved inland towards the 183.1KW Headhouse, concentrations up to 3,540 µg/L Cr(VI) were encountered (well 199-K-137, November 2007). Maximum observed Cr(VI) concentrations in groundwater were 4,800 µg/L in well 199-K-195, located within the footprint of the former 183.1KW Headhouse area.

The K West Cr(VI) groundwater plume diminished during KW P&T system operation. Figures 4-32, 4-33, and 4-34 show Cr(VI) during low river from 2010 to 2015. By January 2016, the groundwater wells (including extraction and monitoring wells) near the KW P&T system exhibited concentrations less than the interim RA 20 µg/L groundwater remediation target (Figure 4-35). A statistical trend analysis using data collected from June 2011 through March 2016 confirmed groundwater Cr(VI) concentrations were exhibiting downward trends. The high river stage Cr(VI) plume at K West (Figure 4-31) for data collected between January 1 and May 16, 2016, further confirmed the trend analysis (DOE/RL-2016-42, *Sampling and Analysis Plan for KW Pump and Treat System Rebound Study*). These conditions supported the decision to shut down the KW P&T system on May 16, 2016 and conduct a rebound study to evaluate aquifer conditions under non-pumping conditions. Figure 4-35 includes monitoring well Cr(VI) trends within the K West plume. The analysis indicated it was appropriate to conduct a Cr(VI) rebound test to assess the potential for concentration rebound due to potential contribution from secondary sources in the PRZ and overlying vadose zone.



1 Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 4-30. 100-KR-4 OU Cr(VI) Plume in 2016 (Low River Stage)



Reference: NAVD88, North American Vertical Datum of 1988.

Figure 4-31. 100-KR-4 OU Cr(VI) Plume in 2016 (High River Stage)

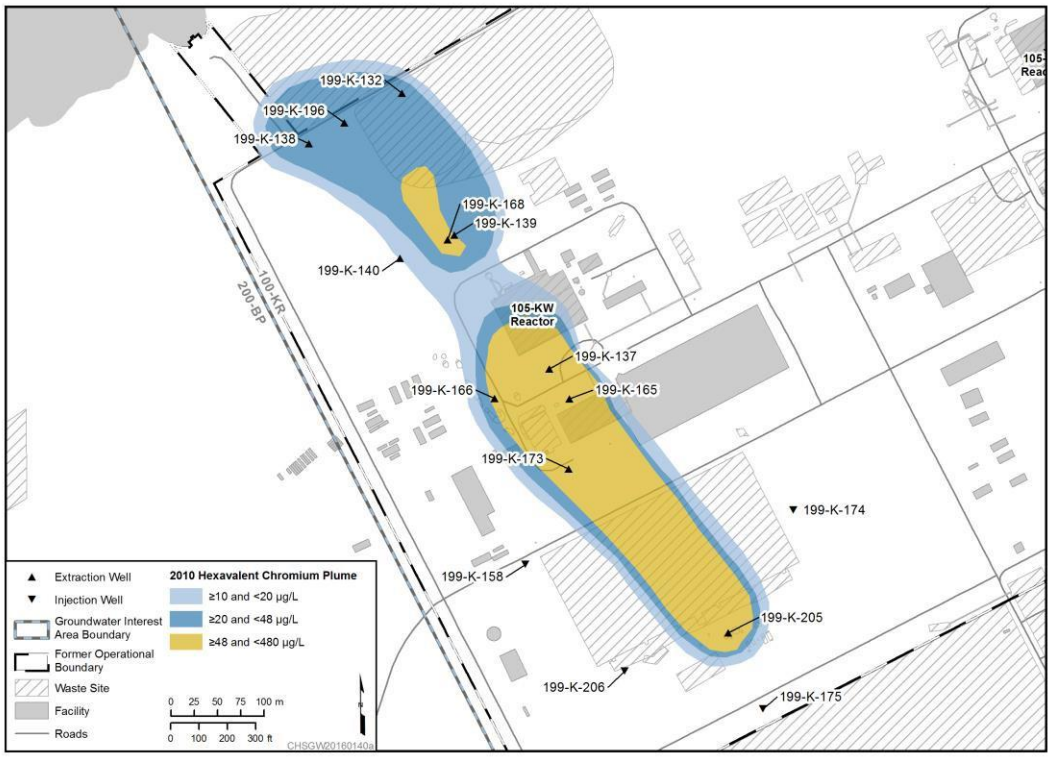


Figure 4-32. K West Cr(VI) Plume in 2010 (Low River Stage)

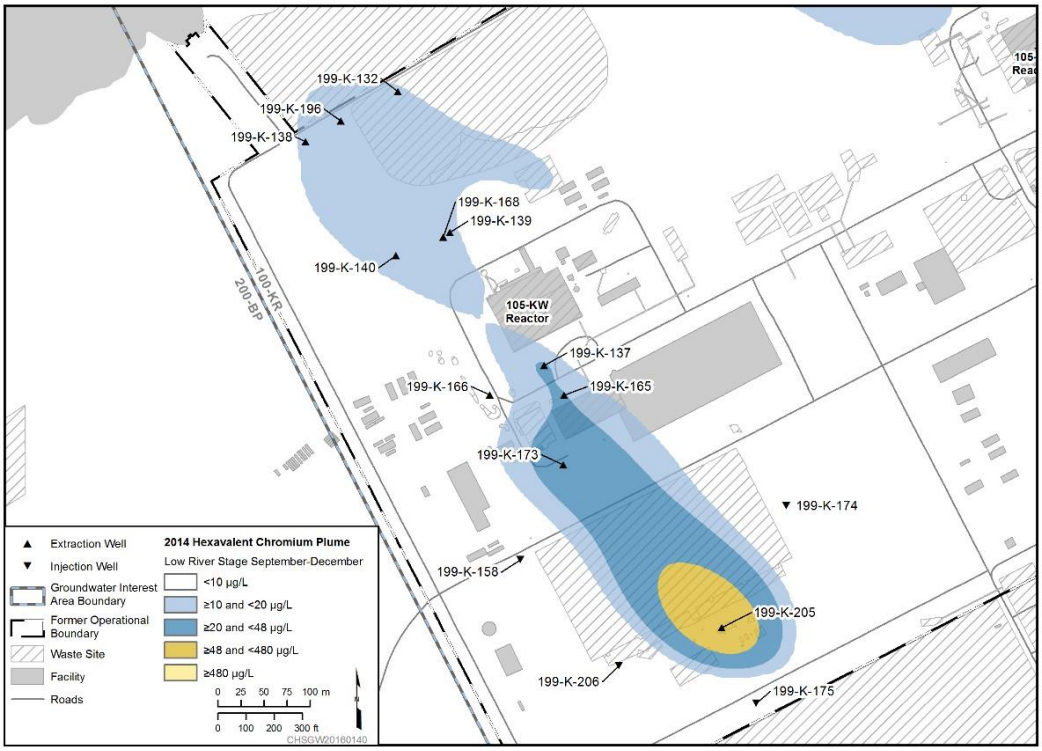


Figure 4-33. K West Cr(VI) Plume in 2014 (Low River Stage)

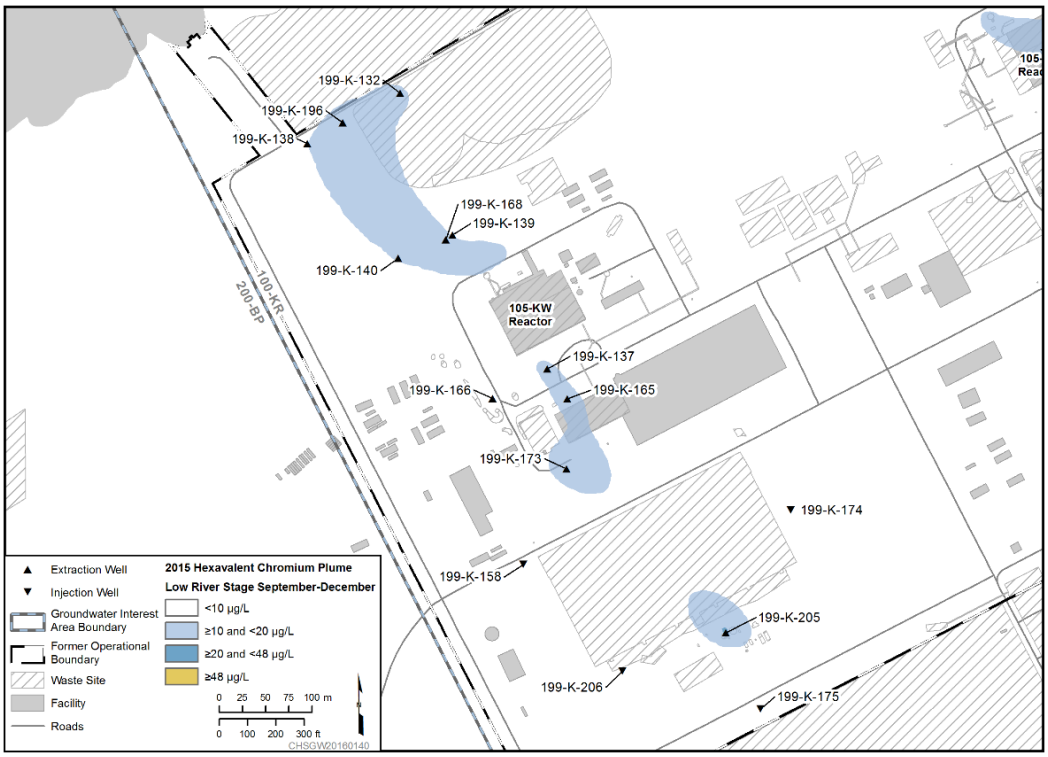


Figure 4-34. K West Cr(VI) Plume in 2015 (Low River Stage)

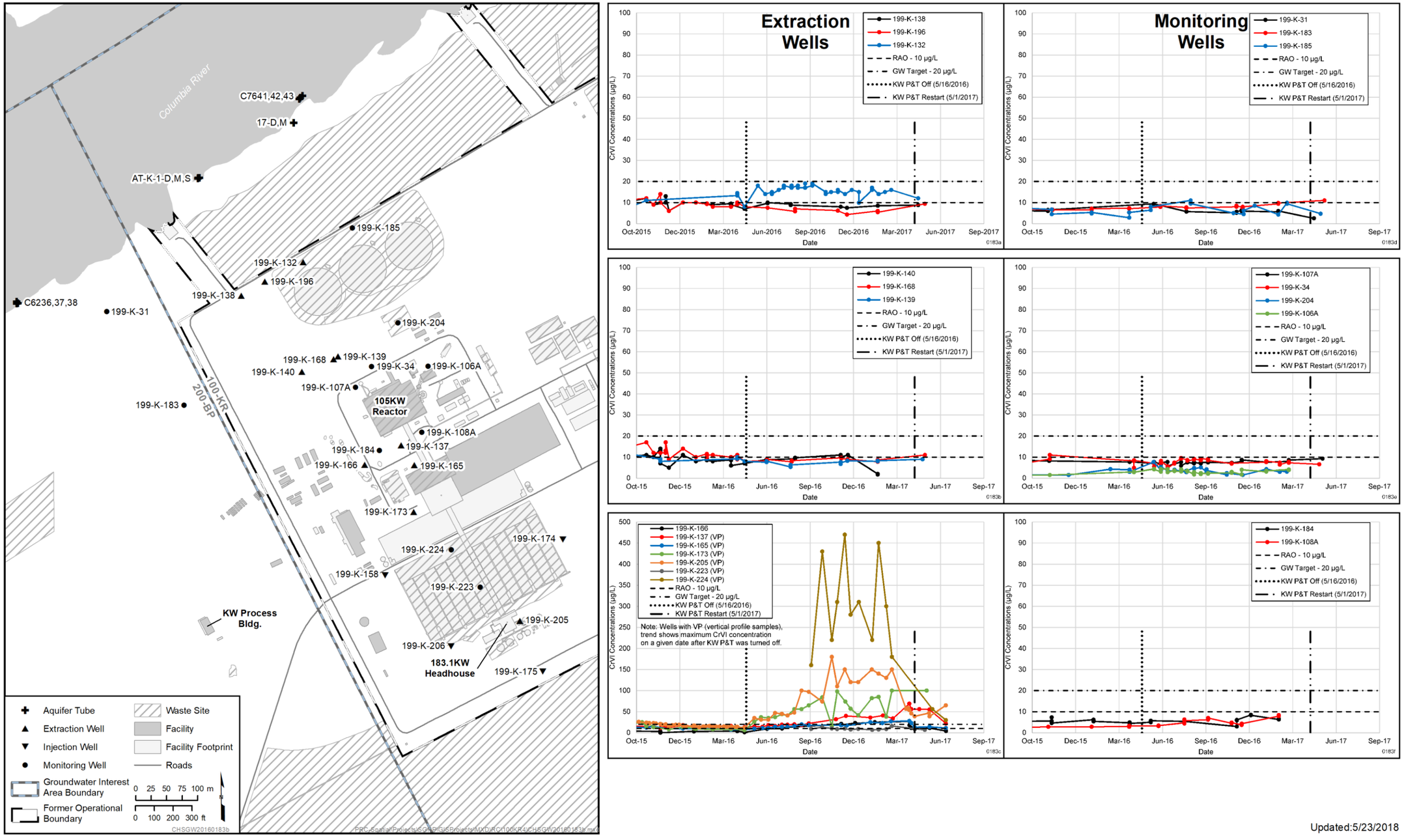


Figure 4-35. Groundwater Monitoring Locations near the KW Pump and Treat System and Cr(VI) Concentration Time Series

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During the KW rebound study, groundwater sample collection was based on the relative proximity to the apparent secondary source areas. Monitoring locations within the source areas were sampled the most frequently (e.g., every other week), and locations more distant from the source areas were sampled less frequently (e.g., monthly, bimonthly, quarterly). During the rebound study, wells and aquifer tubes located between the KW Reactor and the Columbia River (i.e., significantly downgradient from the secondary source area beneath the former KW Headhouse) exhibited very little change in concentration of Cr(VI) (including filtered total chromium). The highest concentration downgradient from the reactor was 19.4 µg/L at well 199-K-132. The extent of contamination >10 µg/L downgradient from the reactor is attributed to low concentration Cr(VI) between operating P&T wells that continued to migrate toward the river under natural flow conditions.

In contrast to the area downgradient of the reactor where concentrations remained relatively stable, the area between the KW Reactor and the 183.1KW Headhouse exhibited a different rebound response. Prior to shutting off the KW P&T, the maximum Cr(VI) concentration was 16 µg/L at well 199-K-137. Following shut off in May 2016, Cr(VI) concentrations increased relatively quickly in wells 199-K-137, 199-K-165, 199-K-173, 199-K-205, and 199-K-166. The largest Cr(VI) concentration change was noted in well 199-K-205 (the well located closest to the secondary source area beneath the former KW Headhouse, Figure 4-36), which increased from 12 to 180 µg/L. A similar increase at lower concentrations was seen in well 199-K-173 (Figure 4-37). Well 199-K-137 showed a concentration rebound, however there was a longer period before increasing concentrations were noted, indicating a greater distance from the source (Figure 4-38).

The rebound effects in Cr(VI) concentrations at these wells (Figure 4-35) confirmed the suspected secondary source material within the overlying vadose zone or PRZ that continue to cause groundwater contamination. Based on the magnitude and locations of observed Cr(VI) rebound, it is likely there are multiple secondary sources within the vadose zone and/or PRZ between the reactor and the headhouse. Vertical profile sampling indicated a vertical distribution of Cr(VI), with higher concentrations near the bottom of the aquifer. This distribution is theorized as related to the injection wells' location near the source areas.

Overall, the high concentration plume area has been constrained to a narrow band starting around the 183.1KW Headhouse and extending towards the Columbia River. The configuration of the injection wells keeps the Cr(VI) from spreading away from the potential source areas.

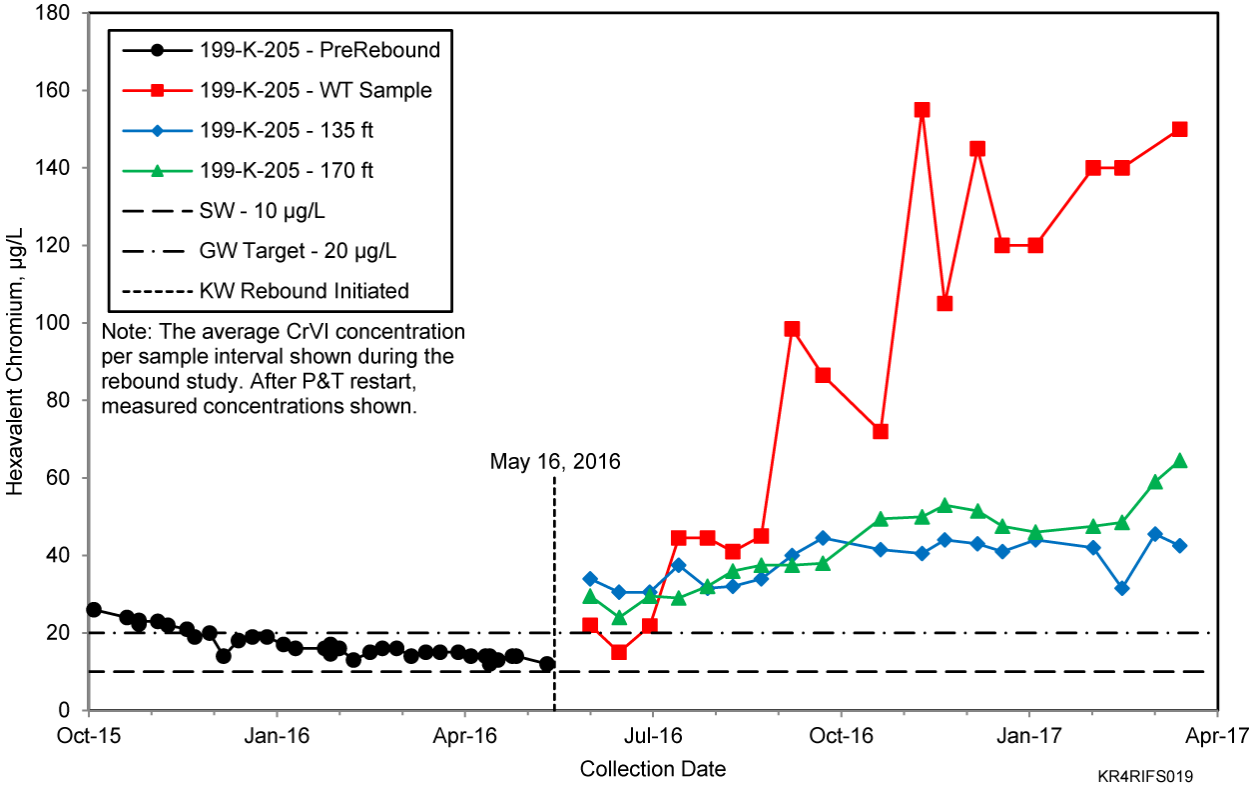

Figure 4-36. Well 199-K-205 Cr(VI) Rebound Trend

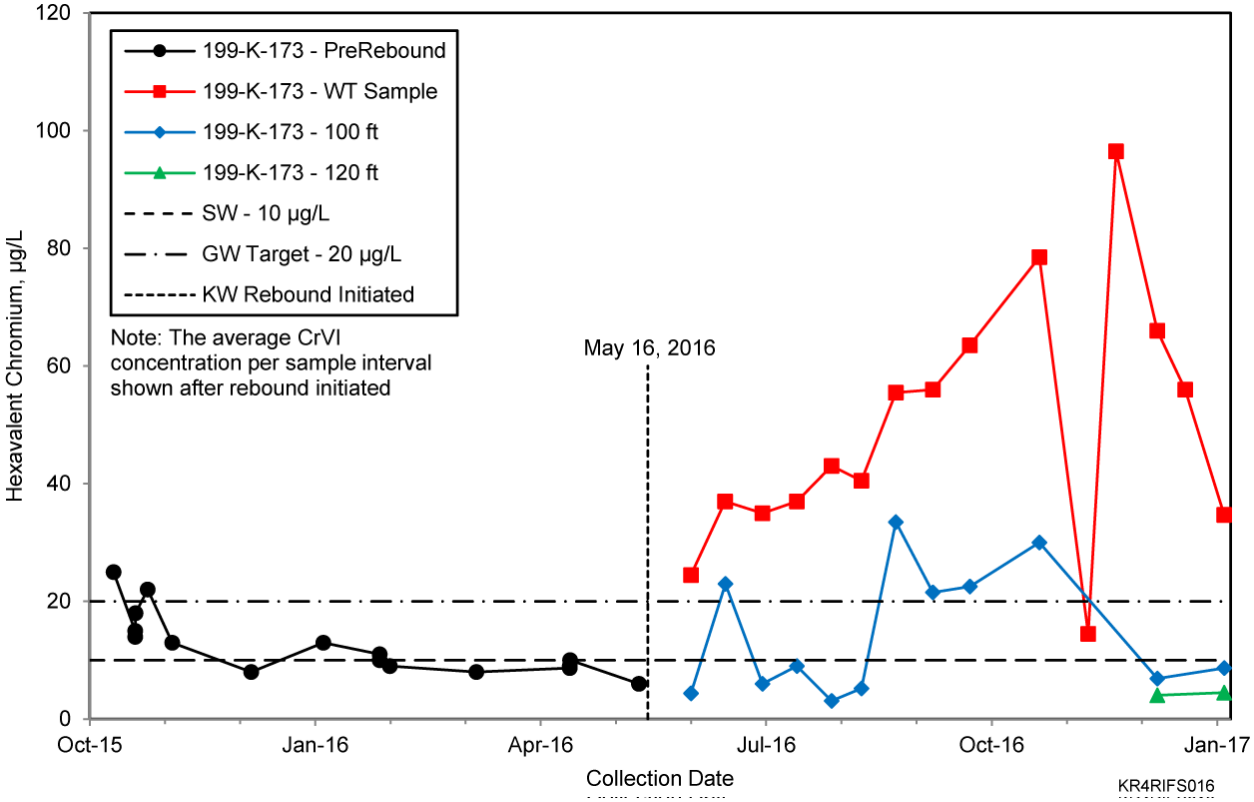

Figure 4-37. Well 199-K-173 Cr(VI) Rebound Trend

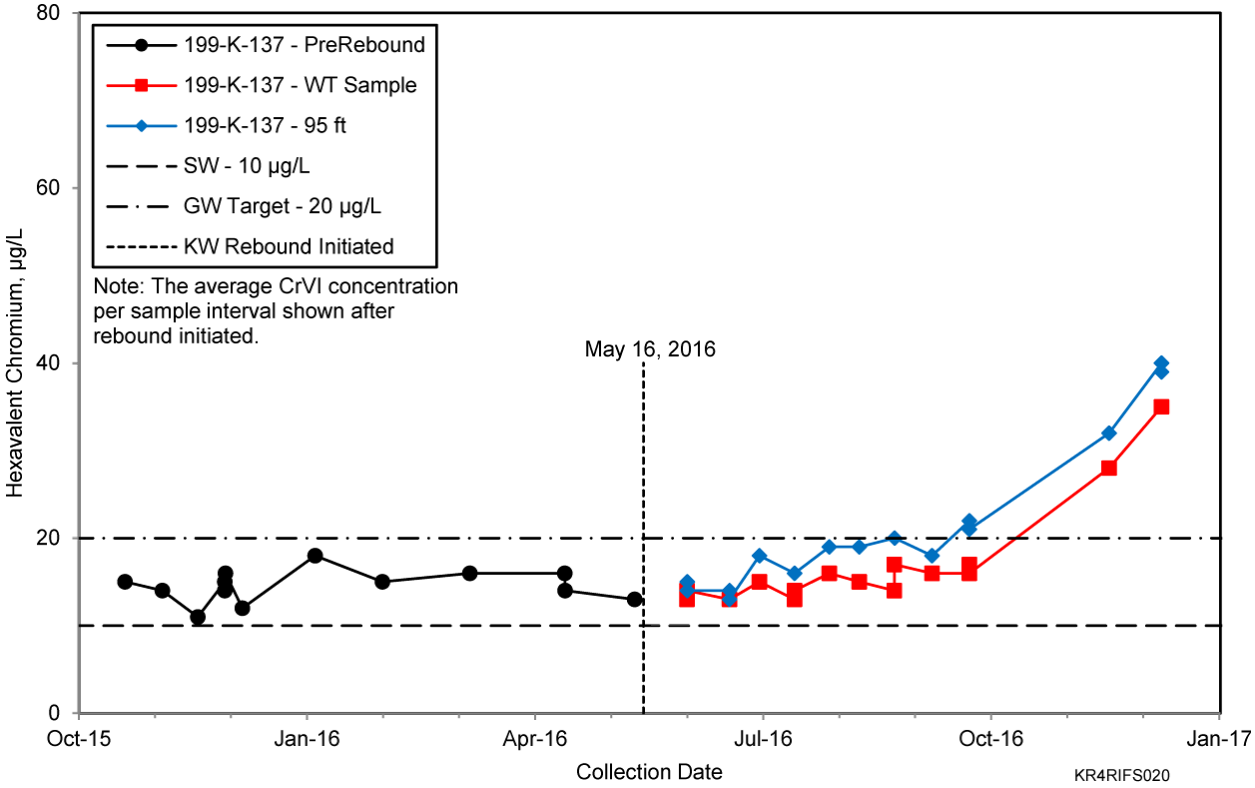

Figure 4-38. Well 199-K-137 Cr(VI) Rebound Trend

K East Plume. Historically, two areas of higher Cr(VI) concentration were in the K East plume—one near the KE Reactor and one near the 118-K-1 Burial Ground, which appears to include contamination that migrated from the 116-K-2 Trench. The western K East plume extends from the 183.1KE Headhouse towards the Columbia River, beneath the KE Reactor (Figure 4-30). As observed at K West, one apparent Cr(VI) continuing secondary source is the 183.1KE Headhouse chemical storage tank farm. Near the 183.1KE Headhouse, Cr(VI) concentrations continue to exceed the groundwater remediation target, but are decreasing. The second highest Cr(VI) concentration area is near the 118-K-1 Burial Ground and extends towards the Columbia River. High Cr(VI) concentrations remain in the area downgradient from the 118-K-1 Burial Ground at wells 199-K-111A and 199-K-226. The persistent Cr(VI) concentration is indicative of a continuing source in this area.

Well 199-K-36, located adjacent to the former 183.1KE Headhouse, had the highest concentrations in the area. The well exhibited increasing Cr(VI) concentrations starting in late 1998, reaching a maximum of 1,332 µg/L in August 2001. Concentrations in well 199-K-36 decreased to levels near 20 µg/L by 2009, but increased from 115 to 403 µg/L between 2011 and 2015. During 2016, concentrations dropped to 18 µg/L but then increased to 45 µg/L and currently exhibit a stable to increasing trend.

Extraction wells 199-K-220 and 199-K-225 are located near the 183.1KE Headhouse to address remaining Cr(VI). Upgradient (inland) of the 183.1KE Headhouse, well 199-K-187 had a maximum concentration of 5.3 µg/L (filtered total chromium) in 2016. This location has consistently low concentrations and appears to bound the inland extent of this plume.

Well 199-K-111A is located in the higher concentration area extending from near the 118-K-1 Burial Ground towards the river. The likely potential source area is the 118-K-1 Burial Ground, northeast of the KE Reactor. This contamination is co-mingled with contamination from the 183.1KE Headhouse, the

116-K-1 Crib, and 116-K-2 Trench. Ongoing remediation activities continue to modify the groundwater flow direction, making locating source area(s) more difficult.

Groundwater remediation in the K East plume is primarily via the KX P&T system, with the KR-4 system affecting the area through an array of inland injection wells. As of April 2017, eight KX extraction wells were operating in the K East plume area. Additional KX P&T system wells are located farther north along the 116-K-2 Trench (Figure 4-29). Most extraction wells at the K East plume are located downgradient from the source areas, and were placed to protect the Columbia River.

Ongoing remediation has reduced the concentrations near the 183.1KE Headhouse and the KE Reactor areas. The Cr(VI) concentrations in downgradient wells (e.g., 199-K-32A and 199-K-178) remain stable, indicating a continuing source in the vadose zone or PRZ. Near the 118-K-1 Burial Ground, concentrations are generally stable or slowly decreasing, as indicated by the trends for wells 199-K-207 and 199-K-111A. To improve the Cr(VI) plume remediation near the 118-K-1 Burial Ground, extraction well 199-K-226 was installed in 2016 to replace well 199-K-181, which had low concentrations. Well 199-K-226 was placed farther inland to target higher Cr(VI) concentrations without increasing tritium capture by the KX P&T system.

KN Plume. The 116-K-2 Trench was the principal liquid waste disposal site for the 100-K reactors and received a range of effluents. As described in Section 1.2.2 of DOE/RL-2008-46-ADD2, approximately 300,000 kg (661,000 lb) of sodium dichromate was discharged to the trench with millions of gallons of water. The large water volumes created an extensive groundwater mound and changed the flow regime (Section 4.6.2.2). Discharges to the trench were sufficient to elevate the water table nearly to the ground surface and the mound extended laterally for approximately 3 km (1.9 mi) south and 2 km (1.2 mi) west and east of the head end of the trench. This extensive groundwater mound was reactor cooling water, and is suspected to have displaced much of the water within the unconfined aquifer in that area. The cooling water contained about 2,000 µg/L sodium dichromate dihydrate (about 700 µg/L Cr(VI)), radioactive fission, and activation products associated with normal reactor operations and fuel cladding failures. The discharges to the trench created wide spread Cr(VI) contamination along the length of the trench and inland.

The KR-4 and KX P&T systems (Figure 4-29) operate in the KN plume area (Figure 4-30). The ongoing remediation activities have decreased concentrations along the 116-K-2 Trench, and segmented the plume into smaller pockets of residual contamination. The Cr(VI) plume associated with the head (southwest) end of the 116-K-2 Trench (e.g., wells 199-K-207, 199-K-208, and 199-K-111A) is co-mingled with Cr(VI) originating at the 183.1KE Headhouse area, as previously discussed. The overall concentrations in wells located on the southwestern end of the 116-K-2 Trench exhibit decreasing trends, indicating the plume core at the southwestern end is decreasing. This decrease is notable in wells 199-K-18, 199-K-157, and 199-K-208, which are near the head end of the 116-K-2 Trench. The continuing Cr(VI) persistence along the river (waste site 100-K-111) is attributed to the lower hydraulic conductivity area measured in the Ringold Formation unit E, although sources in the lower vadose zone may produce or contribute to this observation.

Near the middle of the trench, a narrow plume segment exhibiting concentrations >10 µg/L extends from the 116-K-2 Trench at well 199-K-37 inland to well 199-K-193 (Figure 4-30). The highest concentrations in this plume segment occur near the 116-K-2 Trench at well 199-K-37. Extraction wells 199-K-153 and 199-K-154 operate within this plume to control migration to the river.

K-N Boundary Plume. Another area of Cr(VI) contamination is currently defined by only a few wells with generally decreasing concentrations. This plume is near wells 199-K-182 and 199-N-189.

Concentrations in well 199-N-189 were measured at 40 µg/L in September of 2015, and the well was not monitored in 2016, but concentrations were trending down.

100-N Plume. This is a small Cr(VI) area farther to the north, within the 100-N Area. While the Cr(VI) in this area is probably associated with discharges to the 116-K-2 Trench, it is possible some Cr(VI) originated from 100-N. Sodium dichromate was used for water treatment prior to entering the N Reactor until the mid-1970s when it was discontinued (WHC-EP-0342, Addendum 3, *N Reactor Effluent Stream-Specific Report*). As described in the 100-N Area Technical Baseline Report (WHC-SD-EN-TI-251, *100-N Area Technical Baseline Report*), sodium dichromate discharges were made to the 116-N-1 crib (via the 1301-N liquid waste disposal facility). As a result, the plume centered near wells 199-N-74 and 199-N-27 is considered a co-mingled Cr(VI) plume but will be addressed through the 100-K FS. The overall Cr(VI) concentrations at the KN and K-N boundary plumes have been decreasing. Concentrations in the co-mingled area to the north, within 100-N, however, have stable to increasing trends.

4.4.2 RI Well Concentrations and Vertical Distribution

Nine new monitoring wells and two temporary wells were drilled and sampled to define the extent of contamination in the unconfined aquifer. In 2015, RI wells 199-K-221 and 199-K-222 were installed near the KE Reactor to further investigate the contamination in that area. Wells 199-K-184, 199-K-188, 199-K-192, and 199-K-195 were drilled 15.2 m (50 ft) into the RUM, and were intended to be completed in the uppermost water bearing unit to support Data Gap 10 (Table 2-2). A water-bearing zone in the RUM was only encountered at well 199-K-192, and the well was screened across this zone. The remaining three wells did not encounter a water-bearing zone, so they were screened in the unconfined aquifer (Table 4-38). Vertical profile sampling was conducted in ten of the RI wells during drilling.

Table 4-38. RI Wells with Associated Plume Areas and Aquifer Monitored

Well Name	Plume Location	Planned Aquifer	Vertical Profile Sampling	Aquifer Monitored
199-K-183	K West	Unconfined	--	Unconfined
199-K-184	K West	RUM	X	Unconfined
199-K-185	K West	Unconfined	--	Unconfined
199-K-195	K West	RUM	X	Unconfined
199-K-186	K East	Unconfined	X	Unconfined
199-K-187	K East	Unconfined	X	Unconfined
199-K-188	K East	RUM	X	Unconfined
199-K-189	K East	Unconfined	X	Unconfined
199-K-190	K East	Unconfined	X	Unconfined
199-K-221	K East	Unconfined	--	Unconfined

Table 4-38. RI Wells with Associated Plume Areas and Aquifer Monitored

Well Name	Plume Location	Planned Aquifer	Vertical Profile Sampling	Aquifer Monitored
199-K-222	K East	Unconfined	--	Unconfined
199-K-191	116-K-2 Trench	Unconfined	X	Unconfined
199-K-193	116-K-2 Trench	Unconfined	X	Unconfined
199-K-194	116-K-2 Trench	Unconfined	--	Unconfined
199-K-200	116-K-2 Trench	None	--	Unconfined
199-K-201	116-K-2 Trench	None	--	Unconfined
199-K-192	116-K-2 Trench	RUM	X	RUM

RUM = Ringold Formation upper mud

K West Plume. Within the K West plume area, four RI wells were completed within the unconfined aquifer. Initial Cr(VI) concentrations in well 199-K-183 were <10 µg/L, suggesting that the west-southwest portion of the plume is bounded between wells 199-K-140, 199-K-183, and 199-K-31. Subsequent groundwater monitoring has shown increasing Cr(VI), especially following the rebound test at the KW P&T. However, the plume is bounded by wells 199-K-183 and 199-K-31.

Well 199-K-185 was installed to help define the Cr(VI) plume downgradient of the KW Reactor and has concentrations <10 µg/L, but was exhibiting a slightly upward trend in 2016. Monitoring well 199-K-185 was installed near well 199-K-132, which exhibited decreasing Cr(VI) concentrations. This well appears to represent the K West plume northeast boundary along with wells 199-K-106A and 199-K-203 (Figure 4-35).

Wells 199-K-184 and 199-K-195 were installed within the plume area and exhibited Cr(VI) concentrations consistent with the known plume configuration. Well 199-K-184 was installed adjacent to well 199-K-137, approximately 20 m (65.6 ft) southeast of the KW Reactor building, near the central axis of the K West plume. Well 199-K-195 was installed upgradient of the 183.1KW Headhouse, and approximately 100 m (330 ft) from well 199-K-35. These two wells were sampled during drilling to evaluate the vertical Cr(VI) distribution.

Vertical profile sampling results at wells 199-K-184 and 199-K-195 indicated a higher concentration zone at approximately 30 to 40 m (98 to 131 ft) bgs (Figures 4-39 and 4-40). The higher concentrations were near the aquifer top in well 199-K-195, located near the 183.1KW Headhouse. Farther downgradient, at well 199-K-184, the higher concentrations were about 9 m (29.5 ft) deeper in the aquifer. The Cr(VI) plume deepening is theorized as a result of upgradient water injection.

Cr(VI) concentrations detected in groundwater samples collected during drilling monitoring well 199-K-184 ranged from 116 µg/L at 36 m (119 ft) bgs to 13.5 µg/L at 48 m (159 ft) bgs (Table 4-39). Monitoring results at well 199-K-184 from 2011 to 2014 provided Cr(VI) concentrations between 12.1 and 37.3 µg/L, and concentrations have since been decreasing.

Vertical profile samples collected at well 199-K-195 during drilling (Figure 4-40) had concentrations ranging from a maximum of 4,890 µg/L at 30 m (98 ft) bgs, near the top of the aquifer, to less than detection limits at 53.6 m (175 ft) bgs (Table 4-39). One of the deepest sample intervals (50 m [165 ft] bgs) measured 753 µg/L Cr(VI). Before well 199-K-195 was decommissioned for facility and waste site remediation, groundwater sample results were 3,340 µg/L Cr(VI). Well 199-K-195 was replaced with well 199-K-205, which had a maximum Cr(VI) concentration of 3,280 µg/L in January 2014, shortly after installation. Concentrations decreased to <20 µg/L prior to the rebound test at the KW P&T system, but experienced rebound, as presented in Figure 4-35. The Cr(VI) concentrations are consistent with historic operations and discharges to the ground.

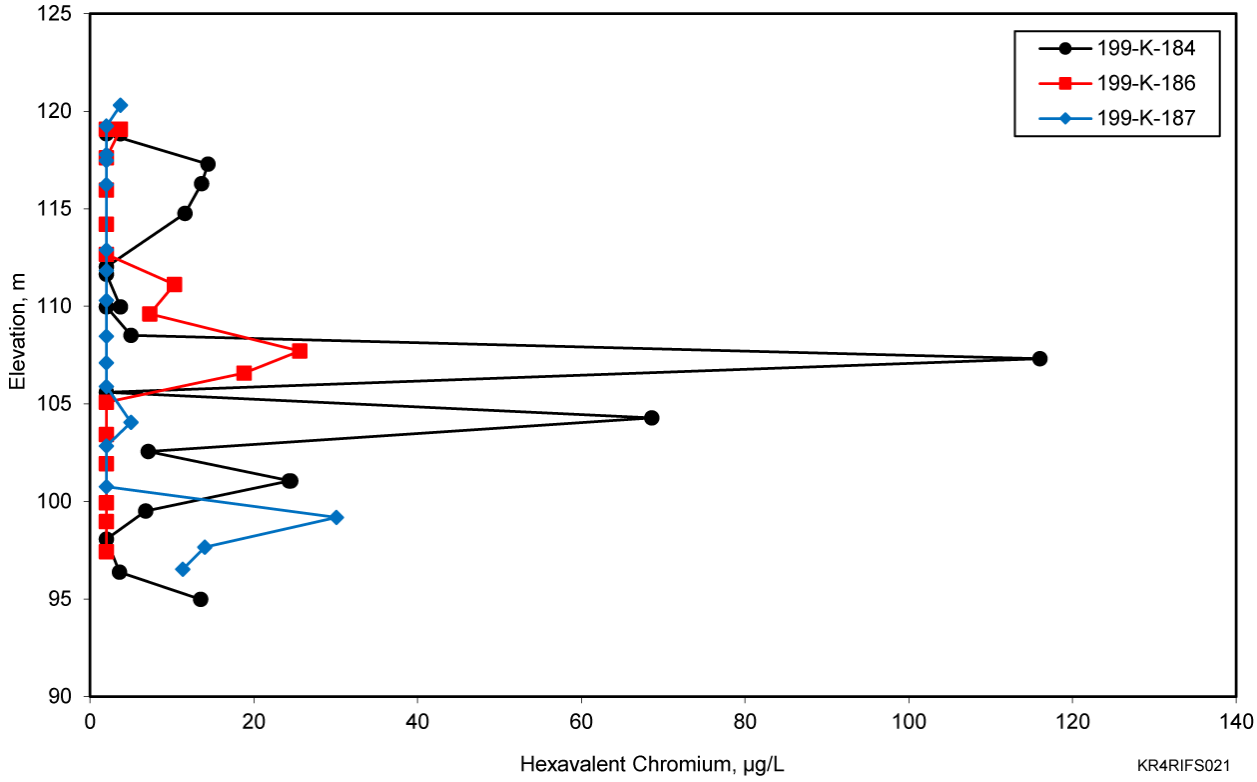

Figure 4-39. Vertical Profile of Cr(VI) Concentrations in Wells 199-K-184, 199-K-186, and 199-K-187

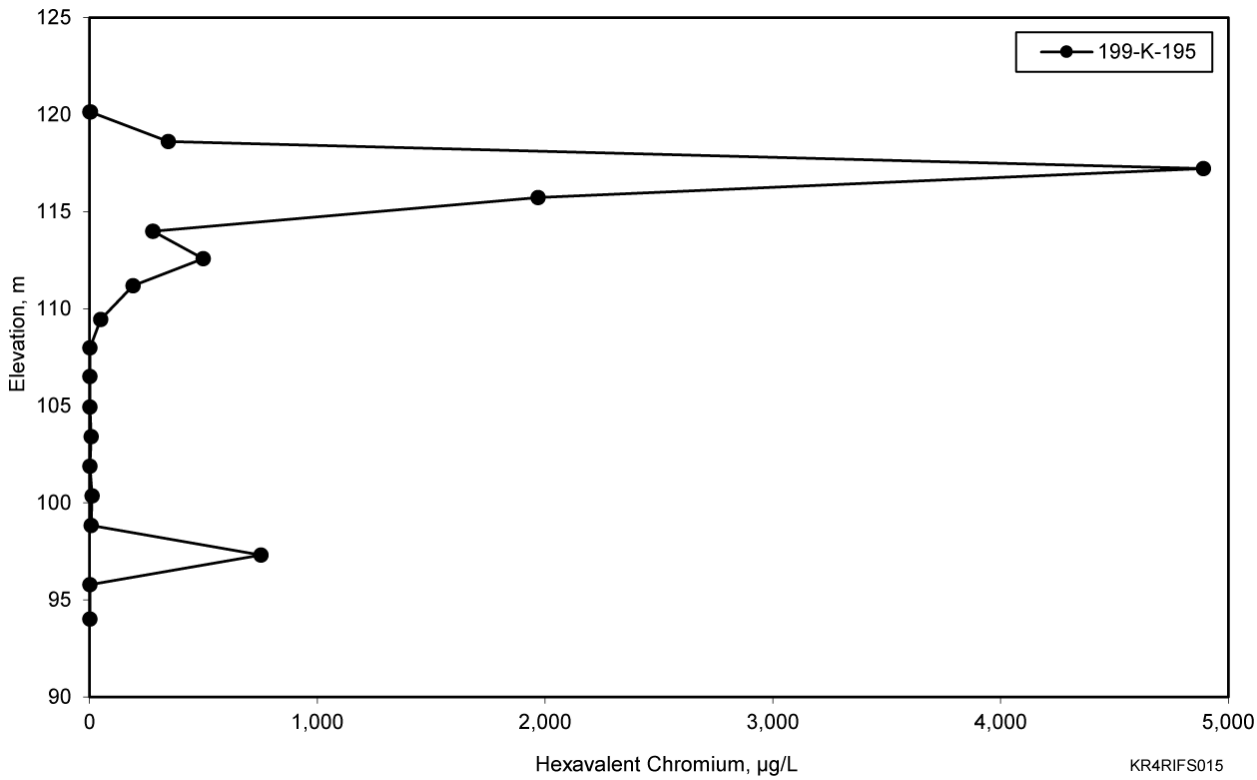

Figure 4-40. Vertical Profile of Cr(VI) Concentrations in Well 199-K-195

K East Plume. Seven RI wells were installed near the K East plume, including wells 199-K-221 and 199-K-222 which were installed in 2015. All seven wells were completed in the unconfined aquifer (Table 4-38). Vertical sampling was conducted during drilling at five locations. Results indicated relatively consistent Cr(VI) distribution through the aquifer at these wells, with concentrations typically <20 µg/L (Table 4-39). RI well 199-K-190 was installed near the southwestern edge of the K East plume area near the 107-KE retention basin (Figure 4-30). The maximum detected concentration measured in well 199-K-190 was 12.9 µg/L at 40 m (133 ft) bgs, which is consistent with concentrations observed in nearby monitoring well 199-K-181. The routine monitoring results from well 199-K-190 remain consistent with concentrations in 199-K-181, with a slightly decreasing trend at this northwest K East plume boundary.

Well 199-K-186 was installed upgradient of the KE Reactor. This well had slightly higher Cr(VI) concentrations (25.6 µg/L) at 38.5 m (126.3 ft) bgs in the middle portion of the aquifer. Most samples from this well were less than detection limits (Figure 4-39). Routine monitoring results at well 199-K-186 exhibit an increasing trend and seasonal variation, with higher concentrations detected during higher water level periods, consistent with a continuing source.

Well 199-K-187 is inland from the 183.1KE Headhouse. Vertical sampling results reported a maximum 30.1 µg/L concentration at 57 m (187 ft) bgs, at the bottom of the aquifer. Most of the samples collected during drilling were less than detection limits. Routine monitoring results are consistently <10 µg/L and the well bounds the K East plume on the inland side.

The remaining RI wells near the K East plume, 199-K-188 and 199-K-189, were installed near the headhouse and the reactor, respectively. Both wells exhibit a seasonal variation in Cr(VI) concentrations, with elevated concentrations occurring during higher water level periods. Concentrations fluctuate between 45 µg/L and less than detection limits. Routine monitoring has not indicated a trend in these wells. Wells 199-K-221 and 199-K-222 were installed in 2015 near the KE Reactor as part of additional RI work. Cr(VI) concentrations detected were <32 µg/L in 199-K-221 and <28 µg/L in 199-K-222, with an apparent seasonal variation similar to 199-K-189.

KN Plume. Six wells were installed during the RI along the 116-K-2 Trench, including well 199-K-192 completed in the uppermost RUM water bearing unit. The remaining five wells were completed within the unconfined aquifer (Table 4-38). Vertical profile sampling was conducted at wells 199-K-191, 199-K-192, and 199-K-193. Boreholes 199-K-200 and 199-K-201 were completed as temporary wells and screened in the unconfined aquifer.

Vertical sampling results observed during drilling at well 199-K-191 (Table 4-39) had a maximum concentration of 35.3 µg/L at 25.3 m (83 ft) bgs, near the top of the aquifer (Figure 4-41). Concentrations throughout the remainder of the vertical profile were less than detection limits. Subsequent monitoring at well 199-K-191 are consistent with the results indicated during drilling, with concentrations <10 µg/L.

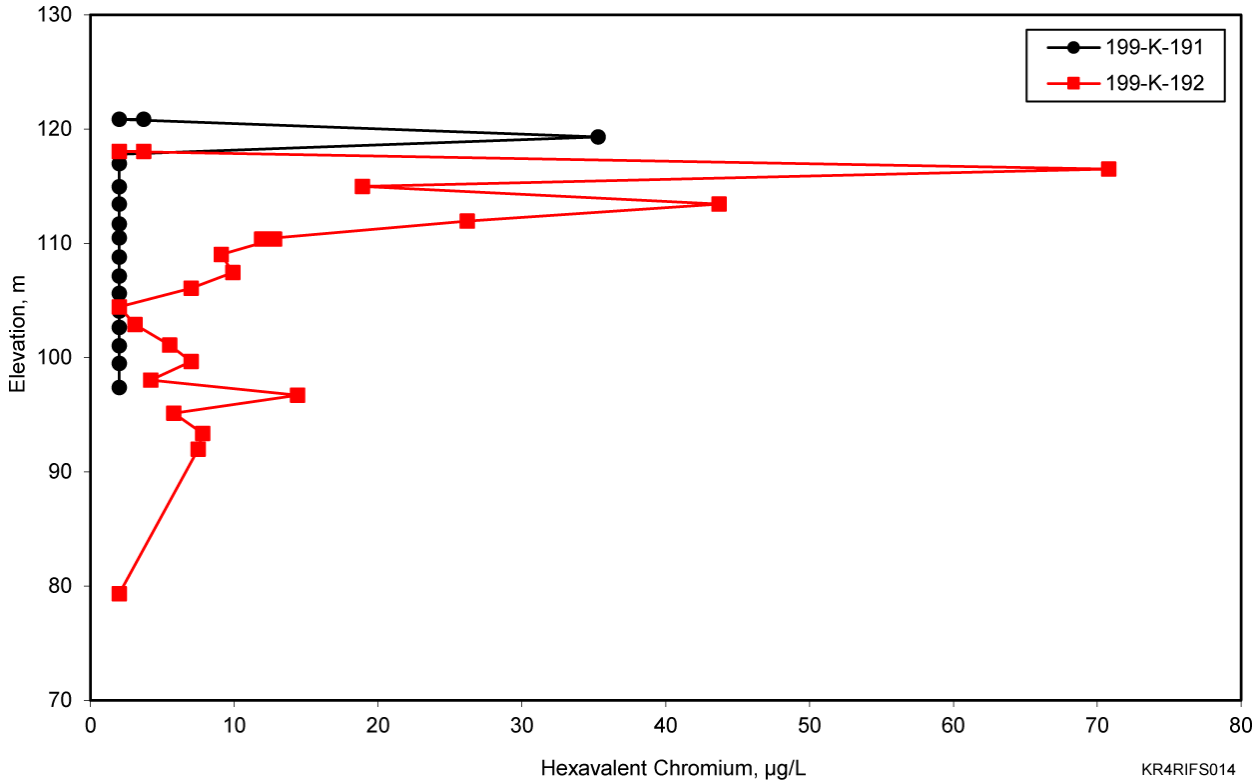

Figure 4-41. Vertical Profile of Cr(VI) Concentrations in Wells 199-K-191 and 199-K-192

Monitoring wells 199-K-193 and 199-K-194 were installed inland to the southeast of the 116-K-2 Trench. It was anticipated well 199-K-193 would define the plume boundary upgradient of well 199-K-171, since concentrations at 199-K-171 were decreasing. Vertical profile sampling at 199-K-193 did not indicate high concentrations within the aquifer, with the highest concentration (14.2 µg/L) at 40.5 m (133 ft) bgs. Monitoring has detected Cr(VI) concentrations fluctuating from less than detection limits to nearly 35 µg/L. The Cr(VI) concentrations at well 199-K-194 were initially <10 µg/L. Subsequent routine monitoring results have risen to as high as 17 µg/L, but were decreasing by August 2016.

Wells 199-K-200 and 199-K-201 did not encounter Cr(VI) at detectable concentrations during drilling. Analytical results from the first routine monitoring event, however, showed Cr(VI) concentrations >10 µg/L at both. Well 199-K-200 had a Cr(VI) concentration of 31.1 µg/L in January 2011, but concentrations have since decreased to at or less than the detection limits. Well 199-K-201 had a Cr(VI) concentration of 111 µg/L in January 2011, with a maximum concentration of 131 µg/L in July 2012. Subsequent monitoring results indicate a decreasing trend at 199-K-201.

Well 199-K-192 was installed downgradient from the 116-K-2 Trench southwestern end and completed within the uppermost water bearing unit of the RUM. The Ringold Formation unit E and RUM contact was encountered at 43.4 m (142.5 ft) bgs and the RUM is mainly silt. A water bearing unit was encountered at 54 to 56.7 m (177 to 186 ft) bgs and the well was screened from 53 to 56 m (175 to 185 ft) bgs. Vertical profile sampling during drilling indicated maximum Cr(VI) concentrations within the unconfined aquifer at 70.8 µg/L, at approximately 18 m (60 ft) bgs near the water table (Figure 4-41), with several results less than detection limits. Analytical results from a sample collected from the RUM water bearing unit during drilling were less than detection limits. Subsequent routine monitoring results ranged from less than detection limits to 9 µg/L (August 2014).

Total Chromium. Total chromium concentrations are greater than the AWQC (65 µg/L) in the K East, K West, and KN plumes. The locations and concentrations are consistent with Cr(VI), with filtered total chromium samples considered essentially equivalent to Cr(VI) results. Table 4-39 presents the total chromium and Cr(VI) results for samples collected during drilling. The results are similar with the exception of a duplicate sample collected at well 199-K-191 from a depth of 23.8 m (78 ft), where the total chromium result was an order of magnitude higher than the Cr(VI) result. Given the primary sample results for total chromium and Cr(VI) were consistent, and similar to the Cr(VI) from the duplicate sample, it is presumed that there was a dilution factor error in reporting the total chromium result for the duplicate.

The total chromium maximum detected concentration measured in well 199-K-195 was 4,300 µg/L at 30 m (99 ft) bgs, compared to 4,890 µg/L Cr(VI) at the same location. The concentration detected in groundwater grab samples from well 199-K-184 was 116 µg/L at 36 m (119 ft) bgs. Total chromium was detected in grab groundwater samples collected from well 199-K-201, located at the eastern end of the 116-K-2 Trench. The maximum detected concentration was 105 µg/L. No other RI wells sampled in either the K East or KN plumes contained measurable concentrations greater than the AWQC.

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-184	C7684	12/28/2010	24.9	81.6	2	U	Y	1	UD	Y
		12/28/2010	24.9	81.6	3.7	U	Y	2.12		Y
		12/29/2010	26.4	86.7	14.4		N	14.8	D	N
		12/30/2010	27.4	90.0	13.6		N	14.4	D	N
		12/30/2010	29.0	95.0	11.6		N	14.2	D	N
		1/3/2011	31.7	104.0	2	U	N	3.5	BD	N
		1/4/2011	32.1	105.2	2	U	Y	2.03	BD	Y
		1/6/2011	33.7	110.7	3.7	U	Y	1.31	BD	Y
		1/6/2011	33.7	110.7	2	U	Y	3.1	U	Y
		1/7/2011	35.2	115.5	5		N	7.63	BD	N
		1/10/2011	36.4	119.4	116		N	116	D	N
		1/11/2011	38.1	125.1	2	U	N	3.43	BD	N
		1/13/2011	39.4	129.4	68.6		N	67.1	D	N
		1/14/2011	41.2	135.0	7.1		N	9.17	BD	N
		1/15/2011	42.7	140.0	24.3		N	25.6	D	N
		1/15/2011	42.7	140.0	24.5		N	26.3	D	N
		1/15/2011	44.2	145	6.8		N	9.49	BD	N
		1/17/2011	45.7	149.8	2	U	N	3.7	BD	N
		1/18/2011	47.3	155.3	3.6	B	N	6.41	BD	N
		1/21/2011	48.7	159.9	13.5	U	N	11.6	D	N

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-186	C7686	1/4/2011	27.13	89	2	U	Y	7.1		Y
		1/4/2011	27.13	89	3.7	U	Y	6.27	BD	Y
		1/5/2011	28.59	93.8	2	U	Y	1	UD	Y
		1/6/2011	30.24	99.2	2	U	N	1	UD	Y
		1/6/2011	30.24	99.2	2	U	Y	1	UD	N
		1/7/2011	32	105	2	U	N	1	UD	N
		1/7/2011	33.53	110	2	U	N	1	UD	N
		1/10/2011	35.082	115.1	10.3		N	14.1	D	N
		1/11/2011	36.58	120	7.3		Y	11	D	Y
		1/14/2011	38.496	126.3	25.6		N	25.2	D	N
		1/14/2011	39.62	130	18.8		N	17	D	N
		1/15/2011	41.118	134.9	2	U	Y	7.27	BD	Y
		1/15/2011	42.763	140.3	2	U	Y	1	UD	Y
		1/17/2011	44.257	145.2	2	U	N	1	UD	N
		2/14/2011	46.269	151.8	2	U	N	1	UD	N
		2/15/2011	47.24	155	2	UN	N	1.17	BD	N
		2/16/2011	48.77	160	2	U	N	1	UD	N

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-187	C7687	5/24/2010	35.875	117.7	3.7	U	Y	4.26		Y
		5/24/2010	36.942	121.2	2	U	Y	3.43	BD	Y
		5/27/2010	38.4	126	2	U	Y	1	UD	Y
		5/24/2010	38.71	127	2	U	Y	3.82	BD	Y
		5/25/2010	39.93	131	2	U	Y	1.7	B	Y
		5/28/2010	43.28	142	2	U	Y	1.72	B	Y
		5/28/2010	43.28	142	2	U	Y	1.98	BD	Y
		6/1/2010	44.348	145.5	2	U	Y	1	UD	Y
		6/1/2010	45.872	150.5	2	U	Y	1.71	BD	Y
		6/2/2010	47.701	156.5	2	U	Y	2.12	BD	Y
		6/2/2010	49.07	161	2	U	Y	1	UD	Y
		6/3/2010	50.29	165	2	U	Y	2.28	BD	Y
		6/3/2010	52.12	171	5		Y	7.09	BD	Y
		6/4/2010	53.34	175	2	U	Y	1	UD	Y
		6/4/2010	55.413	181.8	2	U	Y	5.83	BD	Y
		6/7/2010	57	187	30.1		Y	29.8	D	Y
		6/7/2010	58.52	192	14		Y	16	D	Y
		6/8/2010	59.649	195.7	11.3		Y	14.1	D	Y

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-188	C7688	1/12/2011	32	105	2	U	N	4.32		Y
		1/12/2011	32	105	3.7	U	Y	3.43	BD	N
		1/13/2011	33.498	109.9	2	U	Y	1.26	BD	Y
		1/14/2011	35.022	114.9	3.4	B	Y	4.95	BD	Y
		1/15/2011	36.637	120.2	2	U	Y	0.5	U	Y
		1/17/2011	38.1	125	4.5	B	Y	6.74	BD	Y
		1/17/2011	39.776	130.5	3.1	B	Y	4.5	BD	Y
		1/17/2011	39.776	130.5	3.1	B	Y	4.67	BD	Y
		1/18/2011	41.15	135	2	U	N	3.35	BD	N
		1/19/2011	42.67	140	2	U	N	1	UD	N
		1/19/2011	44.2	145	2	U	N	1.94	BD	N
		1/20/2011	45.72	150	2	U	N	1.68	BD	N
		1/22/2011	48.77	160	2	U	N	2.14	BD	N
		1/24/2011	50.262	164.9	2	U	N	1.9	BD	N
		1/26/2011	50.658	166.2	2	U	N	1.22	BD	N
		1/27/2011	53.34	175	2	B	N	4.18	BD	N
		1/28/2011	54.529	178.9	10.7		N	10	D	N
		1/31/2011	56.08	184	2	U	N	1	UD	N

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-189	C7689	8/17/2010	23.47	77	3.7	U	Y	0.52	B	Y
		8/17/2010	23.47	77	2	U	N	1	UD	N
		8/18/2010	24.99	82	12.2		N	11.9	D	N
		8/19/2010	26.73	87.7	2	U	N	1	UD	N
		8/20/2010	28.04	92	2	U	N	7.11	BD	N
		8/23/2010	29.57	97	4.7	B	N	9.63	BD	N
		8/23/2010	29.57	97	4.8	B	N	8.04	BD	N
		8/24/2010	31.09	102	2	U	N	1	UD	N
		8/25/2010	32.61	107	2	U	N	0.56	B	N
		8/25/2010	34.14	112	7.6		N	9.24	BD	N
		8/26/2010	35.66	117	16.1		N	18.8	D	N
		8/27/2010	37.19	122	9.6		N	12.4	D	N
		8/27/2010	38.71	127	13.8		N	16.1	D	N
		8/30/2010	40.23	132	4.8	B	N	9.12	BD	N
		8/31/2010	41.76	137	9.5		N	10	D	N
		8/31/2010	43.28	142	6		N	8.76	BD	N
		9/1/2010	44.81	147	8		N	11.2	D	N
		9/2/2010	46.33	152	3.7	B	N	6.8	BD	N
		8/3/2010	18.0	59.0	3.7	U	Y	2.18	BD	Y
		8/3/2010	18.0	59.0	2	U	N	2.2		Y

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-190	C7690	8/4/2010	19.5	64.0	2	U	N	1.69	BD	N
		8/4/2010	21.0	69.0	2	U	N	5.13	BD	N
		8/5/2010	22.6	74.0	7.5		N	11.2	D	N
		8/5/2010	24.0	78.6	5.2		N	9.43	BD	N
		8/5/2010	24.0	78.6	5.8		N	9.18	BD	N
		8/6/2010	25.6	84.0	7.5		N	9.16	BD	N
		8/6/2010	27.1	89.0	6.1		N	5.5		N
		8/9/2010	28.5	93.6	2.1	B	N	5.35	BD	N
		8/10/2010	30.2	99.0	4.8	B	N	6.81	BD	N
		8/10/2010	31.6	103.7	2.2	B	N	5.01	BD	N
		8/11/2010	33.0	108.3	2	B	N	6.01	BD	N
		8/11/2010	34.6	113.6	4.3	B	N	16.1	D	N
		8/12/2010	36.2	118.7	3.7	B	N	7.74	BD	N
		8/13/2010	37.6	123.5	6.7		N	10.1	D	N
		8/16/2010	39.3	129.0	9.4		N	9.83	BD	N
		8/17/2010	40.8	133.7	12.9		N	13.8	D	N
		6/24/2010	23.8	78.0	3.7	U	Y	1	UD	Y
		6/24/2010	23.8	78.0	2	U	Y	27.5		Y
		6/25/2010	25.3	83.0	35.3		Y	38.4	D	Y
		6/28/2010	26.8	88.0	2	U	Y	1	UD	Y

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-191	C7691	6/29/2010	27.7	90.7	2	U	Y	1	UD	Y
		6/29/2010	29.7	97.3	2	U	Y	1	UD	Y
		6/30/2010	31.2	102.3	2	U	Y	1	UD	Y
		7/2/2010	32.9	108.0	2	U	Y	4.15	BD	Y
		7/2/2010	32.9	108.0	2	U	Y	4.44	BD	Y
		7/2/2010	34.1	112.0	2	U	Y	1	UD	Y
		7/6/2010	35.8	117.5	2	U	Y	1	UD	Y
		7/8/2010	37.5	123.0	2	U	Y	1	UD	Y
		7/9/2010	39.0	128.0	2	U	Y	2.21	BD	Y
		7/12/2010	40.5	133.0	2	U	Y	2.05	BD	Y
		7/13/2010	42.0	137.7	2	U	Y	1	UD	Y
		7/14/2010	43.6	143.0	2	U	Y	0.5	U	Y
		7/14/2010	45.1	148.1	2	U	Y	1.82	BD	Y
		7/15/2010	47.2	155.0	2	U	Y	4.31	BD	Y
		8/31/2010	16.8	55.0	3.7	U	Y	2.0	U	Y
		8/31/2010	16.8	55.0	2.0	U	Y	1.0	UD	Y
		8/31/2010	18.3	60.0	70.8		Y	72.5	D	Y
		9/1/2010	19.8	65.0	18.9		Y	22.3	D	Y
		9/2/2010	21.4	70.1	43.7		Y	46.1	D	Y
		9/3/2010	22.9	75.0	26.2		Y	26.9	D	Y
		9/7/2010	24.4	80.2	11.9		Y	16.9	D	Y

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-192	C7692	9/7/2010	24.4	80.2	12.8		Y	17.2	D	Y
		9/8/2010	25.8	84.6	9.1		Y	11.0	D	Y
		9/10/2010	27.3	89.7	9.9		Y	11.5	D	Y
		9/14/2010	28.7	94.3	7.0		Y	11.1	D	Y
		9/14/2010	30.4	99.6	2.0	U	Y	2.2	BD	Y
		9/15/2010	31.9	104.7	3.1	B	Y	6.2	BD	Y
		11/2/2010	33.7	110.6	5.5		Y	8.9	BD	Y
		11/3/2010	35.1	115.3	7.0		Y	10.2	D	Y
		11/3/2010	36.8	120.6	4.2	B	Y	8.5	BD	Y
		11/4/2010	38.1	125.0	14.4		Y	17.2	D	Y
		11/4/2010	39.7	130.1	5.8		Y	8.8	BD	Y
		11/8/2010	41.5	136.0	7.8		Y	10.7	D	Y
		11/8/2010	42.8	140.5	7.5		Y	10.0	BD	Y
		11/17/2010	55.5	182.0	2.0	U	N	3.9	BD	Y

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-193	C7693	9/24/2010	25.2	82.5	3.7	U	Y	1.0	UD	N
		9/24/2010	25.2	82.5	2.0	U	N	2.0	UD	Y
		11/2/2010	26.8	88.0	2.0	U	N	1.0	UD	N
		11/3/2010	28.4	93.0	2.0	U	N	1.0	UD	N
		11/4/2010	29.9	98.0	2.0	U	N	1.0	UD	N
		11/8/2010	31.4	103.0	2.0	U	N	1.0	UD	N
		11/9/2010	32.9	108.0	2.0	U	N	1.0	UD	N
		11/9/2010	32.9	108.0	2.0	U	N	1.0	UD	N
		11/10/2010	34.4	113.0	2.0	U	N	1.0	UD	N
		11/11/2010	35.7	117.0	2.5	B	N	4.8	BD	N
		11/12/2010	37.5	123.0	2.0	U	N	1.0	UD	N
		11/12/2010	38.1	125.0	2.0	U	N	4.3	BD	N
		11/15/2010	40.5	133.0	14.2		N	14.9	D	N
		11/15/2010	42.1	138.0	13.2		N	13.2	D	N
		11/16/2010	43.6	143.0	12.0		N	12.0	D	N
		11/17/2010	45.2	148.2	2.0	U	N	1.0	UD	N
		11/18/2010	46.6	153.0	4.1	B	N	6.6	BD	N
		11/22/2010	48.2	158.0	2.0	U	N	1.0	UD	N

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L		Filtered?	Total Chromium Result in µg/L		Filtered?
199-K-195	C7695	11/15/2010	27.5	90.1	2.0	U	N	1.2	B	Y
		11/15/2010	27.5	90.1	3.7	U	Y	1.0	UD	N
		11/16/2010	29.0	95.1	346		N	325	D	N
		11/17/2010	30.4	99.7	4890	D	N	4,300	D	N
		11/18/2010	31.9	104.6	1970	D	N	1,780	D	N
		11/19/2010	33.6	110.3	277		N	248	D	N
		11/19/2010	33.6	110.3	279		N	243	D	N
		11/23/2010	35.0	114.9	499		N	488	D	N
		11/29/2010	36.4	119.5	191		N	192	D	N
		11/30/2010	38.2	125.2	48.7		N	49.9	D	N
		12/1/2010	39.6	130.0	2.0	U	N	1.7	BD	N
		12/2/2010	41.1	134.8	2.0	U	N	3.7	BD	N
		12/3/2010	42.7	140.0	2.0	U	N	2.1	BD	N
		12/6/2010	44.2	145.0	7.0		N	7.0	BD	N
		12/8/2010	45.7	150.0	2.0	U	N	1.0	UD	N
		12/10/2010	47.2	155.0	10.8	U	N	1.0	UD	N
		12/13/2010	48.8	160.0	7.0		Y	11.5	D	Y
		12/14/2010	50.3	165.0	753		Y	701		Y
		12/15/2010	51.8	170.0	2.0	U	Y	0.7	BC	Y
		12/15/2010	53.6	175.8	2.0	U	Y	3.1	BDC	Y

Table 4-39. Cr(VI) and Total Chromium Concentrations in Groundwater During Drilling

Well ID	Borehole ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Cr(VI) Result in µg/L	Filtered?	Total Chromium Result in µg/L	Filtered?

B = the analyte was detected at a value less than the contract required detection limit, but ≥ the instrument detection limit

bgs = below ground surface

C = the analyte was detected in both the sample and the associated quality control blank, and the sample concentration was ≤5x the blank concentration

Cr(VI) = hexavalent chromium

D = analyte was reported at a secondary dilution factor

U = analyzed for but not detected above limiting criteria

4.4.3 Cr(VI) Summary

100-K West. High Cr(VI) concentrations remain near the 183.1KW Headhouse. The KW P&T rebound test indicates a secondary source in that area. Concentrations of Cr(VI) in well 199-K-205, which replaced RI well 199-K-195 near the 183.1KW Headhouse, had decreased to <20 µg/L prior to the KW P&T system shut down in May 2016. Cr(VI) concentrations increased to 160 µg/L and remained >140 µg/L through April 2017. The rebound in Cr(VI) concentrations in the K West plume indicate secondary source materials within the overlying vadose zone or PRZ. Based on the magnitude and locations of observed Cr(VI) rebound, there may be multiple areas of secondary source material within the vadose zone and/or PRZ between the reactor and the headhouse.

Based on the vertical distribution of Cr(VI) contamination and the analytical results between RI wells 199-K-184 and 199-K-195 and other active extraction wells located at the K West plume, a downward Cr(VI) movement exists. The well data indicate vertical dispersion and migration through the unconfined aquifer with increasing distance from the source area near the 183.1KW Headhouse. The active KW P&T system accounts for some dispersion, primarily related to injection wells 199-K-175, 199-K-206, and 199-K-158, which contribute the highest recharge to the area.

100-K East. The K East plume area extends from the 183.1KE Headhouse to the KE Reactor, and continues towards the Columbia River. Ongoing remediation is reducing concentrations near the 183.1KE Headhouse and reactor, though the persistent elevated Cr(VI) concentration indicates secondary source material near the 183.1KE Headhouse. Another potential source area is near the 118-K-1 Burial Ground, co-mingling with residual Cr(VI) from the 116-K-2 Trench. Cr(VI) concentrations near the 118-K-1 Burial Ground remain elevated, but concentrations are generally stable or slowly decreasing, as indicated by the trends for wells 199-K-207 and 199-K-111A.

KN Plume. Overall Cr(VI) concentrations associated with the 116-K-2 Trench have decreased, indicated by the concentration trends at the southwestern end. The P&T injection from the arc of wells 199-K-169 to 199-K-124A contributed to the Cr(VI) reduction. Increased contaminated water migration from the injection area to the extraction wells and potential contaminants flushing from the lower vadose zone may be due to hydraulic mounding created by injection wells. A secondary effect of the ongoing remediation and the injection wells upgradient of the 116-K-2 Trench was segmenting the plume, separating the KN plume from the southwestern end plume. The plume areas separation was helped by a higher hydraulic conductivity zone near the middle of the 116-K-2 Trench, as discussed in Chapter 3.

Small areas of Cr(VI) were defined inland from the 116-K-2 Trench. The initial Cr(VI) concentrations in RI well 199-K-193 fluctuated from less than detection limits to nearly 35 µg/L. Since installation, the concentrations continue to fluctuate, but there is an increasing trend. In addition, the water table in this well has increased about 1 m (3.3 ft) from 2011 to 2016 and continues to exhibit an increasing trend. Farther inland, wells 699-73-61 (located nearly 1,400 m [4,700 ft] to the southeast) and well 199-K-209 (located 1,900 m [6,300 ft] to the east) have Cr(VI) concentrations at or less than the detection limits. These wells indicate the upgradient boundary of the plume, however there are only a few wells in the outer portions of 100-K.

Persistent Cr(VI) concentrations are reported in wells 199-K-201 and 199-K-154, near the eastern end of the 116-K-2 Trench. Well 199-K-201 has shown an overall decreasing trend since installation during the RI, though concentration in May 2017 were 24 µg/L.

K-N Boundary Plume. At the boundary between the 100-K and 100-N areas, contamination near wells 199-K-182 and 199-N-189 is migrating northward. This migration is mitigated by extraction at well 199-K-182 decreasing the hydraulic gradient. Well 199-N-189 is planned for conversion to an extraction well to further mitigate plume migration. The K-N boundary plume is attributed to 116-K-2 Trench discharges.

100-N Plume. Farther north within the 100-N Area is another Cr(VI) area. The majority of the Cr(VI) is associated with the Cr(VI) northern migration related to the 116-K-2 Trench and hydraulic gradient. Sodium dichromate was used for water treatment at the N Reactor prior to the mid-1970s, and it is possible some Cr(VI) originated from 100-N. As a result, the plume centered near well 199-N-74 and 199-N-27 is considered a co-mingled Cr(VI) plume but is characterized in this 100-K-RI and addressed through the 100-K FS (DOE/RL-2018-22).

4.4.3.1 RUM and Aquifer Tubes

Low levels of Cr(VI) contamination were detected in the uppermost water bearing unit of the RUM in wells 199-K-32B and 199-K-192 during routine monitoring. Concentrations range from less than detection limits to 9 µg/L (well 199-K-192 in August 2014). Measured hydraulic heads in the uppermost RUM aquifer at 100-K are upward, precluding downward migration of contaminants under current conditions. During reactor operations, however, the large groundwater mound created by 116-K-2 Trench discharges may have initiated sufficient downward pressure to allow contaminants to migrate into the uppermost RUM aquifer.

Contamination is periodically detected in aquifer tubes at 100-K. During 2016, six aquifer tube locations exceeded 10 µg/L. Aquifer tubes near the K West plume exhibited minimal change from previous years' Cr(VI) concentrations. Aquifer tube 17-D exhibited 9.2 µg/L in a filtered total chromium sample; however, Cr(VI) concentrations were consistent with previous measurements. This was the highest reported value in aquifer tubes near K West.

Downgradient from the K East plume, aquifer tube concentrations were less than detection limits in 2016. This included RI aquifer tubes C6245, C6246, and C6247. Concentrations in these aquifer tubes had a 12 µg/L maximum value in October 2014.

Aquifer tube measurements near the 116-K-2 Trench were at or less than detection limits in 2016 in all but one location. This indicates the KR-4 and KX P&T extraction wells located inland are providing Cr(VI) capture. Aquifer tube 22-D, downgradient from KR-4 P&T extraction well 199-K-114A, continued exhibiting increased Cr(VI) concentration in 2016 compared to 2015. This observation along with a specific conductance >200 µS/cm, higher than the typical river specific conductance, suggests that groundwater is continuing to discharge at this location.

4.4.4 Nitrate

Nitrate was not a designated co-contaminant at 100-K in the 1996 Interim Action ROD (100-HR-3 and 100-KR-4 OU ROD [EPA/ROD/R10-96/134]) but has been historically monitored. The nitrate in 100-K is attributed to oxidation of high concentrations of ammonia in reactor gas dryer condensate (i.e., up to 36,000 mg/L) discharged to the 116-KE-1 and 116-KW-1 gas condensate cribs. Additional nitrate contributions to groundwater may be sanitary waste drain fields at various locations in 100-K. Nitrate is in groundwater in most 100-K wells at concentrations less than the DWS of 45 mg/L. The RI included groundwater sampling to update the nitrate assessment at 100-K.

As of 2016, the total nitrate plume footprint exceeding 45 mg/L was approximately 0.05 km^2 (0.02 mi^2) and is now collocated within the K West Cr(VI) plume (Figure 4-42). Nitrate concentrations exhibit seasonal variation. Nitrate concentrations in the K West area are relatively stable, remaining around 25 mg/L. The persistent nitrate detections indicate a potential secondary source from the 116-KW-1, 1607-K6, and 116-KW-1 waste sites, located near the KW Reactor area.

Prior to the rebound study at K West, three wells (199-K-106A, 199-K-132, and 199-K-185) had nitrate concentrations >45 mg/L. The maximum concentrations occurred during the rebound study, with concentrations rising to 70.8, 53.1, and 75.3 mg/L during September 2016 in wells 199-K-106A, 199-K-132, and 199-K-185, respectively (Figure 4-43). The increase in nitrate and other contaminant concentrations indicates the 116-KW-1 Gas Condensate Crib is an ongoing secondary source. Well 199-K-204, located downgradient of 199-K-106A, exhibited a similar increase but concentrations were 44.3 mg/L. Concentrations observed at wells 199-K-132 and 199-K-185 are related to higher concentrations of nitrate previously observed at well 199-K-106A, which has migrated toward the downgradient extraction wells.

The second area in 100-K with nitrate concentrations persistent around 25 mg/L is near the KE Reactor and within the K East Cr(VI) plume, where a single well had nitrate levels greater than the DWS in 2016. Well 199-K-207, near the 116-KE-1 crib, had a 48.7 mg/L maximum nitrate concentration. The annual average decreased to 44.6 mg/L in this well, just less than the DWS of 45 mg/L. Well 199-K-189, downgradient from 116-KE-1, has an increasing trend since the end of 2014, but remained less than the DWS as of November 2016. Nitrate is currently not detected at concentrations greater than the DWS near the 116-K-2 Trench area or in 100-K aquifer tubes.

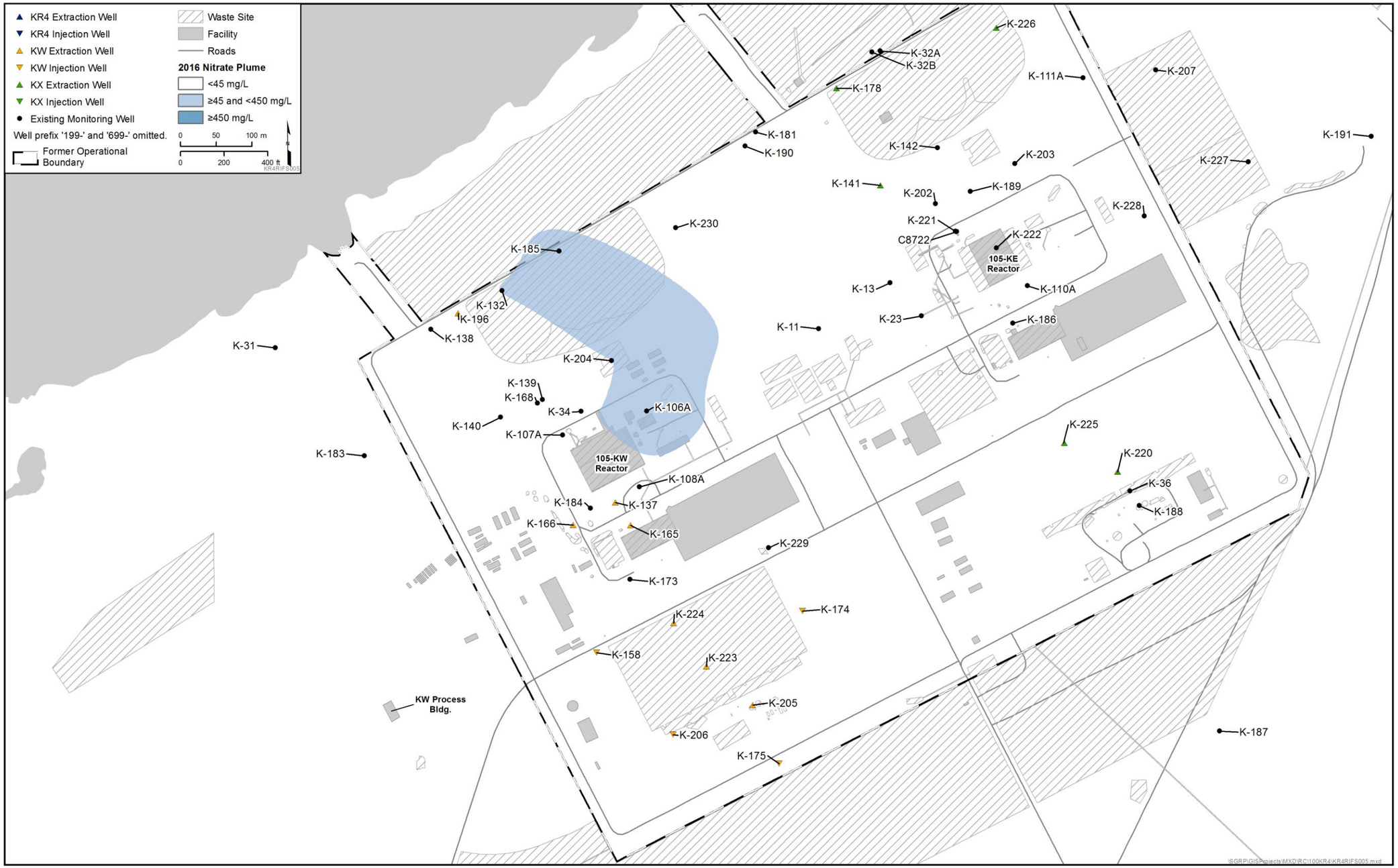

Figure 4-42. 100-KR-4 OU Nitrate Plume in 2016

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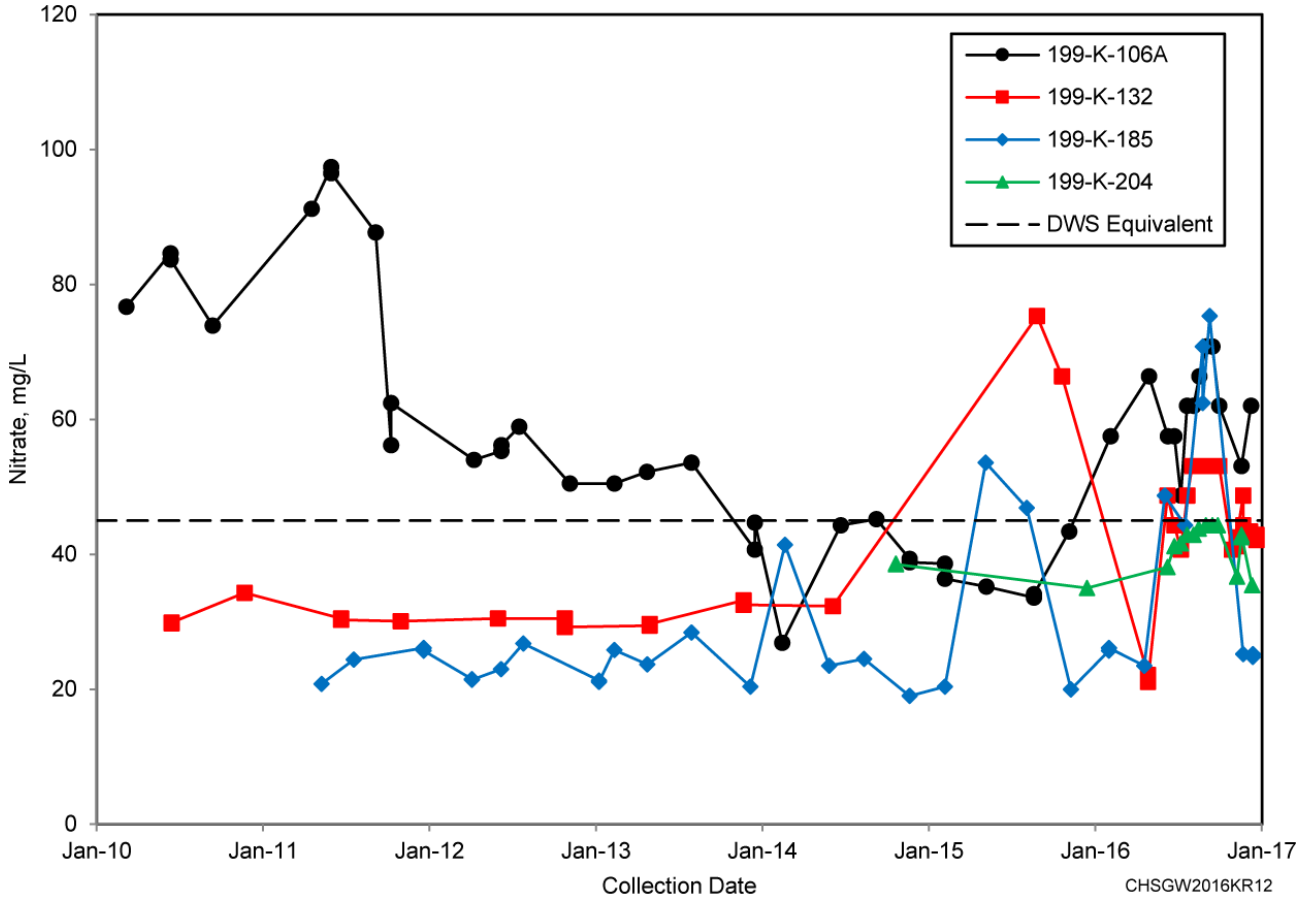

Figure 4-43. Nitrate Data for Wells near the KW Reactor (199-K-106A, 199-K-132, 199-K-185, and 199-K-204)

4.4.4.1 RI Well Concentrations and Vertical Distribution of Nitrate

Wells installed as part of the RI were sampled for nitrate, with vertical profile sampling conducted during drilling at all wells except 199-K-200, 199-K-201, 199-K-221, and 199-K-222. Nitrate was detected at concentrations greater than the DWS in the unconfined aquifer at RI wells 199-K-185, 199-K-190, 199-K-191, and 199-K-192. The nitrate concentration was less than the DWS in the remaining RI monitoring wells. Table 4-40 presents concentrations of nitrate measured in groundwater samples collected during drilling from RI borings and monitoring wells. Table 4-40 includes results from post-development samples for wells 199-K-200 and 199-K-201, and the first routine monitoring sample for wells 199-K-221 and 199-K-222. As noted previously, nitrate is detected in the K East and K West plumes near the reactors. The K West plume area contains the highest frequency of concentrations greater than the DWS in any of the plume areas.

Higher nitrate concentrations were detected near the top of the unconfined aquifer in wells 199-K-185, 199-K-189, 199-K-190, 199-K-191, and 199-K-192 during drilling (Figure 4-44). The maximum concentrations were detected in samples collected from wells 199-K-185 and 199-K-191, with 116 and 76.6 mg/L, respectively (Table 4-40). The RI data collected from well 199-K-185 shows nitrate concentrations elevated at the top of the aquifer and diminished rapidly with depth. Elevated nitrate levels at well 199-K-191 were not observed at downgradient wells.

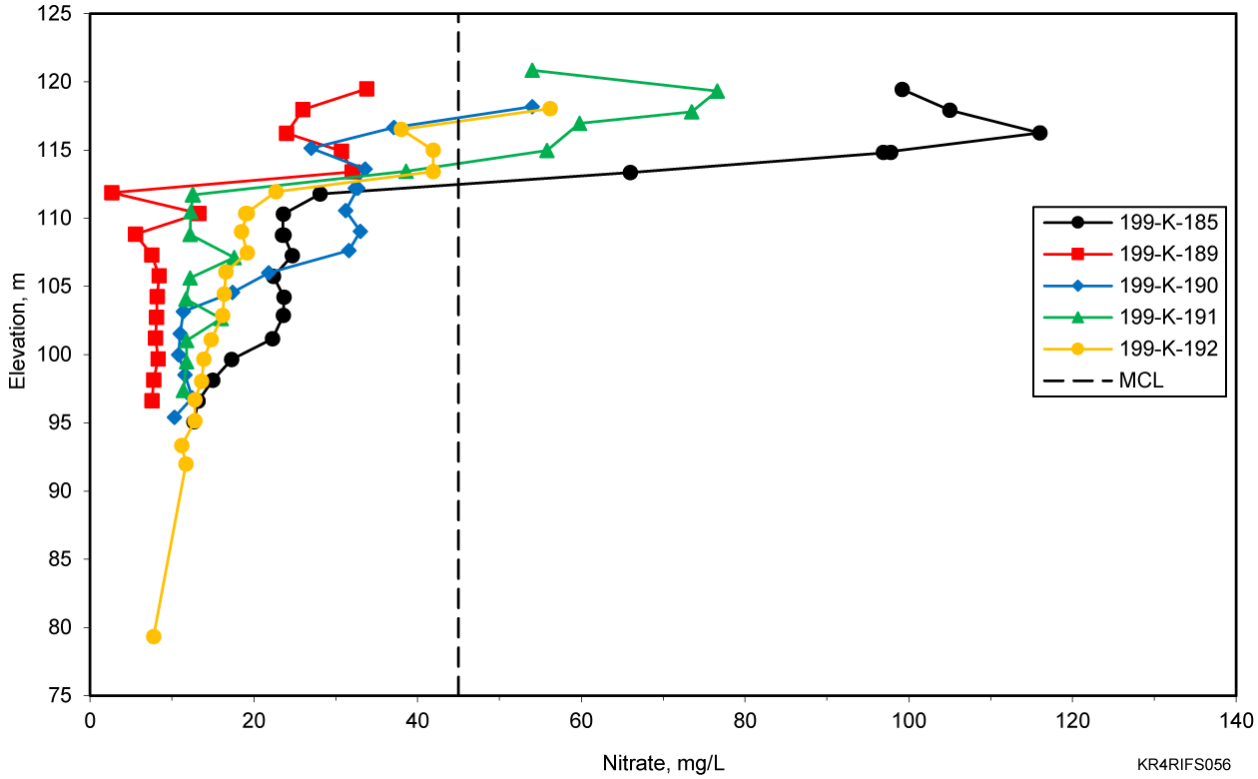

Figure 4-44. Nitrate Concentrations with Depth During Drilling in Select Wells

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
199-K-183	5/21/2010	24.44	80.2	22,800	D	N
	5/24/2010	25.76	84.5	22,400	D	N
	5/24/2010	27.55	90.4	22,400	D	N
	5/27/2010	28.9	94.8	22,400	D	N
	5/28/2010	30.33	99.5	18,100	D	N
	5/28/2010	30.33	99.5	18,100	D	N
	6/1/2010	32	105	15,400	D	N
	6/1/2010	33.53	110	16,100	D	N
	6/2/2010	35.36	116	15,500	D	N
	6/3/2010	36.58	120	13,400	DN	N
	6/3/2010	38.039	124.8	16,000	DN	N
	6/7/2010	39.32	129	15,100	D	N
	6/7/2010	41.209	135.2	14,300	D	N
	6/8/2010	42.763	140.3	14,500	D	N
	6/8/2010	44.135	144.8	14,100	D	N
199-K-184	12/28/2010	24.87	81.6	21,700	D	Y
	12/29/2010	26.43	86.7	21,700	D	N
	12/30/2010	27.43	90	21,600	D	N
	12/30/2010	28.96	95	21,900	D	N
	1/3/2011	31.7	104	20,100	D	N
	1/4/2011	32.065	105.2	19,700	D	Y
	1/6/2011	33.741	110.7	20,900	D	Y
	1/6/2011	33.741	110.7	21,700	D	Y
	1/7/2011	35.204	115.5	21,600	D	N
	1/10/2011	36.393	119.4	18,800	D	N
	1/11/2011	38.13	125.1	17,100	D	N
	1/13/2011	39.441	129.4	19,000	D	N
	1/14/2011	41.15	135	20,900	D	N
	1/15/2011	42.67	140	22,500	D	N
	1/15/2011	42.67	140	22,300	D	N
	1/15/2011	44.2	145	22,500	D	N
	1/17/2011	45.659	149.8	21,200	D	N

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
	1/18/2011	47.335	155.3	21,600	D	N
	1/21/2011	48.738	159.9	20,700	D	N
199-K-185	7/2/2010	15.85	52	**99,200**	D	Y
	7/6/2010	17.37	57	**105,000**	D	Y
	7/6/2010	19.05	62.5	**116,000**	D	Y
	7/8/2010	20.48	67.2	**96,900**	D	Y
	7/8/2010	20.48	67.2	**97,800**	D	Y
	7/8/2010	21.95	72	**66,000**	D	Y
	7/9/2010	23.53	77.2	28,100	D	Y
199-K-185	7/9/2010	24.99	82	23,600	D	Y
	7/12/2010	26.55	87.1	23,500	D	Y
	7/12/2010	26.55	87.1	23,700	D	Y
	7/13/2010	28.04	92	24,700	D	Y
	7/13/2010	29.57	97	22,400	D	Y
	7/14/2010	31.09	102	23,700	D	Y
	7/15/2010	32.431	106.4	23,600	D	Y
	7/16/2010	34.14	112	22,300	D	Y
	7/16/2010	35.66	117	17,300	D	Y
	7/19/2010	37.19	122	15,000	D	Y
	7/19/2010	38.71	127	13,200	D	Y
	7/20/2010	40.23	132	12,700	D	Y
199-K-186	1/4/2011	27.13	89	3,170	D	Y
	1/5/2011	28.59	93.8	1,100	D	Y
	1/6/2011	30.24	99.2	1,030	D	Y
	1/6/2011	30.24	99.2	1,020	D	N
	1/7/2011	32	105	965	D	N
	1/7/2011	33.53	110	921	D	N
	1/10/2011	35.082	115.1	8,630	D	N
	1/11/2011	36.58	120	9,740	D	Y
	1/14/2011	38.496	126.3	9,300	D	N
	1/14/2011	39.62	130	9,650	D	N
	1/15/2011	41.118	134.9	10,400	D	Y

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
	1/15/2011	42.763	140.3	10,500	D	Y
	1/17/2011	44.257	145.2	10,200	D	N
	2/14/2011	46.269	151.8	9,380	D	N
	2/15/2011	47.24	155	9,520	D	N
	2/16/2011	48.77	160	8,990	D	N
199-K-187	5/24/2010	36.942	121.2	24,700	D	Y
	5/24/2010	38.71	127	17,100	D	Y
	5/25/2010	39.93	131	15,700	D	Y
	5/27/2010	38.4	126	13,600	D	Y
	5/28/2010	43.28	142	14,300	D	Y
	5/28/2010	43.28	142	14,500	D	Y
	6/1/2010	44.348	145.5	13,400	D	Y
	6/1/2010	45.872	150.5	13,100	D	Y
	6/2/2010	47.701	156.5	13,800	D	Y
	6/2/2010	49.07	161	14,700	D	Y
	6/3/2010	50.29	165	12,400	DN	Y
	6/3/2010	52.12	171	10,800	D	Y
	6/4/2010	53.34	175	8,230	D	Y
	6/4/2010	55.413	181.8	5,360	D	Y
	6/7/2010	57	187	5,140	D	Y
	6/7/2010	58.52	192	3,800	D	Y
	6/8/2010	59.649	195.7	2,780	D	Y
199-K-188	1/12/2011	32	105	20,500	D	N
	1/13/2011	33.498	109.9	19,000	D	Y
	1/14/2011	35.022	114.9	19,300	D	Y
	1/15/2011	36.637	120.2	19,200	D	Y
	1/17/2011	38.1	125	17,400	D	Y
	1/17/2011	39.776	130.5	17,700	D	Y
	1/17/2011	39.776	130.5	17,800	D	Y
	1/18/2011	41.15	135	18,000	D	N
	1/19/2011	42.67	140	20,100	D	N
	1/19/2011	44.2	145	14,700	D	N

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
	1/20/2011	45.72	150	13,400	D	N
	1/22/2011	48.77	160	8,100	D	N
	1/24/2011	50.262	164.9	8,990	D	N
	1/26/2011	50.658	166.2	7,040	D	N
	1/27/2011	53.34	175	4,830	D	N
	1/28/2011	54.529	178.9	4,000	D	N
	1/31/2011	56.08	184	12,300	D	N
199-K-189	8/17/2010	23.47	77	33,800	D	N
	8/18/2010	24.99	82	26,000	D	N
	8/19/2010	26.73	87.7	24,000	D	N
	8/20/2010	28.04	92	30,700	D	N
	8/23/2010	29.57	97	32,100	D	N
	8/23/2010	29.57	97	32,000	D	N
	8/24/2010	31.09	102	2,660	D	N
	8/25/2010	32.61	107	13,300	D	N
	8/25/2010	34.14	112	5,530	D	N
	8/26/2010	35.66	117	7,530	D	N
	8/27/2010	37.19	122	8,410	D	N
	8/27/2010	38.71	127	8,190	D	N
	8/30/2010	40.23	132	8,100	D	N
	8/31/2010	41.76	137	8,010	D	N
	8/31/2010	43.28	142	8,320	D	N
	9/1/2010	44.81	147	7,750	D	N
	9/2/2010	46.33	152	7,570	D	N
199-K-190	8/3/2010	17.98	59	**54,000**	D	Y
	8/4/2010	19.51	64	37,100	D	N
	8/4/2010	21.03	69	27,000	D	N
	8/5/2010	22.56	74	33,600	D	N
	8/5/2010	23.96	78.6	32,400	D	N
	8/5/2010	23.96	78.6	32,700	D	N
	8/6/2010	25.6	84	31,200	D	N
	8/6/2010	27.13	89	33,000	D	N

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
	8/9/2010	28.53	93.6	31,600	D	N
	8/10/2010	30.18	99	21,800	D	N
	8/10/2010	31.608	103.7	17,400	D	N
199-K-190	8/11/2010	33.01	108.3	11,400	D	N
	8/11/2010	34.625	113.6	11,000	D	N
	8/12/2010	36.18	118.7	10,800	D	N
	8/13/2010	37.643	123.5	11,600	D	N
	8/16/2010	39.32	129	12,500	D	N
	8/17/2010	40.752	133.7	10,300	D	N
199-K-191	6/24/2010	23.77	78	**54,000**	D	Y
	6/25/2010	25.3	83	**76,600**	D	Y
	6/28/2010	26.82	88	**73,500**	D	Y
	6/29/2010	27.65	90.7	**59,800**	D	Y
	6/29/2010	29.66	97.3	**55,800**	D	Y
	6/30/2010	31.181	102.3	38,600	D	Y
	7/2/2010	32.92	108	12,500	D	Y
	7/2/2010	32.92	108	12,600	D	Y
	7/2/2010	34.14	112	12,300	D	Y
	7/6/2010	35.814	117.5	12,200	D	Y
	7/8/2010	37.49	123	17,600	D	Y
	7/9/2010	39.01	128	12,200	D	Y
	7/12/2010	40.54	133	11,700	D	Y
	7/13/2010	41.971	137.7	16,000	D	Y
	7/14/2010	43.59	143	11,800	D	Y
	7/14/2010	45.141	148.1	11,800	D	Y
	7/15/2010	47.24	155	11,400	D	Y
	8/31/2010	16.76	55	**56,200**	D	Y
	8/31/2010	18.29	60	38,000	D	Y
	9/1/2010	19.81	65	41,900	D	Y
	9/2/2010	21.37	70.1	41,900	D	Y
	9/3/2010	22.86	75	22,700	D	Y
	9/7/2010	24.44	80.2	19,200	D	Y

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
	9/7/2010	24.44	80.2	19,000	D	Y
	9/8/2010	25.79	84.6	18,500	D	Y
199-K-192	9/10/2010	27.34	89.7	19,200	D	Y
	9/14/2010	28.74	94.3	16,600	D	Y
	9/14/2010	30.36	99.6	16,400	D	Y
	9/15/2010	31.913	104.7	16,200	D	Y
	11/2/2010	33.711	110.6	14,800	D	Y
	11/3/2010	35.143	115.3	13,900	D	Y
	11/3/2010	36.759	120.6	13,600	D	Y
	11/4/2010	38.1	125	12,800	D	Y
	11/4/2010	39.654	130.1	12,800	D	Y
	11/8/2010	41.45	136	11,200	D	Y
	11/8/2010	42.824	140.5	11,700	D	Y
	11/17/2010	55.47	182	7,750	D	Y
199-K-193	9/24/2010	25.15	82.5	16,700	D	N
	11/2/2010	26.82	88	8,410	D	N
	11/3/2010	28.35	93	9,830	D	N
	11/4/2010	29.87	98	9,610	D	N
	11/8/2010	31.39	103	8,720	D	N
	11/9/2010	32.92	108	17,700	D	N
	11/9/2010	32.92	108	18,100	D	N
	11/10/2010	34.44	113	8,060	D	N
	11/11/2010	35.66	117	7,570	D	N
	11/12/2010	37.49	123	8,900	D	N
	11/12/2010	38.1	125	8,280	D	N
	11/15/2010	40.54	133	6,640	D	N
	11/15/2010	42.06	138	5,580	D	N
	11/16/2010	43.59	143	3,700	D	N
	11/17/2010	45.171	148.2	3,330	D	N
	11/18/2010	46.63	153	3,710	D	N
	11/22/2010	48.16	158	84.1	UD	N
	1/12/2011	26.82	88	18,600	D	N

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L		Filtered ?
	1/12/2011	28.44	93.3	19,000	D	N
	1/13/2011	29.87	98	9,780	D	Y
	1/14/2011	31.455	103.2	9,430	D	N
	1/17/2011	32.979	108.2	9,430	D	N
199-K-194	1/18/2011	34.503	113.2	9,070	D	N
	1/18/2011	34.503	113.2	8,900	D	N
	1/18/2011	31.547	103.5	8,280	D	N
	1/19/2011	37.673	123.6	8,010	D	N
	1/20/2011	39.197	128.6	9,160	D	N
	1/21/2011	40.84	134	9,160	D	N
	1/21/2011	42.06	138	8,590	D	N
	1/24/2011	43.343	142.2	8,460	D	N
199-K-195	11/15/2010	27.46	90.1	18,800	D	N
	11/16/2010	28.99	95.1	23,500	D	N
	11/17/2010	30.39	99.7	37,200	D	N
	11/18/2010	31.882	104.6	27,800	D	N
	11/19/2010	33.619	110.3	22,500	D	N
	11/19/2010	33.619	110.3	22,100	D	N
	11/23/2010	35.022	114.9	84.1	UD	N
	11/29/2010	36.424	119.5	21,100	D	N
	11/30/2010	38.161	125.2	19,400	D	N
	12/1/2010	39.62	130	18,800	D	N
	12/2/2010	41.087	134.8	18,600	D	N
	12/3/2010	42.67	140	17,800	D	N
	12/6/2010	44.2	145	18,300	D	N
	12/8/2010	45.72	150	17,400	D	N
	12/10/2010	47.24	155	16,800		N
	12/13/2010	48.77	160	17,400	D	Y
	12/14/2010	50.29	165	22,000	D	Y
	12/15/2010	51.82	170	16,400	D	Y
	12/15/2010	53.584	175.8	16,000	D	Y

Table 4-40. Nitrate Concentrations in Groundwater During Drilling

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Nitrate Concentration µg/L	Filtered ?
199-K-200	8/26/2010	17.86	58.6	25,200 D	Y
199-K-201	9/15/2010	18.41	60.4	29,500 D	Y
199-K-221	11/13/15	Not reported	--	13,500 D	N
199-K-222	11/13/15	Not reported	--	14,200 D	N

Note: Bold indicates concentration >45,000 µg/L.

bgs = below ground surface

D = analyte was reported at a secondary dilution factor

N = spike and/or spike duplicate sample recovery is outside control limits

U = analyzed for but not detected above limiting criteria

4.4.4.2 Summary for Nitrate

Nitrate sources at 100-K are the 116-KW-1 and 116-KE-1 gas condensate cribs. Nitrate concentrations in 100-K show stable to decreasing trends in wells located in both the K West and K East plume areas. Nitrate concentrations greater than the DWS were not observed near the 116-K-2 Trench. Nitrate has been consistently detected at low concentrations in RUM well 199-K-32B at about 10.5 mg/L, and in RUM well 199-K-192 at about 7.5 mg/L.

Two aquifer tubes (17-D and C6241), downgradient from the 116-KW-1 Gas Condensate Crib and 1607-K-6 septic system and north of the RI aquifer tube cluster, detected nitrate at concentrations exceeding the DWS of 45 mg/L (Fall 2009). None of the other 11 aquifer tubes located along the Columbia River shoreline in 100-K detected nitrate at concentrations greater than the DWS. Nitrate concentrations measured in the RI aquifer tube cluster were less than the DWS.

4.4.5 Tritium

Groundwater sampling for tritium was performed as part of RI activities, and continues to be part of ongoing monitoring at 100-K. The plume footprint for areas exceeding the 20,000 pCi/L DWS in 2016 was approximately 0.12 km^2 (0.05 mi^2). Tritium is currently found in groundwater at several areas that correlate with historical sources. Releases from reactor gas dryer condensate and the FSBs resulted in contamination downgradient from both the KW and KE Reactors and near the 116-KW-1 and 116-KE-1 gas condensate cribs. The highest tritium concentrations were near the 118-K-1 Burial Ground.

With ongoing P&T operations, and a half-life of 12.3 years, the areas with elevated tritium concentrations at the K West plume have diminished to a small area near the KW Reactor. Concentrations in this area >20,000 pCi/L were in a single well, 199-K-106A, downgradient from the 116-KW-1 Gas Condensate Crib. Tritium concentrations in well 199-K-106A peaked at 2,240,000 pCi/L in January 2005 but have since decreased. Concentrations typically ranged from 1,500 to 5,000 pCi/L in well 199-K-106A from mid-2009 until the KW rebound test in May 2016. When the P&T system was shut off, tritium levels rose to 91,900 pCi/L in August 2016 but started decreasing again once the KW system resumed operation. As of March 2017, concentrations were at about 5,000 pCi/L and decreasing.

Tritium concentrations at the K East plume are attributed to the 116-KE-1 Gas Condensate Crib, the KE FSB, and 118-K-1 Burial Ground. Historically, high concentrations were located near the KE Reactor. Decommissioned well 199-K-30, located near the reactor, exhibited concentrations of tritium as high as 3,320,000 pCi/L (May 1993) with a notable seasonal variation. In 2016, the annual average tritium concentrations were greater than the 20,000 pCi/L DWS at only wells 199-K-189 and 199-K-202, as shown on Figure 4-45.

The area downgradient from the 118-K-1 Burial Ground in the K East plume area now has the highest tritium concentrations in 100-K. Well 199-K-227, located on the southern end of the burial ground, had tritium concentrations during drilling at 3,810,000 pCi/L in June 2017 (Figure 4-45). Wells downgradient have also reported high tritium concentrations. Well 199-K-111A reached 375,000 pCi/L during 2016 and well 199-K-207 reported 935,000 pCi/L in 2015. Tritium levels have since decreased in well 199-K-227 to <500,000 pCi/L.

Tritium has not been detected in the RUM since 2001, or greater than the DWS in aquifer tubes at 100-K. The RUM tritium detections have been within the counting error for the radionuclide, and therefore are not considered reliable data points.

4.4.5.1 RI Well Concentrations and Vertical Distribution of Tritium

Wells installed for the RI were sampled for tritium, with vertical profile sampling conducted during drilling at all locations except 199-K-200 and 199-K-201. Tritium was detected at concentrations >10,000 pCi/L in wells 199-K-189, 199-K-192, 199-K-221, and 199-K-222. Analytical results from these wells are presented in Table 4-41. Low levels of tritium were detected during drilling in the remaining RI wells.

During the RI in August 2010, the tritium concentration at well 199-K-192 was 1,400,000 pCi/L near the top of the unconfined aquifer. These concentrations decreased quickly with depth, decreasing to <20,000 pCi/L within 6 m (20 ft). In addition, tritium has not been detected in the RUM, where the well is completed. Concentrations in upgradient well 199-K-157 had a maximum of 380,000 pCi/L in January 2009 and concentrations in upgradient RI well 199-K-200 had a maximum of 6,100 pCi/L in September 2010. This indicates that the source area for tritium is likely related to a preferential pathway from the high concentration area at the 118-K-1 Burial Ground and not from the 116-K-2 Trench. The likelihood of the source area being the burial ground is supported by the 3,810,000 pCi/L tritium detected during drilling (June 2017) at well 199-K-227.

Vertical profile sampling in other RI wells indicated higher activity levels near the top of the unconfined aquifer, decreasing with depth. Near the 183.1-KE gas condensate crib, RI well 199-K-189 exhibited tritium concentrations up to 140,000 pCi/L during drilling in August 2010. This sample was collected at a depth of 28 m (92 ft) bgs (Figure 4-46). Subsequent routine monitoring from well 199-K-189 had tritium concentrations ranging from less than detection limits (May 2014) to 47,900 pCi/L (February 2016).

RI wells 199-K-221 and 199-K-222 were installed near the KE Reactor. Tritium levels in these wells were elevated, and 199-K-221 reported 63,400 pCi/L at 22.8 m (75 ft) bgs. Concentrations in 199-K-221 decreased to 155 pCi/L at the next sample interval, 24 m (78 ft) bgs. Subsequent routine monitoring indicated tritium at 14,400 pCi/L.

Wells 199-K-200 and 199-K-201 were installed at either end of the 116-K-2 Trench. Sampling results in well 199-K-200 decreased from 3,100 pCi/L in the first routine sampling event in January 2011 to 1,770 pCi/L in May 2017. Concentrations in well 199-K-201 were initially at 270 pCi/L and increased to 2,910 pCi/L (November 2016). The results for these two wells are consistent with other sample results along the 116-K-2 Trench reporting low tritium levels.

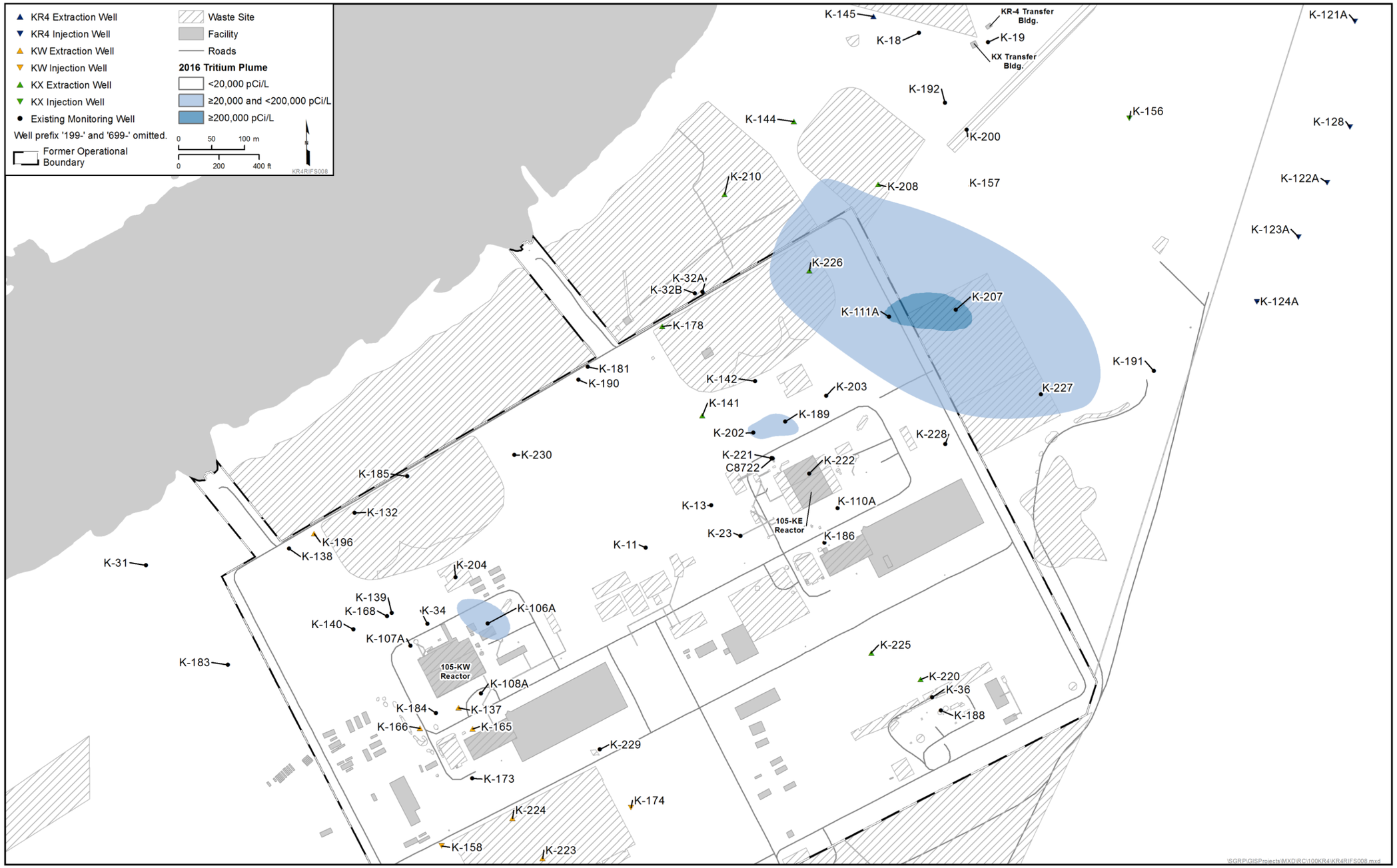

Figure 4-45. 100-KR-4 OU Tritium Plumes in 2016

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Table 4-41. Analytical Results in Wells with Tritium Concentrations Greater Than One-Half DWS

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Tritium Concentration pCi/L
199-K-189	8/17/2010	23.47	77	1,600
	8/18/2010	24.99	82	13,000
	8/19/2010	26.73	87.7	**86,000**
	8/20/2010	28.04	92	**140,000**
	8/23/2010	29.57	97	**92,000**
	8/23/2010	29.57	97	**93,000**
	8/24/2010	31.09	102	4,500
	8/25/2010	32.61	107	**36,000**
	8/25/2010	34.14	112	1,700
	8/26/2010	35.66	117	210
	8/27/2010	37.19	122	270
	8/27/2010	38.71	127	340
	8/30/2010	40.23	132	400
	8/31/2010	41.76	137	110 U
	8/31/2010	43.28	142	680
	9/1/2010	44.81	147	1,100
	9/2/2010	46.33	152	4,000
199-K-192	8/31/2010	16.76	55	**1,400,000**
	8/31/2010	18.29	60	**960,000**
	9/1/2010	19.81	65	**670,000**
	9/2/2010	21.37	70.1	**350,000**
	9/3/2010	22.86	75	**87,000**
	9/7/2010	24.44	80.2	**48,000**
	9/7/2010	24.44	80.2	**49,000**
	9/8/2010	25.79	84.6	**36,000**
	9/10/2010	27.34	89.7	**51,000**
	9/14/2010	28.74	94.3	14,000
	9/14/2010	30.36	99.6	**27,000**
	9/15/2010	31.91	104.7	13,000
	11/2/2010	33.71	110.6	9,500
199-K-192	11/3/2010	35.14	115.3	7,000
	11/3/2010	36.76	120.6	5,600

Table 4-41. Analytical Results in Wells with Tritium Concentrations Greater Than One-Half DWS

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Tritium Concentration pCi/L
	11/4/2010	38.10	125	3,700
	11/4/2010	39.65	130.1	3,800
	11/8/2010	41.45	136	2,300
	11/8/2010	42.82	140.5	3,300
	11/17/2010	55.47	182	400
199-K-221	6/3/2015	19.72	64.7	5,810
	6/9/2015	21.35	70.06	8,640
	6/11/2015	22.85	74.98	**63,400**
	6/11/2015	22.85	74.98	**62,200**
	6/17/2015	24.02	78.81	155
	6/23/2015	27.1	88.9	231
	6/25/2015	31.14	102.18	172
199-K-222	8/26/2015	23.76	77.95	18,500
	8/28/2015	25.27	82.9	3,970
	8/31/2015	27.47	90.11	131
	8/31/2015	27.47	90.11	170
	9/1/2015	28.96	95	465
	9/3/2015	32	105	173
	9/10/2015	35.68	117.05	176 U
	9/10/2015	35.68	117.05	133

Note: **Bold** indicates concentrations greater than the 20,000 pCi/L DWS.

bgs = below ground surface

DWS = drinking water standard

U = analyzed for but not detected above limiting criteria

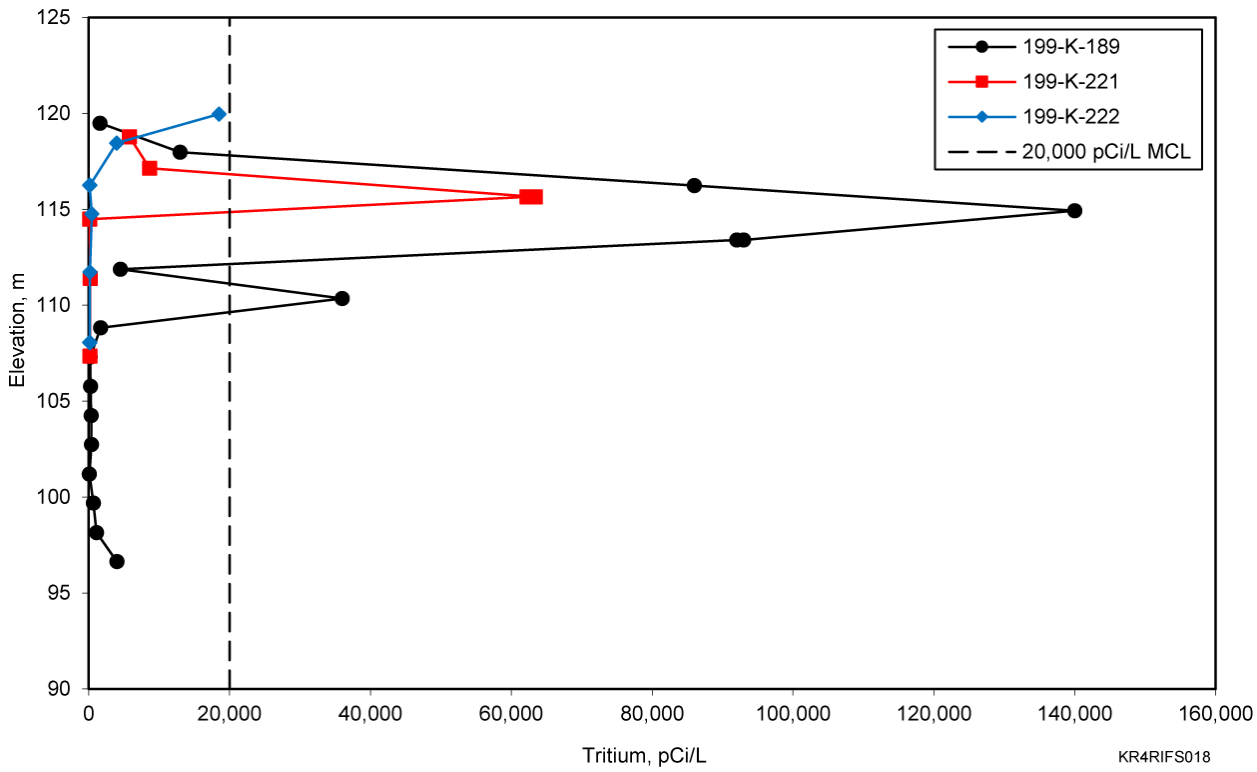

Figure 4-46. Vertical Profile of Tritium Levels in Wells 199-K-189, 199-K-221, and 199-K-222

4.4.5.2 Summary for Tritium

Tritium concentrations are decreasing in the K West and K East plume areas. Small areas of elevated tritium concentrations remain near the KW and KE Reactors, at wells 199-K-106A and 199-K-189, respectively.

The highest tritium concentrations were at the 118-K-1 Burial Ground. The activity levels are related to contaminated solid waste disposal. Tritium in deep vadose zone soil after remediation (CVP-2013-00002) had concentrations up to 13,400 pCi/g. Tritium concentrations in groundwater near the burial ground were 3,810,000 pCi/L during drilling (June 2017) at well 199-K-227. Tritium concentrations near the burial ground increase during extended periods of low water. The fluctuations in activity levels associated with fluctuations in groundwater elevations indicates that contamination remaining in the vadose zone is migrating into groundwater.

Groundwater samples and routine monitoring at well 199-K-192 and monitoring at well 199-K-32B indicate tritium is not in the uppermost water bearing RUM unit. In addition, no 100-K aquifer tubes show tritium concentrations greater than the DWS.

4.4.6 Carbon-14

Carbon-14 is in groundwater at concentrations greater than the DWS of 2,000 pCi/L in the K West and K East plume areas. Low carbon-14 levels were detected along the 116-K-2 Trench. Most carbon-14 in 100-K groundwater originated from historical discharges of reactor gas dryer condensate to the 116-KE-1 and 116-KW-1 gas condensate cribs. Carbon-14 concentrations in gas dryer condensate collected during operation ranged from 2.9×10^8 pCi/L at the KW Reactor to 1.04×10^9 pCi/L at the KE Reactor. Discharges at the gas condensate cribs resulted in the highest groundwater activities near each crib. The 2016 groundwater plume footprint for carbon-14 areas greater than the DWS was approximately 0.05 km^2 (0.02 mi^2), with most elevated concentrations in the K West plume area (Figure 4-47).

During 2016 and the KW rebound study, carbon-14 concentrations at the K West area remained consistent with previous years, ranging from 400 to 1,000 pCi/L. Concentrations increased in wells downgradient from the 116-KW-1 Gas Condensate Crib. Well 199-K-106A, 32 m (105 ft) downgradient from 116-KW-1, had a 40,100 pCi/L maximum concentration, similar to the historic maximum in 1997. Concentrations in well 199-K-106A decreased to 28,500 pCi/L in May of 2017. The results indicate the 116-KW-1 Gas Condensate Crib is a continuing source of carbon-14, along with nitrate and tritium.

Monitoring wells 199-K-204 and 199-K-185, and KW extraction well 199-K-132, located downgradient from 199-K-106A, showed similar concentration increases during 2016 (Figure 4-48). Well 199-K-204 showed a similar concentration change to well 199-K-106A, but the increase started and peaked later at 25,500 pCi/L maximum concentration. The delayed concentration peak indicates the well is farther from the source area. Downgradient wells 199-K-132 and 199-K-185 had maximum concentrations of 10,900 pCi/L (August 2015) and 4,400 pCi/L (August 2016), respectively. The carbon-14 concentrations in well 199-K-132 have decreased since the restart of the KW P&T system. Well 199-K-185 has shown seasonal variation, but concentrations remain elevated during low river stage.

A lower concentration carbon-14 plume exists in the K East area, associated with the 116-KE-1 Gas Condensate Crib. This plume was formerly defined by wells 199-K-29 and 199-K-30, decommissioned in 2011. In 2010, wells 199-K-29 and 199-K-30 had 3,120 and 6,900 pCi/L maximum activity levels, respectively. These wells monitored downgradient of the 116-KE-1 Gas Condensate Crib. Similar to the K West area, the carbon-14 plume at K East is migrating downgradient from the source area (Figure 4-47). The extrapolated concentrations likely exceed 20,000 pCi/L in the downgradient area where monitoring was not available and currently does not exist. The carbon-14 plume at K East may not lie completely within the operating KX extraction wells capture zone. Well 199-K-202 had a 2,000 pCi/L carbon-14 concentration in 2016. Well 199-K-189, located between wells 199-K-202 and 199-K-203, exhibited a range in carbon-14 concentrations, fluctuating from 163 to 2,480 pCi/L during 2016, and an overall decreasing trend.

Low carbon-14 levels are detected along the 116-K-2 Trench area. These are related to reactor effluent discharges to the trench. Concentrations are less than the DWS.

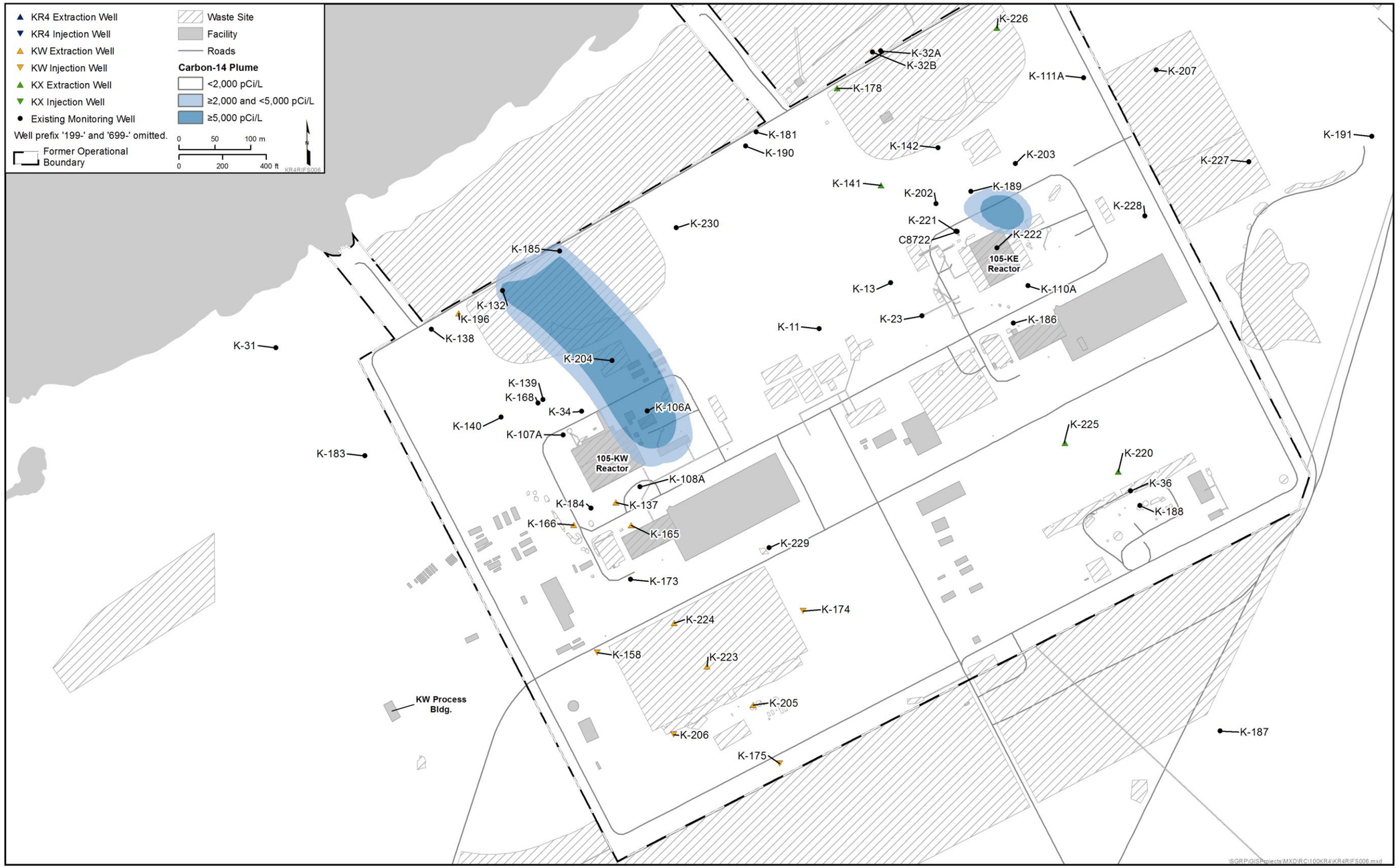

Figure 4-47. 100-KR-4 OU Carbon-14 Plume in 2016

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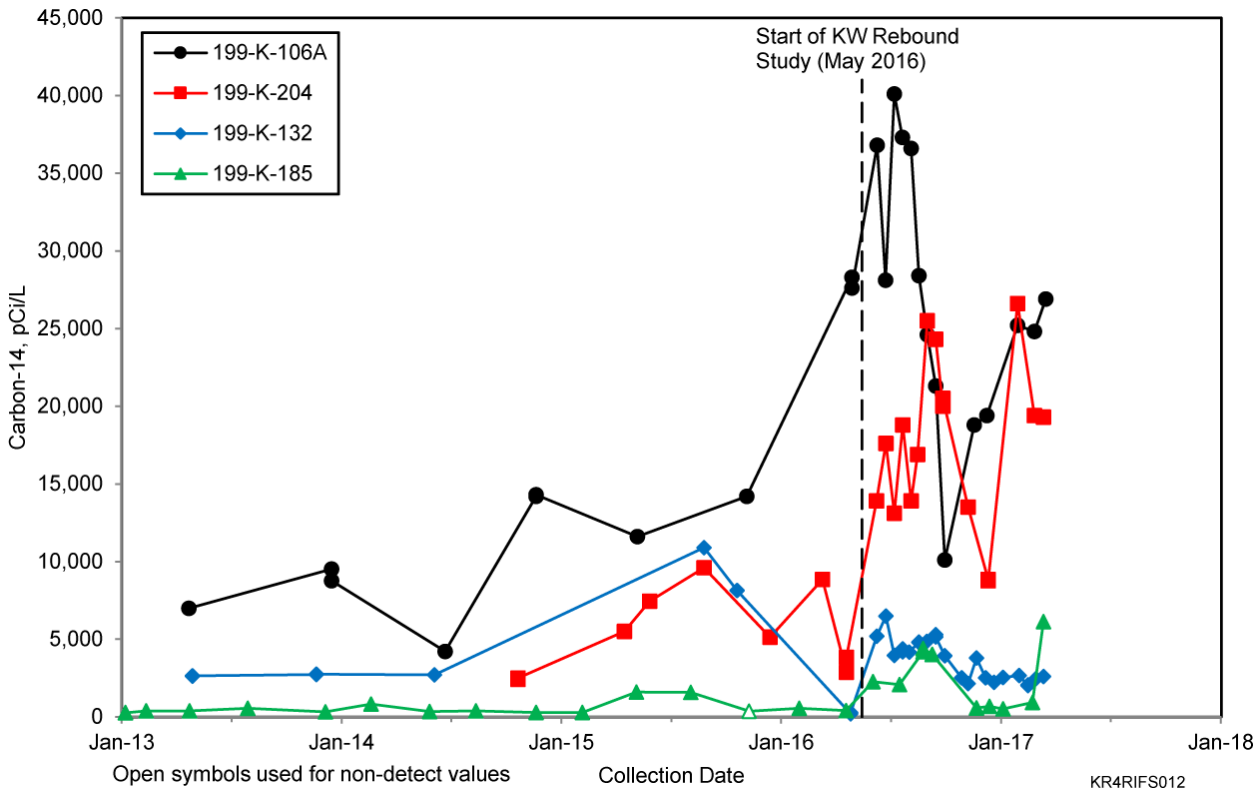

Figure 4-48. Carbon-14 Data for Wells Downgradient of the 116-KW-1 Gas Condensate Crib

4.4.6.1 RI Well Concentrations and Vertical Distribution of Carbon-14

Wells installed for the RI were all sampled for carbon-14, with vertical profile sampling conducted during drilling at all locations except 199-K-200 and 199-K-201. Carbon-14 was >1,000 pCi/L (half of the standard) in wells 199-K-184, 199-K-185, 199-K-189, 199-K-221, and 199-K-222. Table 4-42 presents the analytical results from these wells. Similar to other analytes, the concentrations show variation in vertical distribution. Carbon-14 appears to be higher near the top or middle of the aquifer, depending on the well location relative to the potential source area. The highest concentrations detected during the RI were found in wells 199-K-221 and 199-K-222, near the KE Reactor, and have the most pronounced vertical distribution within the aquifer. Figure 4-49 presents the vertical profile results for wells 199-K-221 and 199-K-222.

Table 4-42. Analytical Results in Wells with Carbon-14 Concentrations Greater Than One-Half the DWS

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Carbon-14 Concentrations (pCi/L)
199-K-184	12/28/2010	24.87	81.6	582
	12/29/2010	26.43	86.7	1,020
	12/29/2010	27.43	90	782
	12/30/2010	28.96	95	806
	1/3/2011	31.7	104	1,270

Table 4-42. Analytical Results in Wells with Carbon-14 Concentrations Greater Than One-Half the DWS

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Carbon-14 Concentrations (pCi/L)
	1/4/2011	32.065	105.2	1,470
	1/6/2011	33.741	110.7	380
	1/6/2011	33.741	110.7	683
	1/7/2011	35.204	115.5	602
	1/10/2011	36.393	119.4	1,210
	1/11/2011	38.13	125.1	1,640
	1/13/2011	39.441	129.4	1,090
	1/14/2011	41.15	135	631
	1/15/2011	42.67	140	606
	1/15/2011	42.67	140	558
	1/15/2011	44.2	145	602
	1/17/2011	45.659	149.8	596
	1/18/2011	47.335	155.3	9.43 U
	1/21/2011	48.738	159.9	544
199-K-185	7/2/2010	15.85	52	1,620
	7/6/2010	17.37	57	**2,390**
	7/6/2010	19.05	62.5	**2,070**
	7/8/2010	20.48	67.2	1,730
	7/8/2010	20.48	67.2	1,720
	7/8/2010	21.95	72	958
	7/9/2010	23.53	77.2	466
	7/9/2010	24.99	82	636
	7/12/2010	26.55	87.1	236
	7/12/2010	26.55	87.1	195
199-K-185	7/13/2010	28.04	92	233
	7/13/2010	29.57	97	210
	7/14/2010	31.09	102	221
	7/15/2010	32.431	106.4	-0.44 U

Table 4-42. Analytical Results in Wells with Carbon-14 Concentrations Greater Than One-Half the DWS

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Carbon-14 Concentrations (pCi/L)
	7/16/2010	34.14	112	198
	7/16/2010	35.66	117	530
	7/19/2010	37.19	122	358
	7/19/2010	38.71	127	626
	7/20/2010	40.23	132	682
199-K-189	8/17/2010	23.47	77	514
	8/18/2010	24.99	82	1,200
	8/19/2010	26.73	87.7	981
	8/20/2010	28.04	92	751
	8/23/2010	29.57	97	639
	8/23/2010	29.57	97	666
	8/24/2010	31.09	102	275
	8/25/2010	32.61	107	388
	8/25/2010	34.14	112	297
	8/26/2010	35.66	117	164
	8/27/2010	37.19	122	128
	8/27/2010	38.71	127	152
	8/30/2010	40.23	132	137
	8/31/2010	41.76	137	71.5
	9/1/2010	44.81	147	101
	9/2/2010	46.33	152	155
199-K-221	6/3/2015	19.72	64.7	**2,530**
	6/9/2015	21.354	70.06	821
	6/11/2015	22.854	74.98	**3,150**
	6/11/2015	22.854	74.98	**3,320**
199-K-221	6/17/2015	24.021	78.81	261
	6/23/2015	27.1	88.9	139
	6/25/2015	31.14	102.18	76.7

Table 4-42. Analytical Results in Wells with Carbon-14 Concentrations Greater Than One-Half the DWS

Well ID	Sample Date	Sample Depth (m bgs)	Sample Depth (ft bgs)	Carbon-14 Concentrations (pCi/L)
199-K-222	8/26/2015	23.759	77.95	**4,830**
	8/28/2015	25.27	82.9	1,990
	8/31/2015	27.47	90.11	868
	8/31/2015	27.47	90.11	865
	9/1/2015	28.96	95	636
	9/3/2015	32	105	143
	9/10/2015	35.68	117.05	61.7
	9/10/2015	35.68	117.05	61.4

Note: **Bold** indicates concentrations greater than the 2,000 pCi/L DWS.

bgs = below ground surface

DWS = drinking water standard

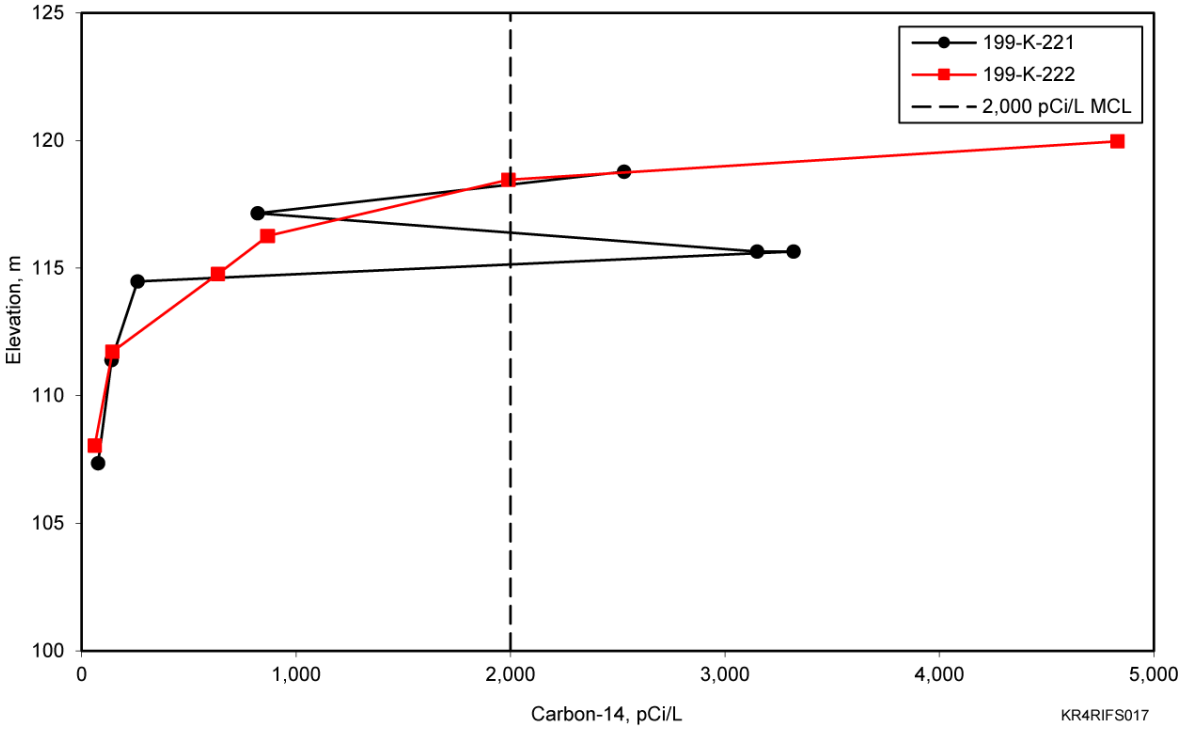

Figure 4-49. Vertical Profile of Carbon-14 Concentrations in Wells 199-K-221 and 199-K-222

4.4.6.2 Summary for Carbon-14

The carbon-14 plumes are concentrated near and downgradient from the KW and KE Reactors. The highest activities were detected in well 199-K-106A, 32 m (105 ft) downgradient from the 116-KW-1 Gas Condensate Crib, with a maximum concentration of 40,100 pCi/L in 2016. Rebound test results at K West indicate the 116-KW-1 Gas Condensate Crib represents a continuing source.

Near the KE Reactor, concentrations are lower and the plume is between the reactor and well 199-K-189. Low concentrations of carbon-14 were detected in the 116-K-2 Trench area, but there have been no recent detections greater than the DWS. Carbon-14 has not been detected in the uppermost water bearing RUM unit within 100-K.

Aquifer tubes downgradient of the KW and KE reactor areas exhibit low carbon-14 concentrations. Reported concentrations in aquifer tubes were less than 500 pCi/L. Aquifer tube 17-M, downgradient of the 116-KW-1 Gas Condensate Crib, reported the maximum concentration in 2016 at 358 pCi/L. Carbon-14 was detected in RI aquifer tube C6247 at 326 pCi/L in October 2014, but concentrations have since decreased to less than the detection limits.

4.4.7 Strontium-90

Cooling water contaminated by fuel rod failure fission products (including strontium-90) was held in the KW or KE retention basins and subsequently discharged to the 116-K-1 Crib and 116-K-2 Trench. The 116-KW-2 and 116-KE-3 cribs were both used for overflow disposal of an undetermined volume of sub-basin drainage containing strontium-90 from the KW and KE FSBs from 1955 to 1971. Each crib had a reverse well extending to approximately 3 m (10 ft) greater than the water table. Strontium-90 was also historically released to groundwater via FSB leaks (Section 1.2.2.5). The FSBs stored SNF from 1975 (KE) and 1981 (KW) until SNF removal in 2004. Both FSBs leaked, with KE releasing a much greater volume, approximately 56.8 million L (15 million gal) from 1976 to 1979 and 570,000 L (150,000 gal) in 1993. The KE FSB leak from 1976 to 1979 is estimated to have released 2,500 Ci of radionuclides, exclusive of tritium. The leaks and releases resulted in three strontium-90 plumes, one at the K West plume area, one at the K East plume area, and one near the 116-K-1 Crib and 116-K-2 Trench. The highest strontium-90 concentrations in groundwater are associated with historical releases from the KE FSB.

Figure 4-50 presents the 2016 strontium-90 plumes. These plumes are not inferred to extend to the Columbia River at concentrations greater than the 8 pCi/L DWS. The plumes migrate slowly, and radioactive decay effectively decreases concentration at the plumes' leading edges. The relative plume stabilities are attributed to the strong strontium-90 adsorption by ion exchange to aquifer sediment and the radioactive half-life of 29.1 years (EPA 402-R-99-001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*). Due to its sorptive properties, strontium-90 typically moves over 100 times slower than the surrounding groundwater flow. Studies of the Hanford 100-N Area showed that only about 1% of the strontium-90 contamination is dissolved in the groundwater (PNNL-16891, *Hanford 100-N Area Apatite Emplacement: Laboratory Results of Ca-Citrate-PO4 Solution Injection and Sr-90 Immobilization in 100-N Sediments*), with the remaining 99% geochemically bonded to the vadose zone and aquifer sediments near the water table. Similar strontium-90 distribution is expected at 100-K because the hydrogeology is comparable to 100-N.

The 2016 strontium-90 plume in the K West area was in a small area downgradient of the KW Reactor. Strontium-90 at concentrations greater than the 8 pCi/L DWS was detected in wells 199-K-34, 199-K-107A, and 199-K-139. The highest strontium-90 concentration reported for the KW plume in 2016 was 41.5 pCi/L at well 199-K-34. The strontium-90 measurements indicate minimal plume migration from near well 199-K-107A and the 116-KW-2 Crib toward nearby extraction wells

(e.g., well 199-K-139). Fluctuating concentrations observed in well 199-K-107A are attributed to changes in water table elevation associated with shut down of the KW P&T system during the rebound test. Concentrations are near detection limits in wells farther downgradient. Strontium-90 was not detected in 100-K seep samples during 2016.

A high-concentration strontium-90 plume is near the KE Reactor within the K East plume area. The highest concentration was formerly represented by well 199-K-109A. The historical maximum strontium-90 concentration at well 199-K-109A was 18,600 pCi/L in September 1997. Strontium-90 concentrations at this well were >5,000 pCi/L from 1996 to 2000. The strontium-90 concentration was 1,120 pCi/L the last time the well was sampled in March 2008, prior to decommissioning to facilitate demolition activities. A concentration of 15,600 pCi/L was reported in a sample from well 199-K-222 collected in early 2017. Previous sampling at this well reported lower concentrations that were inconsistent with results during drilling. The revised sampling technique used in 2017 that focused on the upper aquifer produced a sample result consistent with sampling during drilling. The sample result is used for strontium-90 groundwater plume evaluation at the KE area.

Well 199-K-202, downgradient from the KE Reactor, helps delineate the strontium-90 plume. This well has not detected strontium-90 through April 2017, providing a bounding measurement for the strontium-90 plume. It appears the plume is slowly migrating from the FSB towards extraction well 199-K-141. This plume movement is consistent with the current interpretation of the groundwater gradient in this area, which is influenced by the P&T system and especially extraction well 199-K-141. About 120 m (390 ft) directly downgradient from well 199-K-109A, strontium-90 concentrations continued to increase in extraction well 199-K-141 to a 75 pCi/L maximum in mid-2016 (Figure 4-50).

Groundwater sample data during drilling at wells 199-K-221 and 199-K-222, at the 116-KE-3 and UPR-100-K-1 waste sites, exhibited strontium-90 in groundwater. Samples collected from these wells during 2016 exhibited maximum strontium-90 concentrations of 8.69 pCi/L at well 199-K-221 and 38.2 pCi/L at well 199-K-222. Concentrations about two orders of magnitude greater were observed at well 199-K-222, located in the former KE FSB footprint, during drilling in 2015. Strontium-90 inventory is in the vadose zone, as discussed in Section 4.2.2.3. The concentration in 2016 was attributed to the sampling technique that collected groundwater from the middle and lower portion of the aquifer. The sample collection method was revised to obtain water from the upper portion of the aquifer, near the water table, where the highest concentration was measured during drilling (4,000 pCi/L). The concentration from a sample in early 2017 at well 199-K-222 was 15,600 pCi/L. The elevated concentration indicates strontium-90 source material remains in the vadose zone.

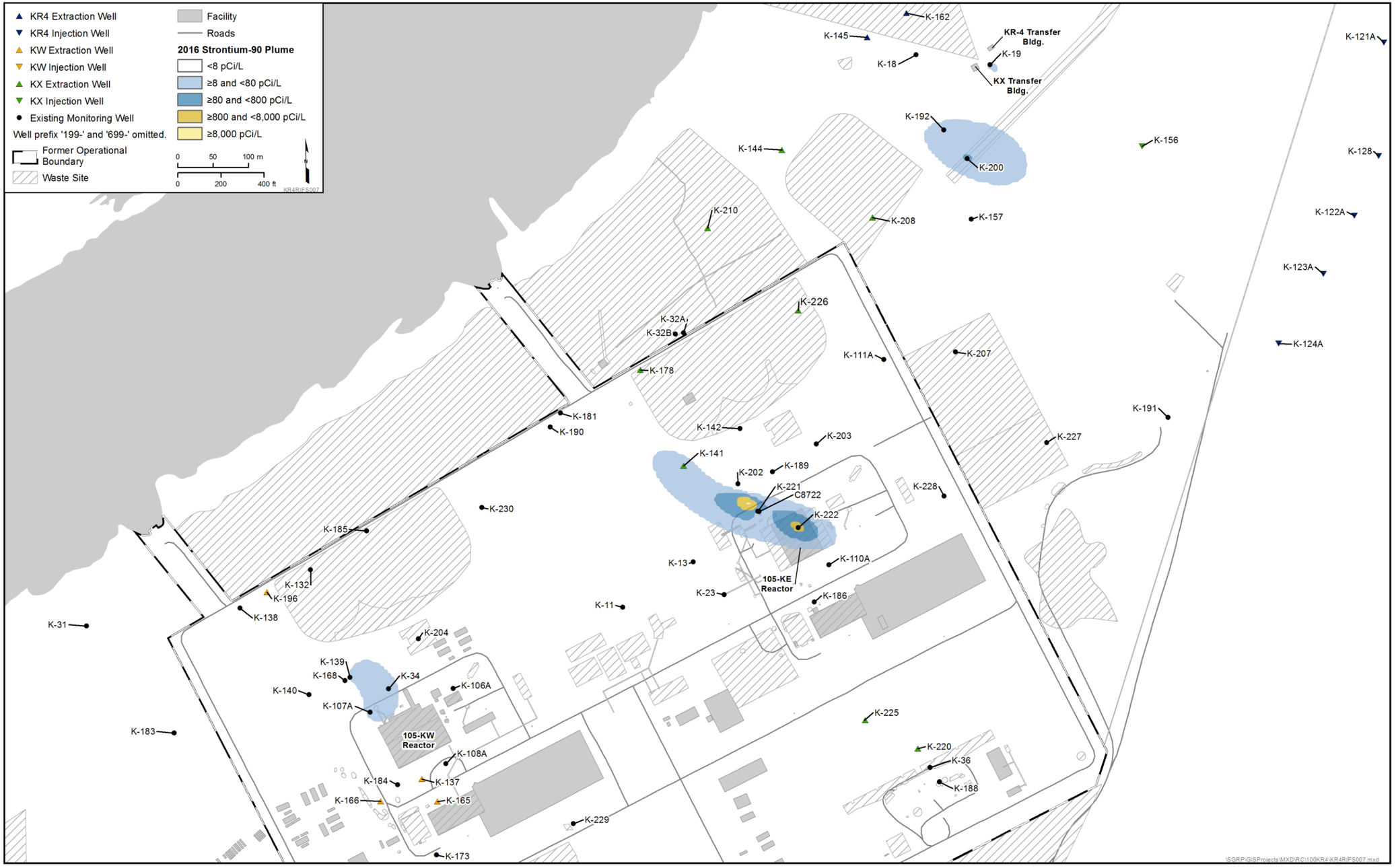

Figure 4-50. 100-KR-4 OU Strontium-90 Plumes in 2016

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At the 116-K-1 Crib and 116-K-2 Trench plume area, many of the wells monitoring the 116-K-2 Trench have detectable strontium-90, but most concentrations are less than the 8 pCi/L DWS. The highest concentration during 2016 was 164 pCi/L at well 199-K-200, which was drilled near the trench southwest end. Concentrations in other wells near 116-K-2 Trench were consistently less than 20 pCi/L. Downgradient wells 199-K-19, 199-K-20, 199-K-21, and 199-K-161 each had at least one result exceeding the DWS during 2016, showing the apparent downgradient strontium-90 migration toward the river.

Aquifer tubes downgradient of the 116-K-2 Trench historically had strontium-90 detections. Aquifer tube 22-M exhibited a 6.48 pCi/L maximum strontium-90 concentration in 2016, similar to the 6.36 pCi/L observed in 2015 and 7.16 pCi/L in 2014. This result indicates potential strontium-90 downgradient migration toward the river from the northeast end of the trench, consistent with historical plume behavior. Recent concentration trends indicate the plume concentrations in this area are decreasing through radioactive decay while groundwater flow oscillates back and forth from fluctuations in river stage and groundwater flow direction.

4.4.8 Trichloroethene

The trichloroethene sources at 100-K are likely related to using solvents during equipment maintenance activities, but specific trichloroethene release points have not been identified. The trichloroethene plume is poorly defined by the available measurements, as there are relatively few wells with concentrations near the 5 µg/L DWS, leading to uncertainty in interpolating the plumes extent. Trichloroethene is primarily within the K West plume area (Figure 4-51).

Similar to other contaminant plumes at the KW plume area, the trichloroethene plumes use the maximum concentration detected since the KW rebound study was initiated in May 2016. Several wells showed trichloroethene concentrations greater than the 5 µg/L DWS in at least one sample in 2016. The highest concentrations in samples collected in 2016 were from wells 199-K-11, 199-K-185, and 199-K-190 (6.0, 9.48, and 5.92 µg/L, respectively). These concentrations are lower than the historical maximum concentrations (e.g., 35 µg/L at well 199-K-106A in 1995).

Trichloroethene was detected in aquifer tubes 17-D and 17-M, downgradient of the K West plume area, at estimated concentrations around 1.0 µg/L in 2016. In addition, seep SK-063-1, downgradient of well 199-K-132, had trichloroethene at concentrations less than 1.0 µg/L during 2016. Detection of trichloroethene also occurred in aquifer tubes outside the K West plume area at aquifer tube cluster C6236, C6237, and C6238. This result is likely due to KW P&T operations and the injection of low concentration trichloroethene into upgradient injection wells. Similar concentrations are exhibited inland at monitoring wells 199-K-31 and 199-K-183.

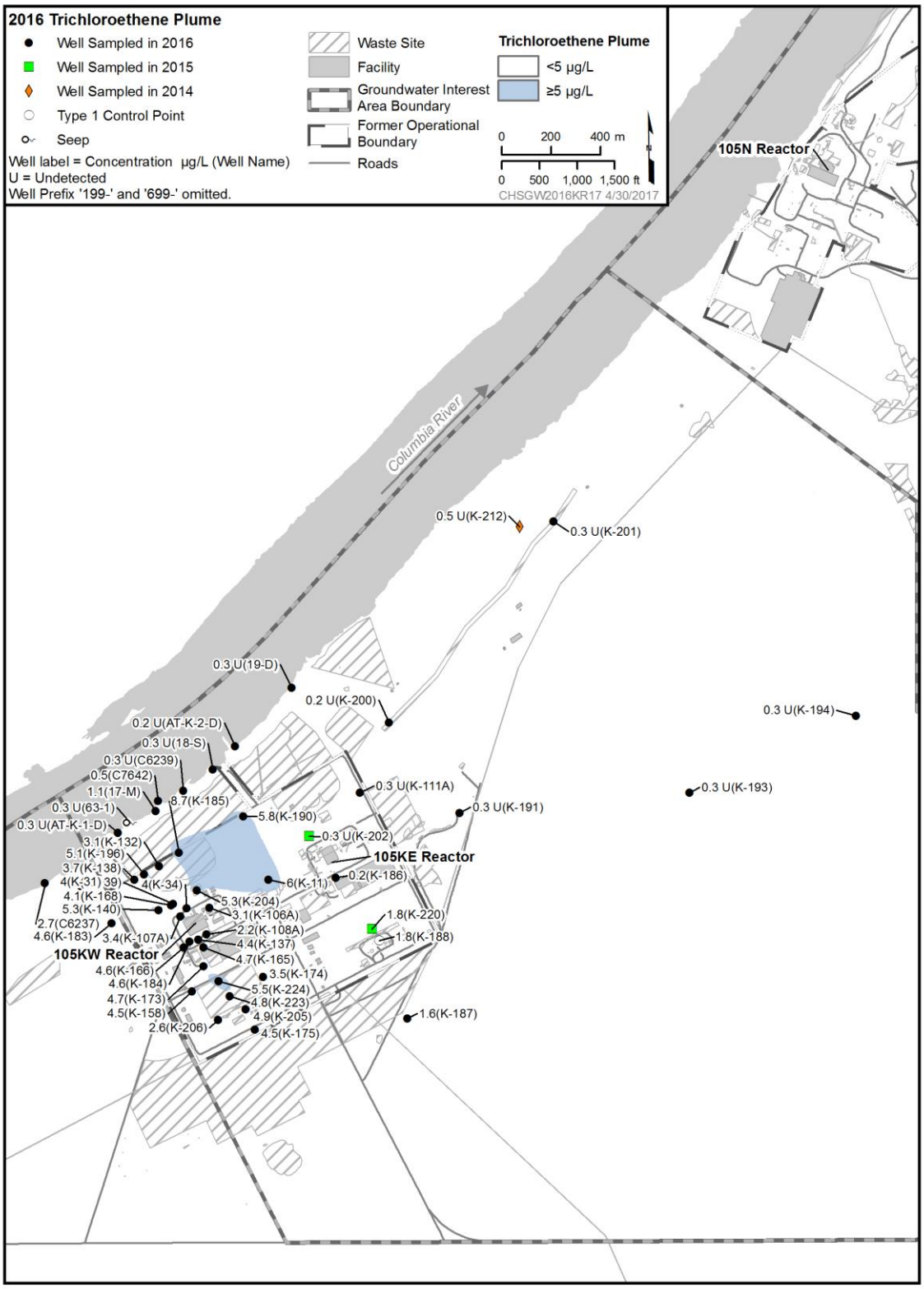

Figure 4-51. 100-KR-4 OU Trichloroethene Plume in 2016

4.4.9 Key Conclusions for Nature and Extent of Groundwater Contamination

Current Cr(VI) contamination in groundwater at 100-K consists of general plume areas based on geographic areas. Figures 4-30 and 4-31 show the main plume areas, identified as K West, K East, KN, K-N boundary, and 100-N. Nitrate, tritium, carbon-14, strontium-90, and trichloroethene plumes are in limited and smaller geographic areas.

High Cr(VI) concentrations remain near the 183.1KW Headhouse in the K West plume area. As a result of the KW P&T operations, concentrations decreased to <20 µg/L and the system was shut off for a rebound test. Rebound test results indicated a secondary Cr(VI) source in that area. The concentration magnitude and locations suggest it is likely that multiple areas of secondary source material are within the vadose zone and PRZ between the KW Reactor and the 183.1KW Headhouse.

The vertical distribution of Cr(VI) contamination and the analytical results between RI wells 199-K-184 and 199-K-195 and other active extraction wells located at the K West plume indicate Cr(VI) downward movement within the aquifer. The well data indicate vertical dispersion and migration through the unconfined aquifer, as the Cr(VI) locations become deeper within the aquifer with increased distance from the source area at the 183.1KW Headhouse. The KW P&T system may account for some dispersion, primarily related to water injection at wells 199-K-175, 199-K-206, and 199-K-158, which contribute the highest portion of injection water to the area.

The K East Cr(VI) plume extends from the 183.1KE Headhouse towards the river, and a second area near the 118-K-1 Burial Ground. The Cr(VI) concentrations exceed the groundwater remediation target near the 183.1KE Headhouse, but are decreasing as a result of ongoing remediation. As concentrations continue to decrease, the potential for a secondary source in the vadose zone will be evaluated. In the area downgradient from the 118-K-1 Burial Ground, elevated concentrations of Cr(VI) remain at well 199-K-111A. Contamination in this area appears to be co-mingled from the 183.1KE Headhouse, 116-K-1 Crib, and 116-K-2 Trench.

Large volumes of water were discharged to the 116-K-2 Trench during operations, creating an extensive groundwater mound and distributing Cr(VI) contamination along the trench and inland. The discharges resulted in the KN, K-N boundary, and 100-N plume areas. The KR-4 and KX P&T systems have been installed to address this Cr(VI) contamination. The arc of injection wells, from well 199-K-169 to 199-K-124A, creates a groundwater mound that modifies the groundwater gradient near the southwestern end of the 116-K-2 Trench. This mounding results in co-mingling of the Cr(VI) contamination from the 116-K-2 Trench southwestern end with the KE plume. The ongoing remediation activities have decreased concentrations along the length of the 116-K-2 Trench, and the plume has been segmented into smaller areas of residual contamination.

Concentrations in wells located on the southwestern end of the 116-K-2 Trench exhibit decreasing Cr(VI) trends, indicating that the plume core located there is shrinking. The persistence of elevated Cr(VI) along the river in this area near the 100-K-111 waste site is attributed to the lower hydraulic conductivity in the Ringold Formation unit E in that area, although secondary sources in the lower vadose zone may also produce this observation.

A narrow plume segment, discussed as the KN plume area, exhibits concentrations >10 µg/L and extends from the 116-K-2 Trench at well 199-K-37, inland to well 199-K-193 (Figure 4-30). The highest concentrations in this plume segment occur near the 116-K-2 Trench at well 199-K-37. Concentrations at 199-K-193 appeared to exhibit an increasing trend through 2016.

The K-N boundary plume is at the boundary with the 100-N Area, identified by Cr(VI) contamination near wells 199-K-182 and 199-N-189 (Figure 4-30). The migration of contaminated cooling water from

the 116-K-2 Trench is attributed to the effects of historical discharges, river stage fluctuations, and injection of groundwater by the KR-4 and KX treatment systems at the trench. The 100-N plume is farther to the north, within the 100-N Area. The majority of the Cr(VI) in this area is likely associated with the northern migration of Cr(VI) from 100-K sources.

Nitrate: Nitrate concentrations in 100-K show stable to decreasing trends in wells located in both the K West and K East plume areas. The sources of nitrate at 100-K appear related to the 116-KW-1 and 116-KE-1 gas condensate cribs. Nitrate concentration greater than the DWS are not observed in the 116-K-2 Trench area. Within the RUM, nitrate has been consistently detected at low concentrations.

Tritium: Tritium concentrations are highest at the 118-K-1 Burial Ground. These activity levels are related to the solid waste disposed of at the burial ground. Tritium remaining in deep vadose zone soil after remediation had concentrations up to 13,400 pCi/g and is a secondary source of contamination. The groundwater tritium concentration in June 2017 drilling well 199-K-227 near the burial ground was 3,810,000 pCi/L.

Smaller areas of elevated tritium concentrations remain near the KW and KE Reactors. During the K West rebound test, tritium concentrations increased while the system was off. Samples from monitoring wells 199-K-192 and 199-K-32B indicate tritium is not in the uppermost RUM aquifer, and tritium concentrations greater than the DWS have not been observed in 100-K aquifer tube samples.

Carbon-14: The carbon-14 plumes are near the KW and KE Reactors, downgradient from the 116-KW-1 and 116-KE-1 gas condensate cribs. The highest activities were in well 199-K-106A, located downgradient of the 116-KW-1 Gas Condensate Crib. Results of the KW rebound test indicate that 116-KW-1 is a continuing source.

Near the 116-KE-1 Gas Condensate Crib, concentrations are lower and the plume area is near well 199-K-189. Low levels of carbon-14 were detected in the 116-K-2 Trench area, but there were no recent detections greater than the DWS in this area. Carbon-14 has not been detected in the uppermost water bearing RUM unit within 100-K. Aquifer tubes downgradient of the KW and KE reactor areas have low concentrations of carbon-14. Carbon-14 was detected in RI aquifer tube C6247 at 326 pCi/L in October 2014, but levels have since decreased to less than the detection limits.

Strontium-90: A high-concentration strontium-90 plume near the KE Reactor is indicated by the analytical results from wells 199-K-109A (decommissioned in 2008), 199-K-141 (increasing activity levels), 199-K-221, and 199-K-222. This plume is associated with the 116-KE-3 Crib and reverse well and leaks from the KE Reactor FSB.

Lower activity strontium-90 plumes are also near the KW Reactor and the southwest end of the 116-K-2 Trench. All three of the strontium-90 plumes at 100-K are relatively small and are not inferred to extend to the Columbia River at concentrations greater than the DWS. Strontium-90 contamination has not been identified in the uppermost water bearing RUM unit.

Trichloroethene: Trichloroethene sources at 100-K are related to the solvent use during equipment maintenance activities, but specific trichloroethene release points have not been identified. The trichloroethene plume is poorly defined due to relatively few wells with concentrations near the 5 µg/L DWS. The maximum detected concentrations measured in RI wells are consistent with historical concentrations observed in samples collected near the KE and KW Reactors. The highest concentrations in samples collected in 2016 were from wells 199-K-11, 199-K-185, and 199-K-190 (6.0, 9.48, and 5.92 µg/L, respectively).

4.5 Evaluation of Potential Effects on the Columbia River Adjacent to 100-K

Appendix J presents an evaluation of contaminants in riparian and nearshore media and the Columbia River. This evaluation addresses the potential for Hanford Site contaminants in soil or groundwater from the 100-K reactor area to migrate to riparian or nearshore areas or to the Columbia River at concentrations that could be of concern to ecological receptors.

The Appendix J evaluation supplements the River Corridor-wide ecological risk analysis presented in the RCBRA (DOE/RL-2007-21) ERA. The ERA identifies, on a site-wide basis, some contaminants of ecological concern (COECs) in riparian and nearshore media (soil, sediment, and water) that could warrant further evaluation.

Appendix J also addresses COECs identified in the CRC ERA (DOE/RL-2010-117), specifically those identified for 100-K. The following text describes the results of the two risk assessments, including the types of data collected to complete the assessments.

Table 4-43 lists the combined COECs from the RCBRA and the CRC. The evaluation of the human health and the environment risk presented in the CRC (DOE/RL-2010-117, Volume II) addresses all the data collected throughout the Hanford Reach and downstream to McNary Dam, as directed in the Columbia River RI Work Plan (DOE/RL-2008-11). Chapters 6 and 7 summarize the Appendix J analysis, including results regarding which, if any, of the following COECs could be attributed to sources within 100-K.

Table 4-43. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC

COEC	Receptors	Media
Arsenic [b]	Terrestrial Plants	Riparian Soil
Cadmium [b]	Aquatic Plants and Invertebrates	Sediment
Chromium [a,b]	Aquatic Plants and Invertebrates and the Bufflehead	Sediment
Chromium [b]	Terrestrial Plants and Invertebrates	Riparian Soil
Cr(VI) [a,b]	Aquatic Plants and Invertebrates	Sediment
Cr(VI) [a,b]	Fish Aquatic Invertebrates Aquatic Plants Amphibians	Pore water
Lead [b]	Terrestrial Plants	Riparian Soil
Manganese [b]	Aquatic Plants and Invertebrates	Sediment
Manganese [a,b]	Fish Aquatic Invertebrates Aquatic Plants Amphibians	Pore water
Mercury [b]	Terrestrial Invertebrates	Riparian Soil
TPH–Diesel [b]	Terrestrial Invertebrates	Riparian Soil
Uranium [b]	Aquatic Plants and Invertebrates	Pore water

Table 4-43. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC

COEC	Receptors	Media
Zinc [b]	Terrestrial Plants and Invertebrates and Kingbirds	Riparian Soil

References: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment.*

DOE/RL-2010-117, *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment, and Volume II: Baseline Human Health Risk Assessment.*

a. COECs presented in the CRC (DOE/RL-2010-117).

b. COECs presented in Sections 8.4 and 8.5 of the RCBRA (DOE/RL-2007-21).

COEC = contaminant of ecological concern

CRC = Columbia River Component

RCRBA = River Corridor Baseline Risk Assessment

4.5.1 Summary of Results and Conclusions of RCBRA and CRC

The RCBRA (DOE/RL-2007-21) evaluated ecological risks at 48 nearshore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia River and in areas between the plumes. Twenty-two COPECs were identified for the nearshore environment, and 16 of these (all inorganics) were further identified as COECs. The RCBRA concluded that across the Hanford Reach of the Columbia River (i.e., corridor-wide), five COPECs are COECs (cadmium, chromium, Cr(VI), manganese, and uranium) in the nearshore environment that may present an unacceptable level of risk for one or more assessment endpoint entities (aquatic plants, aquatic invertebrates, amphibians, fish, and wildlife). These results are based primarily on the comparisons of COPEC concentrations to toxicity benchmarks, measures of exposure and effects in biota, or wildlife exposure analyses results.

The RCBRA also evaluated ecological risks at 18 representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (i.e., groundwater seeps, soil, and sediment). As with the nearshore environment, 22 COPECs were identified for the riparian environment. The RCBRA identified arsenic, chromium, copper, lead, mercury, selenium, TPH-diesel, vanadium, and zinc as possibly presenting some risk level for one or more assessment endpoint entities (terrestrial plants, invertebrates, and wildlife). This was based on soil bioassays, COPEC concentrations comparison to plant or terrestrial invertebrate benchmarks, or wildlife exposure analyses results. Conclusions in the RCBRA were that on a River Corridor-wide basis, only six of these COPECs should be considered further (arsenic, chromium, lead, mercury, TPH-diesel, and zinc). Section 7.7 discusses these RCBRA-specified-COECs with respect to ecological risk within 100-K.

The CRC (DOE/RL-2010-117) included an ecological risk assessment that combined both screening and baseline elements. Abiotic media were compared to surface water, sediment, and pore water screening benchmarks to identify COPECs. Soil concentrations were compared to plant and invertebrate benchmarks while desktop food web models were used to evaluate risks to wildlife. A baseline assessment was conducted to assess risk to fish using tissue residue data. The CRC concluded that there were nine COECs (aluminum, chromium, Cr(VI), lead, manganese, nickel, nitrate, selenium, and uranium) within pore water, surface water, and sediment near the 100 and 300 areas. The evaluation included distinct conclusions for the reach adjacent to the 100 Area versus those for the reach adjacent to the 100-K source OUs. Discussion of these COECs with respect specifically to ecological risk within 100-K is provided in Section 7.7.

4.5.2 Columbia River Surface Water, Pore Water, and Sediment Investigation

A process was established in 2004 to compile, classify, and manage environmental data (e.g., surface water and sediment) associated with the Columbia River. A CRC database was created through these efforts and documented in WCH-64, *Existing Source Information Summary Report Compilation/Evaluation Effort, December 2004 to September 2005: Columbia River Component of the River Corridor Baseline Risk Assessment*. The subsequent WCH-91, *Columbia River Component Data Evaluation Summary Report*, described the activities to evaluate the data collected in the compilation effort and assist in defining the extent of Hanford Site-related contamination. The compiled data were used to identify potential data gaps in the existing data set spatial, temporal, and chemical composition and formed the sampling plan foundation documented in the Columbia River RI Work Plan (DOE/RL-2008-11).

The scope of the Columbia River RI Work Plan included the following fieldwork component, which has generated data necessary to fill data gaps in the understanding of current conditions in the Columbia River. The data from the field activities were evaluated in both ecological and human health risk assessments reported in the CRC (DOE/RL-2010-117). During that time, sampling was underway supporting DOE/RL-2004-37. Samples of surface water, groundwater, nearshore sediment, soil, and biota were collected and analyzed to support the RCBRA data evaluation (DOE/RL-2007-21), also summarized in Section 7.7 and Appendix J.

Sampling to fulfill the needs defined in the Columbia River RI Work Plan (DOE/RL-2008-11) was initiated in October 2008 and was completed in June 2010. Media sampled included surface water, pore water, sediment (shoreline, shallow, cores), island soils, and six fish species. The RI field activities associated with the collection of sediment, river water, and island soil in the Columbia River adjacent to and downstream of the Hanford Site and in nearby tributaries are documented in the Field Summary Report for Columbia River RI (WCH-352). The Field Summary Report for Columbia River RI (WCH-352) describes the sampling locations, identifies samples collected, and describes modifications and additions made to the SAP that was provided as Appendix A to the Columbia River RI Work Plan (DOE/RL-2008-11). Groundwater upwelling field activities and data collection are documented in the Columbia River RI Report (WCH-380).

Groundwater Upwelling Investigation at 100-K. Groundwater beneath the Hanford Site discharges to the Columbia River via seeps and upwelling to the riverbed. This groundwater flow path transports Hanford Site-associated contaminants that entered the groundwater from past waste disposal practices to the Columbia River. The nearshore groundwater conditions are affected by river stage. The greatest contaminant flux and highest concentrations at exposure locations occur during periods of low river stage, when the hydraulic gradient toward the river is greatest, and mixing between river water and groundwater is minimal.

Sediment samples were analyzed for a range of radiological and nonradiological analytes including metals, pesticides, SVOCs, VOCs, PCBs, and other chemicals. Sediment samples were obtained as close to the pore water sample locations as possible, with a preference given to locations with fine sediment deposits. Sample volume was limited in some locations because of riverbed cobbles. In locations with limited volume, not all analyses were performed. Additional sediment, island soil, and surface water samples were collected in areas identified in WCH-201 and the Columbia River RI Work Plan (DOE/RL-2008-11).

Data were collected near 100-K to address uncertainty related to contamination entering the Columbia River via upwelling, including the contaminant transport mechanisms. Pore water, surface water, and sediment sampling was conducted in 2009 and 2010 per the Columbia River RI Work Plan (DOE/RL-2008-11).

Specific conductance or conductivity pore water measurements were used as a groundwater indicator because surface water conductivity in the Columbia River is typically lower (130 to 145 µS/cm) than groundwater (400 to 600 µS/cm). Pore water temperature can be also used as a groundwater indicator by comparison to surface water temperature. Near the Hanford Site, surface water temperatures typically range from approximately 0.5ºC (33ºF) in the winter months to more than 27ºC (80ºF) during the late summer months, whereas groundwater typically stays between 7ºC (45ºF) and 15ºC (60ºF) (WCH-380).

Contaminant influence on water quality above groundwater upwelling locations was determined by surface water column sampling. River water was collected at approximately 0.3 m (12 in.) above the riverbed during pore water sampling. Table 2-6 summarizes surface water sample analyses.

Phase II(a) and Phase II(b) Sampling. Pore water sampling for the Phase II(a) groundwater upwelling investigation of the Columbia River RI Work Plan (DOE/RL-2008-11) scope helped to delineate areas of groundwater upwelling into the river bottom. Conductivity and temperature pore water measurements were used to guide selection of Phase II(b) stations for indicator contaminants sampling. Cr(VI) was the indicator contaminant at 100-K. WCH-380 presents further investigation discussion. Additional analytical results from these areas are in the Hanford Site Releases Data Summary (WCH-398).

Pore water conductivity measured near 100-K during Phase II(b) were generally higher than measured at these sites during Phase II(a). Although some pore water conductivity variation was apparent throughout 100-K, groundwater was detected at all 32 pore water sample locations. Both the 181-KE and 181-KW river pump stations showed consistent elevated conductivity compared to other stations. In general, the pore water conductivity decreased as distance from the shoreline increased.

Twelve of 32 pore water sample locations reported Cr(VI) concentrations greater than the PQL of 3.7 µg/L near 100-K. Nine of the 12 results were ≥10 µg/L, with concentrations ranging from 10 to 44 µg/L. Three of these nine samples were collected nearshore and six were collected offshore. The highest Phase IIb Cr(VI) result (44 µg/L) was collected from the furthest offshore location, at a depth of approximately 6.4 m (21 ft) below the low water mark.

Phase III Sampling. Phase III sample locations were selected as a subset of the previous pore water, surface water (defined as water 0.3 m [1 ft] above the riverbed), and collocated sediment locations, and analyzed per the Columbia River RI Work Plan (DOE/RL-2008-11). These results and other analyses are in the Hanford Site Releases Data Summary (WCH-398).

Six sample locations were selected for Phase III sampling near 100-K, and five included sediment. Pore water conductivity ranged from 164 to 483 µS/cm, and surface water conductivity ranged from 140 to 158 µS/cm. The maximum pore water conductivity (483 µS/cm) during Phase III was downstream of 100-K at location J100K24 (Figure 2-4). This site reported 36 µg/L of Cr(VI) during Phase II(b), with a pore water conductivity of 350 µS/cm.

Cr(VI), total uranium, and strontium-90 were not detected in Phase III surface water samples. Cr(VI) concentrations in pore water samples ranged from 18 to 56 µg/L. At locations T100K3A and T100K24 (Figure 2-4), Cr(VI) concentrations were 56 and 55 µg/L, respectively, an increase from Phase II(b) concentrations of 17 and 36 µg/L, respectively. At the four other locations, the Cr(VI) concentrations during Phase III were less than Phase II(b). Tritium was also detected in pore water at concentrations from 658 to 6,500 pCi/L, with the maximum at location T100K3A. Total uranium and strontium-90 were not detected in pore water in 100-K during the Phase III sampling event.

4.5.3 Additional RI Sampling Near 100-K

In addition to the groundwater upwelling investigation sampling, sediment, surface water, and island soil samples were collected to investigate the nature and extent of potential Hanford Site contaminant releases and support subsequent risk assessments.

Shallow sediment cores were collected near the 181-KE and 181-KW river pump stations, five sediment samples were collected from the shoreline across the river, and a surface water sample was collected upstream and on the opposite side of the river from 181-KW near 100-K. Sample results are presented in the Hanford Site Releases Data Summary (WCH-398).

4.5.4 Risk Conclusions for Columbia River Relative to 100-K

Volume I of the CRC (DOE/RL-2010-117) presented a final list of the COPEC ecological risk for nitrate, nitrite, TPH-diesel, TPH-motor oil, chromium, Cr(VI), lead, and selenium, and Volume II presented a table of COPCs for human health.

COPECs presented in the CRC (DOE/RL-2010-117) were further broken down by media and subarea (100 Area, 300 Area, and Lake Wallula). The list of COPECs was reduced to just chromium and Cr(VI) in sediment at 100-K. The CRC only presents final conclusions by subarea, and analysis of the CRC indicate the other six COPECs are not above medium-specific ecotoxicological thresholds within the abiotic media collected in 100-K. Sediment total chromium concentrations in 100-K were less than ecotoxicological thresholds, and there is no Cr(VI) threshold. The only potential link from 100-K to potential risks observed in the Columbia River is from elevated groundwater Cr(VI) concentrations that may contribute to Cr(VI) in sediment.

4.6 Biota

This section summarizes ecological sampling and biological monitoring data collected for 100-K. Biota data are useful to understand biological receptors, which are evaluated in Chapter 7.

Biota data from two main environmental sampling projects conducted at Hanford were reviewed and summarized for this section. The Surface Environmental Surveillance Program (SESP) is a multimedia environmental surveillance project. The primary goals of SESP are to measure radionuclides and chemicals concentrations in environmental media to demonstrate compliance with applicable environmental quality standards and public exposure limits, and to assess environmental effects. Annual ambient air, surface water, agricultural products, fish, wildlife, and sediment sampling is performed. Soil and vegetation samples are collected about every 5 years. SESP measures concentrations of radionuclides and nonradiological constituents including, metals, anions, VOCs, and total organic carbon (TOC). The SESP sampling design is in DOE/RL-91-50.

Fish tissue has been a part of monitoring at the Hanford Site for many years, producing a variety of species and fish tissue data. Within the historical fish tissue data set, there is inconsistency in species evaluated, tissue type (whole body, fillet, skin on, skin off, etc.), and analytes. Multiple collection and analysis approaches, as well as variability in species lifespans, have introduced result variability. The Columbia River RI fish sampling program was created to support the CRC HHRA (DOE/RL-2010-117), and provided a consistent sampling and analysis approach among species, tissue types, and analytes. Only fish tissue data from 2009 to 2010 were used in the CRC. The 2009 to 2010 program focused on target fish species intended to be representative of the HHRA exposure scenarios including:

- Common carp (Cyprinus carpio)
- Mountain whitefish (Prosopium williamsoni)

- Walleye (Stizostedion vitreum)
- Smallmouth bass (Micropterus dolomieui)
- Bridgelip sucker (Catostomus columbianus)
- White sturgeon (Acipenser transmontanus)

These fish species are year-round resident fish that represent a range of trophic levels and have higher local population harvest and consumption rates. Salmon were not sampled as part of this study because they spend a majority of their lifecycle in the ocean as opposed to near the Hanford Site.

For all species except sturgeon, fish tissue samples were composite samples of tissue from approximately five fish. Generally, five samples of each fish species were collected from each area, and each sample included separate fillet, carcass (which included the head and skeleton of the fish), and combined liver and kidney tissue for analysis. For carp, sufficient tissue mass was available to obtain separate liver and kidney samples. Fillet samples for all of these species except sturgeon were prepared with the skin on, since skin for these types of fish is often left on during preparation and consumed. Sturgeon samples were not composited and represent tissue from individual fish. Sturgeon fillet samples were collected with the skin off, and separate liver and kidney samples were prepared.

Biota data are also summarized from ecological samples collected to support the RCBRA (DOE/RL-2007-21) ERA. The primary goal of the RCBRA was to evaluate current and potential future risks to the environment posed by releases of hazardous substances along the Columbia River. The RCBRA evaluates contaminant sources, exposure pathways, and concentrations for several environmental media and receptors including surface soil, vegetation, soil invertebrates, small mammals, and birds. RCBRA analyses included the measurement of radionuclides, metals, anions, SVOCs, herbicides, pesticides, and physical properties (pH, moisture, particle size) in selected media. Most RCBRA samples were collected in 2006 and 2007. Sampling and analysis are documented in the RCBRA SAP (DOE/RL-2005-42).

SESP and RCBRA (DOE/RL-2007-21) biota samples locations are shown in Figure 4-52. The terrestrial plant and animal species collected and the tissues analyzed are as follows:

- Perennial vegetation: stems and leaves (combined):
  - Dominant shrub: current year's growth
  - Dominant grass: current year's growth
  - Balsamroot: leaves, roots
- Terrestrial invertebrate: whole body composites
- Mouse: whole body composites; kidney and liver (combined)
- Mule deer: antler
- Bird: Western Kingbird organs, crop

Table 4-44 summarizes the plant tissue samples collected within 100-K for the SESP and RCBRA (DOE/RL-2007-21) projects. RCBRA samples were analyzed for radioactive and nonradioactive constituents. The SESP samples were analyzed for radionuclides and total uranium only. Table 4-44 summarizes plant tissue samples collected from several RCBRA reference areas (unimpacted areas). The reference samples were analyzed for the same suites of analytes. The plant tissue sample results near 100-K were within the range of reference area sample results.

Table 4-45 summarizes RCBRA (DOE/RL-2007-21) invertebrate tissue sampling in the 100-K Area. The samples were analyzed for metals and radionuclides only. Because of insufficient sample volumes,

organic constituents were not analyzed. The table also shows a summary of invertebrate tissue samples collected from several RCBRA reference areas. The reference samples were analyzed for the same suites of analytes. The inorganic analytes' invertebrate tissue sample results from the 100-K study sites were within the range of reference sample results except for aluminum, arsenic, total uranium, lead, nickel, silicon, and zinc, which showed higher concentrations. The invertebrate tissue sample results for radionuclides were within the range of reference sample results except for technetium-99 and uranium-233/234, which showed higher concentrations.

Table 4-46 summarizes the RCBRA (DOE/RL-2007-21) mouse tissue sampling within 100-K. The samples were analyzed for radioactive and nonradioactive constituents. The table also shows a summary of mouse tissue sampling for RCBRA reference areas. The reference samples were analyzed for the same suites of analytes. The mouse tissue inorganic analyte sample results were within the range of the reference area results except for boron, sodium, and tin, which showed higher concentrations. The mouse tissue sample radionuclide results were within the range of reference sample results except for potassium-40 and radium-228, which showed higher concentrations.

Table 4-47 summarizes two mule deer antler samples collected for the SESP. The samples were analyzed for strontium-90 only. No anomalies were observed for strontium-90. There are no comparable reference samples for the mule deer antler samples.

Table 4-48 summarizes the Western Kingbird organ and crop tissue samples collected within 100-K for the RCBRA (DOE/RL-2007-21) project. The samples were analyzed for metals and radionuclides only. Due to insufficient sample volumes, organic constituents were not analyzed. Table 4-48 also shows a summary of bird tissue samples collected from several reference areas (unimpacted areas) as a part of the RCBRA project. The reference samples were analyzed for the same suite of analytes as the RCBRA study site samples. For the inorganic analytes, the bird tissue sample results from the 100-K study sites are within the range of the results for the reference area samples with the exception of boron, phosphorus, and zinc, which show slightly higher concentrations. For the radionuclides, the invertebrate tissue sample results from the 100-K study sites are within the range of the results for the reference area samples with the exception of potassium-40, which shows slightly higher concentrations.

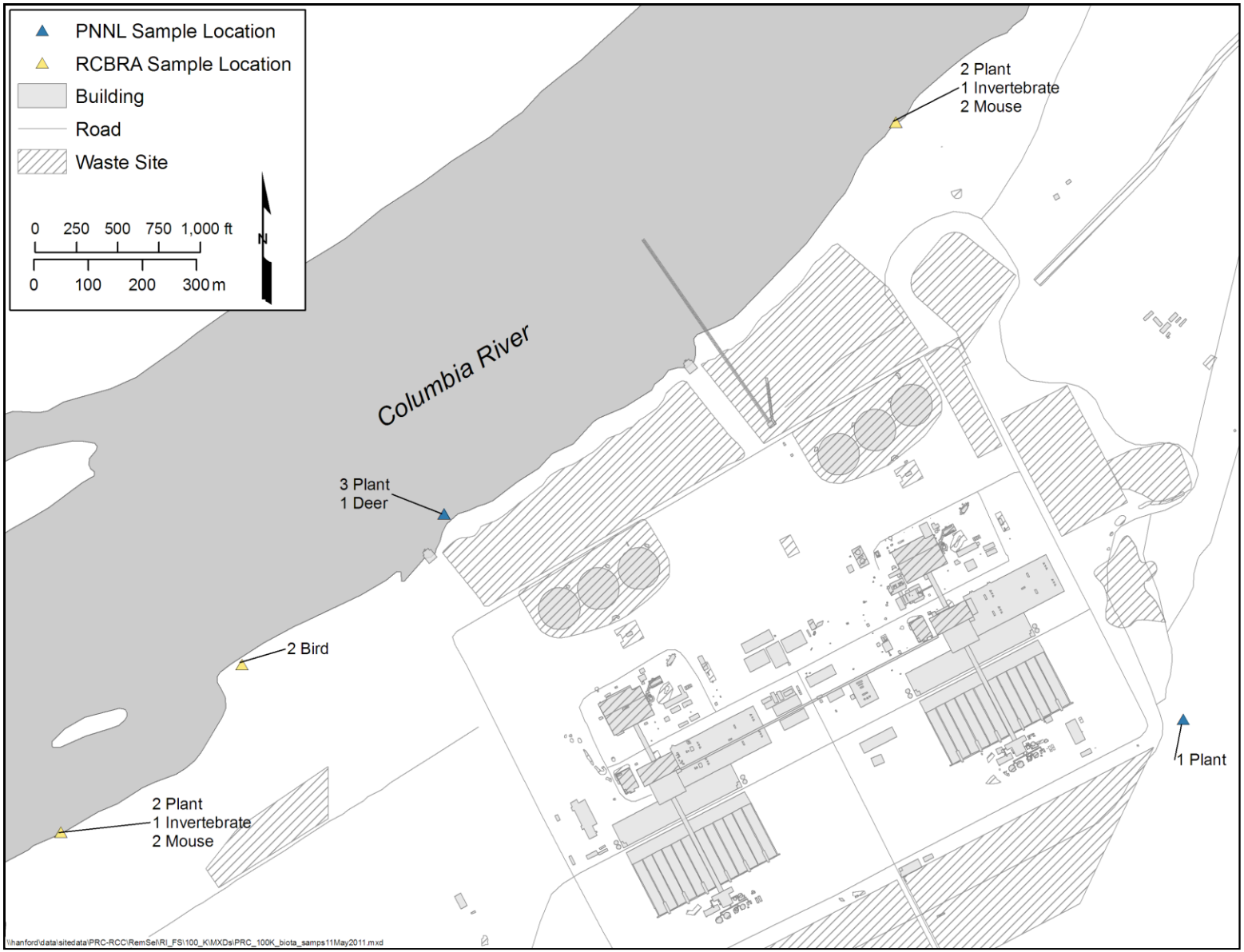

Figure 4-52. Terrestrial Upland Biota Sampling Locations at the 100-K Area

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Inorganics (mg/kg)													
Aluminum	RCBRA	--	--	--	4	3.7	168	4	3.7	168	36	1.7	470
Antimony	RCBRA	3	0.21	0.43	1	0.29	0.29	4	0.21	0.43	36	0.3	2.7
Arsenic	RCBRA	4	0.39	0.6	--	--	--	4	0.39	0.6	36	0.39	3.7
Barium	RCBRA	--	--	--	4	3.5	7.3	4	3.5	7.3	36	1.3	38.5
Beryllium	RCBRA	3	0.01	0.02	1	0.02	0.02	4	0.01	0.02	36	0.01	0.12
Bismuth	RCBRA	4	0.38	0.5	--	--	--	4	0.38	0.5	36	0.31	3.1
Boron	RCBRA	--	--	--	4	0.49	5.9	4	0.49	5.9	36	0.36	52
Cadmium	RCBRA	4	0.05	0.07	--	--	--	4	0.05	0.07	36	0.03	0.43
Calcium	RCBRA	--	--	--	4	722	3220	4	722	3220	36	235	33,200
Calculated total uranium	SESP	2	0.0014	0.0033	1	0.0029	0.0029	3	0.0014	0.0033	--	--	--
	RCBRA	4	0.000005	0.0125	--	--	--	4	0.000005	0.0125	36	-0.0190	0.155
Chromium	RCBRA	2	0.17	0.37	2	0.3	0.63	4	0.17	0.63	36	0.14	3.5
Cobalt	RCBRA	3	0.08	0.14	1	0.18	0.18	4	0.08	0.18	36	0.09	0.86
Copper	RCBRA	--	--	--	4	1.6	2.5	4	1.6	2.5	36	1.2	13.3
Iron	RCBRA	2	18.3	33.4	2	189	342	4	18.3	342	36	16.8	850
Lead	RCBRA	2	0.32	0.33	2	0.37	0.49	4	0.32	0.49	36	0.27	1.9
Lithium	RCBRA	2	0.03	0.06	2	0.1	0.21	4	0.03	0.21	36	0.03	0.96

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Magnesium	RCBRA	--	--	--	4	386	793	4	386	793	36	164	4,740
Manganese	RCBRA	--	--	--	4	3.8	17.5	4	3.8	17.5	36	2.3	87.5
Mercury	RCBRA	4	0.01	0.02	--	--	--	4	0.01	0.02	36	0.01	0.08
Molybdenum	RCBRA	2	0.15	0.28	2	0.23	0.57	4	0.15	0.57	36	0.13	1.8
Nickel	RCBRA	--	--	--	4	0.26	1.9	4	0.26	1.9	36	0.18	2.3
Nitrogen in nitrite and nitrate	RCBRA	--	--	--	2	8.2	97.6	2	8.2	97.6	--	--	--
Phosphorus	RCBRA	--	--	--	4	334	1120	4	334	1120	36	335	3,140
Potassium	RCBRA	--	--	--	4	3,840	6,490	4	3,840	6,490	36	3,800	22,300
Selenium	RCBRA	4	0.41	0.46	--	--	--	4	0.41	0.46	36	0.36	2.9
Silicon	RCBRA	--	--	--	4	63	277	4	63	277	36	47.3	726
Silver	RCBRA	4	0.07	0.09	--	--	--	4	0.07	0.09	36	0.07	1.1
Sodium	RCBRA	2	12	12.2	2	16.8	40.9	4	12	40.9	36	7.8	71.2
Strontium (elemental)	RCBRA	--	--	--	4	2.8	10.8	4	2.8	10.8	36	1.1	134
Thallium	RCBRA	4	0.68	0.79	--	--	--	4	0.68	0.79	36	0.54	4.3
Tin	RCBRA	4	1	2.5	--	--	--	4	1	2.5	36	1	6.6
Titanium	RCBRA	--	--	--	2	8.6	13.3	2	8.6	13.3	30	0.58	32.9
Uranium (inorganic)	RCBRA	4	0.85	1.4	--	--	--	4	0.85	1.4	36	0.82	5.4
Vanadium	RCBRA	2	0.08	0.08	2	0.28	0.55	4	0.08	0.55	36	0.08	1.7

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Zinc	RCBRA	--	--	--	4	8.8	11.5	4	8.8	11.5	36	4.4	43.8
Zirconium	RCBRA	2	1	1	--	--	--	2	1	1	30	0.99	6.5
Organics (mg/kg)													
1,2,4-Trichlorobenzene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
1,2-Dichlorobenzene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
1,3-Dichlorobenzene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
1,4-Dichlorobenzene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2,4,5-Trichlorophenol	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
2,4,6-Trichlorophenol	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2,4-Dichlorophenol	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2,4-Dimethylphenol	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2,4-Dinitrophenol	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
2,4-Dinitrotoluene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2,6-Dinitrotoluene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2-Chloronaphthalene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2-Chlorophenol	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2-Methylnaphthalene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
2-Methylphenol [cresol, o-]	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
2-Nitroaniline	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
2-Nitrophenol	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
3,3*-Dichlorobenzidine	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
3+4 Methylphenol [cresol, m+p]	RCBRA	3	8	16	1	0.43	0.43	4	0.43	16	35	3.4	52
3-Nitroaniline	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
4,6-Dinitro-2-methylphenol	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
4-Bromophenylphenyl ether	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
4-Chloro-3-methylphenol	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
4-Chloroaniline	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
4-Chlorophenylphenyl ether	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
4-Nitroaniline	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
4-Nitrophenol	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
Acenaphthene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Acenaphthylene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Aldrin	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
Alpha-BHC	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
alpha-Chlordane	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
Anthracene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Aroclor 1016	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Aroclor 1221	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Aroclor 1232	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Aroclor 1242	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Aroclor 1248	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Aroclor 1254	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Aroclor 1260	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.08	1.9
Benzo[a]anthracene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Benzo[a]pyrene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Benzo[b]fluoranthene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Benzo[ghi]perylene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Benzo[k]fluoranthene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
beta-1,2,3,4,5,6-Hexachloro-cyclohexane	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.01	0.24
Bis[2-chloro-1-methylethyl]ether	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Bis[2-Chloroethoxy]methane	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Bis[2-chloroethyl] ether	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Bis[2-ethylhexyl] phthalate	RCBRA	3	8	16	1	0.27	0.27	4	0.27	16	36	0.36	52
Butylbenzylphthalate	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Carbazole	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Chrysene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Delta-BHC	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.008	0.24
Dibenz[a,h]anthracene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Dibenzofuran	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Dichlorodiphenyl-dichloroethane	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.01	0.24
Dichlorodiphenyl-dichloroethylene	RCBRA	3	0.008	0.02	1	0.073	0.073	4	0.008	0.073	36	0.0061	0.34
Dichlorodiphenyl-trichloroethane	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.0091	0.24
Dieldrin	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.012	0.24
Diethylphthalate	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Dimethyl phthalate	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Di-n-butylphthalate	RCBRA	4	2	16	--	--	--	4	2	16	36	0.33	52
Di-n-octylphthalate	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Endosulfan I	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.0042	0.24
Endosulfan II	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
Endosulfan sulfate	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
Endrin	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
Endrin aldehyde	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Endrin ketone	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.013	0.24
Fluoranthene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Fluorene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Gamma-BHC (lindane)	RCBRA	3	0.008	0.02	1	0.013	0.013	4	0.008	0.02	36	0.0051	0.24
gamma-Chlordane	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.017	0.24
Heptachlor	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.0067	0.24
Heptachlor epoxide	RCBRA	3	0.008	0.02	1	0.0085	0.0085	4	0.008	0.02	36	0.0042	0.24
Hexachlorobenzene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Hexachlorobutadiene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Hexachlorocyclopentadiene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Hexachloroethane	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Indeno[1,2,3-cd]pyrene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Isophorone	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Methoxychlor	RCBRA	4	0.008	0.02	--	--	--	4	0.008	0.02	36	0.0055	0.24
Naphthalene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Nitrobenzene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
N-Nitrosodi-n-propylamine	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
N-Nitrosodiphenylamine	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Pentachlorophenol	RCBRA	4	5	40	--	--	--	4	5	40	35	8.6	130
Phenanthrene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Phenol	RCBRA	4	2	16	--	--	--	4	2	16	35	0.65	52
Pyrene	RCBRA	4	2	16	--	--	--	4	2	16	35	3.4	52
Toxaphene	RCBRA	4	0.08	0.2	--	--	--	4	0.08	0.2	36	0.024	2.4
Radionuclides (pCi/g)													
Americium-241	RCBRA	4	0.081	0.75	--	--	--	4	0.081	0.75	36	0.02	1.6
Antimony-125	SESP	5	-0.0071	0.0020	--	--	--	5	-0.0071	0.0020	--	--	--
	RCBRA	4	0.19	0.32	--	--	--	4	0.19	0.32	36	0.046	0.5
Beryllium-7	SESP	--	--	--	5	0.254	1.1	5	0.254	1.1	--	--	--
	RCBRA	3	-0.3	1.7	1	3.11	3.11	4	-0.3	3.11	36	0	3.2
Carbon-14	RCBRA	4	-0.3	3.11	--	--	--	4	-0.3	3.11	2	0.167	2.67
Cesium-134	SESP	5	-0.0111	0.0008	--	--	--	5	-0.0111	0.0008	--	--	--
	RCBRA	4	0.13	0.175	--	--	--	4	0.13	0.175	36	0.025	0.24
Cesium-137	SESP	5	0.0005	0.0136	--	--	--	5	0.0005	0.0136	--	--	--
	RCBRA	4	0.11	0.143	--	--	--	4	0.11	0.143	36	0.02	0.22
Cobalt-60	SESP	5	-0.0108	0.0046	--	--	--	5	-0.0108	0.0046	--	--	--
	RCBRA	4	0.11	0.151	--	--	--	4	0.11	0.151	36	0.019	0.22

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Europium-152	SESP	1	0.0050	0.0050	--	--	--	1	0.0050	0.0050	--	--	--
	RCBRA	4	0.15	0.373	--	--	--	4	0.15	0.373	36	0.047	0.58
Europium-154	SESP	5	-0.0043	0.0451	--	--	--	5	-0.0043	0.0451	--	--	--
	RCBRA	4	0.36	0.463	--	--	--	4	0.36	0.463	36	0.063	0.69
Europium-155	SESP	5	-0.0070	0.015	--	--	--	5	-0.0070	0.015	--	--	--
	RCBRA	4	0.079	0.31	--	--	--	4	0.079	0.31	36	0.031	0.73
Plutonium-238	SESP	3	-0.000004	0.000007	--	--	--	3	-0.000004	0.000007	--	--	--
Plutonium-239/240	SESP	2	0.000013	0.000017	1	0.0002	0.0002	3	0.000013	0.0002	--	--	--
Potassium-40	SESP	--	--	--	5	2.42	12.9	5	2.42	12.9	--	--	--
	RCBRA	2	0	0.027	2	4.16	5.38	4	0	5.38	36	0	11
Radium-226	RCBRA	4	0.19	0.307	--	--	--	4	0.19	0.307	36	0.036	0.5
Radium-228	RCBRA	4	0.49	0.66	--	--	--	4	0.49	0.66	36	0.077	1
Ruthenium-106	SESP	5	-0.0353	0.01774	--	--	--	5	-0.0353	0.0177	--	--	--
	RCBRA	4	0.87	1.33	--	--	--	4	0.87	1.33	36	0.18	2
Strontium-90	SESP	3	0.0008	0.0015	2	0.0778	0.672	5	0.0008	0.6720	--	--	--
	RCBRA	4	-0.042	0.006	--	--	--	4	-0.042	0.006	36	-0.17	15.8
Technetium-99	RCBRA	2	0.108	0.182	--	--	--	2	0.108	0.182	--	--	--
Thorium-228	RCBRA	4	-0.059	0.054	--	--	--	4	-0.059	0.054	36	-0.146	0.17

Table 4-44. Plant Tissue Samples from 100-K Area Compared to RCBRA Reference Sample Results

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Thorium-230	RCBRA	3	0.006	0.108	1	0.322	0.322	4	0.006	0.322	36	-0.162	0.469
Thorium-232	RCBRA	4	-0.029	0.006	--	--	--	4	-0.029	0.006	36	-0.04	0.096
Tritium	RCBRA	2	-2.17	-0.995	--	--	--	2	-2.17	-0.995	--	--	--
Uranium-233/234	SESP	2	-0.0004	0.0011	1	0.0025	0.0025	3	-0.0004	0.0025	--	--	--
	RCBRA	4	-0.017	0.03	--	--	--	4	-0.017	0.03	36	-0.01	0.083
Uranium-235	SESP	2	0.0001	0.0003	1	0.0012	0.0012	3	0.0001	0.0012	--	--	--
	RCBRA	4	0	0.027	--	--	--	4	0	0.027	36	-0.008	0.025
Uranium-238	SESP	2	0.0004	0.0009	1	0.0010	0.0010	3	0.0004	0.0010	--	--	--
	RCBRA	4	0	0	--	--	--	4	0	0	36	-0.007	0.052

Source: RCBRA (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*).

-- = not applicable

Table 4-45. Invertebrate Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Inorganics (mg/kg)													
Aluminum	RCBRA	--	--	--	2	12.5	54.2	2	12.5	54.2	18	11.6	49.7
Antimony	RCBRA	2	0.22	0.42	--	--	--	2	0.22	0.42	18	0.21	0.66
Arsenic	RCBRA	1	0.59	0.59	1	1.7	1.7	2	0.59	1.7	18	0.57	1.3
Barium	RCBRA	--	--	--	2	0.59	2.1	2	0.59	2.1	18	0.59	3
Beryllium	RCBRA	2	0.01	0.02	--	--	--	2	0.01	0.02	18	0.01	0.03
Bismuth	RCBRA	2	0.4	0.49	--	--	--	2	0.4	0.49	18	0.38	0.76
Boron	RCBRA	--	--	--	2	0.39	3.4	2	0.39	3.4	18	1.1	5.6
Cadmium	RCBRA	--	--	--	2	0.12	0.46	2	0.12	0.46	18	0.05	0.12
Calcium	RCBRA	--	--	--	2	211	641	2	211	641	18	222	714
Calculated total uranium	RCBRA	1	0.17	0.17	--	--	--	1	0.17	0.17	3	0.00000419	0.0863
Chromium	RCBRA	--	--	--	2	0.22	0.55	2	0.22	0.55	18	0.12	0.7
Cobalt	RCBRA	2	0.08	0.13	--	--	--	2	0.08	0.13	18	0.08	0.24
Copper	RCBRA	--	--	--	2	7.9	10.9	2	7.9	10.9	18	3.8	13.4
Iron	RCBRA	--	--	--	2	40.8	130	2	40.8	130	18	43.3	170
Lead	RCBRA	--	--	--	2	0.32	0.48	2	0.32	0.48	18	0.29	0.46
Lithium	RCBRA	1	0.1	0.1	1	0.06	0.06	2	0.06	0.1	18	0.03	0.17
Magnesium	RCBRA	--	--	--	2	244	588	2	244	588	18	352	1,030

Table 4-45. Invertebrate Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Manganese	RCBRA	--	--	--	2	6.8	8.4	2	6.8	8.4	18	3.7	8.4
Mercury	RCBRA	2	0.01	0.02	--	--	--	2	0.01	0.02	18	0.01	0.36
Molybdenum	RCBRA	1	0.28	0.28	1	0.43	0.43	2	0.28	0.43	18	0.26	0.79
Nickel	RCBRA	1	0.23	0.23	1	0.44	0.44	2	0.23	0.44	18	0.22	0.37
Phosphorus	RCBRA	--	--	--	2	1,740	2,170	2	1,740	2170	18	2,010	2,840
Potassium	RCBRA	--	--	--	2	2,010	2,590	2	2,010	2,590	18	2,220	3,060
Selenium	RCBRA	1	0.69	0.69	1	1	1	2	0.69	1	18	0.44	0.88
Silicon	RCBRA	--	--	--	2	18.5	108	2	18.5	108	18	27.2	84.3
Silver	RCBRA	2	0.07	0.09	--	--	--	2	0.07	0.09	18	0.07	0.12
Sodium	RCBRA	--	--	--	2	656	670	2	656	670	18	259	1,040
Strontium (elemental)	RCBRA	--	--	--	1	5.7	5.7	1	5.7	5.7	13	1.1	6
Thallium	RCBRA	2	0.67	0.79	--	--	--	2	0.67	0.79	18	0.65	1
Tin	RCBRA	2	1	2.9	--	--	--	2	1	2.9	18	1	4
Titanium	RCBRA	--	--	--	1	1.1	1.1	1	1.1	1.1	5	1.3	1.9
Uranium (inorganic)	RCBRA	2	0.85	1.4	--	--	--	2	0.85	1.4	18	0.82	2.2
Vanadium	RCBRA	--	--	--	2	0.09	0.12	2	0.09	0.12	18	0.08	0.4
Zinc	RCBRA	--	--	--	2	43.1	60.2	2	43.1	60.2	18	27.4	49.9
Zirconium	RCBRA	1	1	1	--	--	--	1	1	1	12	0.99	1.6

Table 4-45. Invertebrate Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Radionuclides (pCi/g)													
Strontium-90	RCBRA	1	-0.011	-0.011	--	--	--	1	-0.011	-0.011	3	-0.076	0.067
Technetium-99	RCBRA	1	0.179	0.179	--	--	--	1	0.179	0.179	3	-0.04	0.069
Thorium-228	RCBRA	1	-0.068	-0.068	--	--	--	1	-0.068	-0.068	3	0	0.344
Thorium-230	RCBRA	1	-0.034	-0.034	--	--	--	1	-0.034	-0.034	3	-0.04	-0.029
Thorium-232	RCBRA	1	-0.034	-0.034	--	--	--	1	-0.034	-0.034	3	0	0.065
Uranium-233/234	RCBRA	1	0.057	0.057	--	--	--	1	0.057	0.057	3	0	0
Uranium-235	RCBRA	1	0	0	--	--	--	1	0	0	3	0	0.029
Uranium-238	RCBRA	1	0.057	0.057	--	--	--	1	0.057	0.057	3	-0.076	0.067

Source: RCBRA (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*).

-- = not applicable

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Inorganics (mg/kg)													
Aluminum	RCBRA	--	--	--	4	4.4	56.7	4	4.4	56.7	38	1.7	115
Antimony	RCBRA	4	0.22	0.43	--	--	--	4	0.22	0.43	38	0.21	0.43
Arsenic	RCBRA	2	0.59	0.6	2	0.42	0.57	4	0.42	0.6	38	0.39	0.76
Barium	RCBRA	--	--	--	4	0.11	2.8	4	0.11	2.8	38	0.04	6.6
Beryllium	RCBRA	3	0.01	0.02	1	0.01	0.01	4	0.01	0.02	38	0.01	0.02
Bismuth	RCBRA	4	0.39	0.5	--	--	--	4	0.39	0.5	38	0.38	0.5
Boron	RCBRA	3	0.23	0.35	1	2.2	2.2	4	0.23	2.2	38	0.22	0.9
Cadmium	RCBRA	2	0.05	0.07	2	0.1	0.28	4	0.05	0.28	38	0.05	0.44
Calcium	RCBRA	--	--	--	4	99.6	12,700	4	99.6	12,700	38	46.3	18,400
Calculated total uranium	RCBRA	2	0.16	0.17	--	--	--	2	0.16	0.17	19	-0.0804	0.241
Chromium	RCBRA	--	--	--	4	0.17	0.68	4	0.17	0.68	38	0.12	0.91
Cobalt	RCBRA	4	0.08	0.14	--	--	--	4	0.08	0.14	38	0.08	0.14
Copper	RCBRA	--	--	--	4	3.7	7	4	3.7	7	38	2.5	11.3
Iron	RCBRA	--	--	--	4	97.2	148	4	97.2	148	38	82.4	233
Lead	RCBRA	2	0.3	0.32	2	0.35	0.49	4	0.3	0.49	38	0.29	1.2
Lithium	RCBRA	3	0.03	0.09	1	0.05	0.05	4	0.03	0.09	38	0.03	0.16
Magnesium	RCBRA	--	--	--	4	233	575	4	233	575	38	111	656

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Manganese	RCBRA	--	--	--	4	2.7	4.9	4	2.7	4.9	38	1.8	7.4
Mercury	RCBRA	2	0.01	0.02	2	0.02	0.04	4	0.01	0.04	38	0.01	0.07
Molybdenum	RCBRA	1	0.28	0.28	3	0.39	1.4	4	0.28	1.4	38	0.25	1.9
Nickel	RCBRA	2	0.23	0.26	2	0.35	1	4	0.23	1	38	0.22	2.9
Phosphorus	RCBRA	--	--	--	4	3,060	8,050	4	3,060	8,050	38	2,420	10,300
Potassium	RCBRA	--	--	--	4	2,400	3,100	4	2,400	3,100	38	1,980	3,200
Selenium	RCBRA	--	--	--	4	0.63	2.3	4	0.63	2.3	38	0.45	2.6
Silicon	RCBRA	--	--	--	4	4.6	67.6	4	4.6	67.6	38	2.6	91.7
Silver	RCBRA	4	0.07	0.09	--	--	--	4	0.07	0.09	38	0.06	0.15
Sodium	RCBRA	--	--	--	4	1,130	1,780	4	1,130	1,780	38	905	1,690
Strontium (elemental)	RCBRA	--	--	--	2	0.13	6.3	2	0.13	6.3	28	0.05	12.7
Thallium	RCBRA	4	0.68	0.78	--	--	--	4	0.68	0.78	38	0.65	0.79
Tin	RCBRA	2	1	3.4	2	1.3	2.4	4	1	3.4	38	0.99	2.8
Titanium	RCBRA	1	0.03	0.03	1	0.55	0.55	2	0.03	0.55	14	0.03	9.1
Uranium (inorganic)	RCBRA	3	0.85	1.4	1	1.4	1.4	4	0.85	1.4	38	0.81	1.5
Vanadium	RCBRA	3	0.08	0.09	1	0.11	0.11	4	0.08	0.11	38	0.08	0.4
Zinc	RCBRA	--	--	--	4	28.4	95.4	4	28.4	95.4	38	19.5	120
Zirconium	RCBRA	--	--	--	2	0.63	0.7	2	0.63	0.7	21	0.31	1.1

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Organics (mg/kg)													
1,2,4-Trichlorobenzene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
1,2-Dichlorobenzene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
1,3-Dichlorobenzene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
1,4-Dichlorobenzene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2,4,5-Trichlorophenol	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
2,4,6-Trichlorophenol	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2,4-Dichlorophenol	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2,4-Dimethylphenol	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2,4-Dinitrophenol	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
2,4-Dinitrotoluene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2,6-Dinitrotoluene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2-Chloronaphthalene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2-Chlorophenol	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2-Methylnaphthalene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2-Methylphenol [cresol, o-]	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
2-Nitroaniline	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
2-Nitrophenol	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
3,3*-Dichlorobenzidine	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
3+4 Methylphenol [cresol, m+p]	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	0.18	4.5
3-Nitroaniline	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
4,6-Dinitro-2-methylphenol	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
4-Bromophenylphenyl ether	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
4-Chloro-3-methylphenol	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
4-Chloroaniline	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
4-Chlorophenylphenyl ether	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
4-Nitroaniline	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
4-Nitrophenol	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11
Acenaphthene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Acenaphthylene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Aldrin	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.011	0.028
Alpha-BHC	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
alpha-Chlordane	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Anthracene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Aroclor 1016	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.081	0.8
Aroclor 1221	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.081	0.8

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Aroclor 1232	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.081	0.8
Aroclor 1242	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.081	0.8
Aroclor 1248	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.081	0.8
Aroclor 1254	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.079	0.8
Aroclor 1260	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.081	0.8
Benzo[a]anthracene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Benzo[a]pyrene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Benzo[b]fluoranthene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Benzo[ghi]perylene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	0.22	4.5
Benzo[k]fluoranthene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
beta-1,2,3,4,5,6-Hexachlorocyclohexane	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.064
Bis[2-chloro-1-methylethyl]ether	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Bis[2-Chloroethoxy]methane	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Bis[2-chloroethyl] ether	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Bis[2-ethylhexyl] phthalate	RCBRA	1	2	2	1	0.57	0.57	2	0.57	2	19	0.17	3.3
Butylbenzylphthalate	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Carbazole	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Chrysene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Delta-BHC	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.012	0.033
Dibenz[a,h]anthracene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Dibenzofuran	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Dichlorodiphenyldichloroethane	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Dichlorodiphenyldichloroethylene	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Dichlorodiphenyl-trichloroethane	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.01	0.02
Dieldrin	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Diethylphthalate	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Dimethyl phthalate	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Di-n-butylphthalate	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	0.16	4.5
Di-n-octylphthalate	RCBRA	1	3.9	3.9	1	0.36	0.36	2	0.36	3.9	19	0.42	4.3
Endosulfan I	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.012	0.02
Endosulfan II	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Endosulfan sulfate	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Endrin	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Endrin aldehyde	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Endrin ketone	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Fluoranthene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Fluorene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Gamma-BHC (lindane)	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.0073	0.02
gamma-Chlordane	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Heptachlor	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Heptachlor epoxide	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.02
Hexachlorobenzene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Hexachlorobutadiene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Hexachlorocyclopentadiene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Hexachloroethane	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Indeno[1,2,3-cd]pyrene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Isophorone	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Methoxychlor	RCBRA	2	0.018	0.019	--	--	--	2	0.018	0.019	19	0.014	0.03
Naphthalene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Nitrobenzene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
N-Nitroso-di-n-dipropylamine	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
N-Nitrosodiphenylamine	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Pentachlorophenol	RCBRA	2	9.6	9.8	--	--	--	2	9.6	9.8	19	6.8	11

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Phenanthrene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Phenol	RCBRA	1	3.9	3.9	1	0.26	0.26	2	0.26	3.9	19	0.16	4.5
Pyrene	RCBRA	2	3.8	3.9	--	--	--	2	3.8	3.9	19	2.7	4.5
Toxaphene	RCBRA	2	0.18	0.19	--	--	--	2	0.18	0.19	19	0.14	0.2
Radionuclides (pCi/g)													
Americium-241	RCBRA	2	0.179	0.21	--	--	--	2	0.179	0.21	19	0.041	2.2
Antimony-125	RCBRA	2	0.116	0.13	--	--	--	2	0.116	0.13	19	0.071	1.4
Beryllium-7	RCBRA	2	0	0.53	--	--	--	2	0	0.53	7	0.032	0.079
Carbon-14	RCBRA	1	-0.23	-0.23	--	--	--	1	-0.23	-0.23	19	0	8.1
Cesium-134	RCBRA	2	0.061	0.079	--	--	--	2	0.061	0.079	3	-1.92	-0.622
Cesium-137	RCBRA	2	0.056	0.064	--	--	--	2	0.056	0.064	19	0.034	0.69
Cobalt-60	RCBRA	2	0.048	0.075	--	--	--	2	0.048	0.075	19	0.031	0.65
Europium-152	RCBRA	2	0.14	0.16	--	--	--	2	0.14	0.16	19	0.032	0.64
Europium-154	RCBRA	2	0.136	0.2	--	--	--	2	0.136	0.2	19	0.076	1.5
Europium-155	RCBRA	2	0.13	0.17	--	--	--	2	0.13	0.17	19	0.092	1.8
Potassium-40	RCBRA	2	0	2.2	--	--	--	2	0	2.2	19	0.073	1.4
Radium-226	RCBRA	2	0.112	0.14	--	--	--	2	0.112	0.14	11	-0.036	0.051
Radium-228	RCBRA	2	0.224	0.32	--	--	--	2	0.224	0.32	11	-0.032	0.043

Table 4-46. Small Mammal (Mouse) Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Ruthenium-106	RCBRA	2	0.419	0.51	--	--	--	2	0.419	0.51	19	0	11
Strontium-90	RCBRA	2	0.024	0.116	--	--	--	2	0.024	0.116	19	0.055	1.1
Technetium-99	RCBRA	1	0.155	0.155	--	--	--	1	0.155	0.155	19	0.13	2.7
Thorium-228	RCBRA	2	-0.07	0.021	--	--	--	2	-0.07	0.021	19	0.28	5.7
Thorium-230	RCBRA	1	0.175	0.175	1	0.362	0.362	2	0.175	0.362	19	-0.082	0.505
Thorium-232	RCBRA	2	0	0.007	--	--	--	2	0	0.007	19	-0.112	0.186
Uranium-233/234	RCBRA	2	0	0.028	--	--	--	2	0	0.028	19	0	0.064
Uranium-235	RCBRA	2	0	0	--	--	--	2	0	0	19	0	0.1
Uranium-238	RCBRA	2	0.053	0.056	--	--	--	2	0.053	0.056	19	-0.027	0.081

Source: RCBRA (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*).

-- = not applicable

Table 4-47. Mule Deer Antler Samples from the 100-K Area

Analyte	Data Source	Detect Samples			Total of All Samples		
		Number	Minimum	Maximum	Number	Minimum	Maximum
Radionuclides (pCi/g)							
Strontium-90	SESP	2	0.151	0.932	2	0.151	0.932

SESP = Surface Environmental Surveillance Program

Table 4-48. Western Kingbird Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Inorganics (mg/kg)													
Aluminum	RCBRA	--	--	--	2	6.8	39.7	2	6.8	39.7	21	2.3	2,420
Antimony	RCBRA	1	0.21	0.21	1	0.26	0.26	2	0.21	0.26	21	0.2	1.3
Arsenic	RCBRA	2	0.4	0.41	--	--	--	2	0.4	0.41	21	0.38	1.8
Barium	RCBRA	--	--	--	2	0.57	7.5	2	0.57	7.5	21	0.2	36.1
Beryllium	RCBRA	1	0.01	0.01	1	0.01	0.01	2	0.01	0.01	21	0.009	0.08
Bismuth	RCBRA	2	0.39	0.4	--	--	--	2	0.39	0.4	21	0.37	1.5
Boron	RCBRA	1	0.35	0.35	1	5.9	5.9	2	0.35	5.9	21	0.23	2.6
Cadmium	RCBRA	2	0.05	0.05	--	--	--	2	0.05	0.05	21	0.05	0.42
Calcium	RCBRA	--	--	--	2	6,410	8,700	2	6,410	8,700	21	239	68,500

Table 4-48. Western Kingbird Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Calculated total uranium	RCBRA	1	-0.0057	-0.0057	--	--	--	1	-0.0057	-0.0057	11	-0.00185	0.134
Chromium	RCBRA	--	--	--	2	0.24	0.29	2	0.24	0.29	21	0.17	4.5
Cobalt	RCBRA	2	0.08	0.08	--	--	--	2	0.08	0.08	21	0.07	0.94
Copper	RCBRA	--	--	--	2	1.6	3.5	2	1.6	3.5	21	2	14.4
Iron	RCBRA	--	--	--	2	33.8	60.5	2	33.8	60.5	21	29.1	2,830
Lead	RCBRA	2	0.32	0.33	--	--	--	2	0.32	0.33	21	0.29	0.89
Lithium	RCBRA	--	--	--	2	0.03	0.18	2	0.03	0.18	21	0.01	1.4
Magnesium	RCBRA	--	--	--	2	352	706	2	352	706	21	153	1,820
Manganese	RCBRA	--	--	--	2	0.77	4.8	2	0.77	4.8	21	0.61	225
Mercury	RCBRA	1	0.03	0.03	1	0.02	0.02	2	0.02	0.03	21	0.01	0.04
Molybdenum	RCBRA	--	--	--	2	0.16	0.19	2	0.16	0.19	21	0.15	0.99
Nickel	RCBRA	1	0.26	0.26	1	0.55	0.55	2	0.26	0.55	21	0.23	1.7
Phosphorus	RCBRA	--	--	--	2	278	5,820	2	278	5,820	21	610	4,630
Potassium	RCBRA	--	--	--	2	2,150	2,480	2	2,150	2,480	21	1,090	3,260
Selenium	RCBRA	1	0.43	0.43	1	1.4	1.4	2	0.43	1.4	21	0.41	2.2
Silicon	RCBRA	--	--	--	2	9	131	2	9	131	21	2.5	866
Silver	RCBRA	2	0.09	0.09	--	--	--	2	0.09	0.09	21	0.07	0.2
Sodium	RCBRA	--	--	--	2	1,150	1,190	2	1,150	1,190	21	524	1,850
Strontium (elemental)	RCBRA	--	--	--	2	6.8	47.7	2	6.8	47.7	21	1.1	71.6

Table 4-48. Western Kingbird Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Thallium	RCBRA	2	0.78	0.8	--	--	--	2	0.78	0.8	21	0.66	2
Tin	RCBRA	--	--	--	2	0.98	2.6	2	0.98	2.6	21	0.93	6.2
Uranium (inorganic)	RCBRA	2	1.4	1.4	--	--	--	2	1.4	1.4	5	0.09	6.6
Vanadium	RCBRA	2	0.08	0.08	--	--	--	2	0.08	0.08	21	0.83	3.1
Zinc	RCBRA	--	--	--	2	20.2	32.1	2	20.2	32.1	21	0.07	4.8
Radionuclides (pCi/g)													
Americium-241	RCBRA	1	0.067	0.067	--	--	--	1	0.067	0.067	11	0.056	0.95
Antimony-125	RCBRA	1	0.151	0.151	--	--	--	1	0.151	0.151	11	0.153	0.95
Beryllium-7	RCBRA	1	0.009	0.009	--	--	--	1	0.009	0.009	3	0.11	0.4
Cesium-134	RCBRA	1	0.074	0.074	--	--	--	1	0.074	0.074	11	0	3.9
Cesium-137	RCBRA	1	0.065	0.065	--	--	--	1	0.065	0.065	11	0.079	0.68
Cobalt-60	RCBRA	1	0.076	0.076	--	--	--	1	0.076	0.076	11	0.065	0.57
Europium-152	RCBRA	1	0.164	0.164	--	--	--	1	0.164	0.164	11	0.064	0.7
Europium-154	RCBRA	1	0.19	0.19	--	--	--	1	0.19	0.19	11	0.151	0.96
Europium-155	RCBRA	1	0.106	0.106	--	--	--	1	0.106	0.106	11	0.2	1.9
Potassium-40	RCBRA	--	--	--	1	3.05	3.05	1	3.05	3.05	11	0.107	0.87
Radium-226	RCBRA	1	0.125	0.125	--	--	--	1	0.125	0.125	11	-0.004	21.4
Radium-228	RCBRA	1	0.269	0.269	--	--	--	1	0.269	0.269	11	0.124	2.02
Ruthenium-106	RCBRA	1	0.531	0.531	--	--	--	1	0.531	0.531	11	0.349	2.5

Table 4-48. Western Kingbird Tissue Samples from the 100-K Area

Analyte	Data Source	Nondetect Samples			Detect Samples			Total of All Samples			RCBRA Reference Sample Results		
		No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.	No.	Min.	Max.
Strontium-90	RCBRA	1	-0.008	-0.008	--	--	--	1	-0.008	-0.008	11	-0.067	0.376
Thorium-228	RCBRA	1	0.027	0.027	--	--	--	1	0.027	0.027	11	-0.058	0.066
Thorium-230	RCBRA	1	-0.134	-0.134	--	--	--	1	-0.134	-0.134	11	-0.189	0.301
Thorium-232	RCBRA	1	-0.027	-0.027	--	--	--	1	-0.027	-0.027	11	-0.034	0.047
Uranium-233/234	RCBRA	1	0	0	--	--	--	1	0	0	11	-0.02	0.062
Uranium-235	RCBRA	1	0.007	0.007	--	--	--	1	0.007	0.007	11	-0.004	0.034
Uranium-238	RCBRA	1	-0.003	-0.003	--	--	--	1	-0.003	-0.003	11	0	0.045

Source: RCBRA (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*).

-- = not applicable

4.7 Air

This section summarizes air sampling and monitoring data that have been collected for 100-K. As discussed in Section 2.1.6, near-facility air sampling monitors (NFMs) measure the effectiveness of waste management, environmental remediation controls, and effluent treatment systems in reducing effluents and emissions. These air samplers also monitor diffuse source emissions. Air radioactivity was sampled by a network of continuously operating samplers at 11 locations in 100-K in 2008.

AOP-00-05-06, *Hanford Site Air Operating Permit*, (Federal Facility License FF-01) requires regulatory notification for composite (isotopic) air sample results that exceed 10% of EPA Table 2 (40 CFR 61 [“National Emission Standards for Hazardous Air Pollutants”], “Compliance Procedures Methods for Determining Compliance with Subpart I” (Appendix E), Table 2) values. During 2008, the following notifications were submitted to the Washington State Department of Health for the following 100-K East NFM sampling stations:

- Stations N401, N402 and N404: plutonium-239/240 and americium-241, second half of 2008
- Station N403: cesium-137, plutonium-239/240, and americium-241, second half of 2008

A radiological contamination event that occurred in July 2008 during D4 activities was the probable cause of these elevated results. Concentrations of plutonium-239/240 and americium-241 at all four locations were >10% of EPA’s concentration values. The cesium-137 concentration at one location was also >10% of EPA’s concentration value. A review of the biweekly air sample results during the period revealed several statistically elevated alpha and beta concentrations. For all of 100-K during 2008:

- Uranium-234, uranium-238, and americium-241 were detected in about 95% of the samples
- Plutonium-239/240 was detected in about 63% of the samples
- Cesium-137, uranium-235, plutonium-238, and plutonium-241 were detected in about 25% of the samples

Figures 4-53 to 4-55 present the 2008 cesium-137, plutonium-239/240, and americium-241 in historical perspective for radionuclide air monitoring results at 100-K. The dashed line represents the lower limit of detection for each analyte. The results showed low concentrations, with resultant individual public exposure less than the dose standard of 10 mrem/yr total effective dose equivalent.

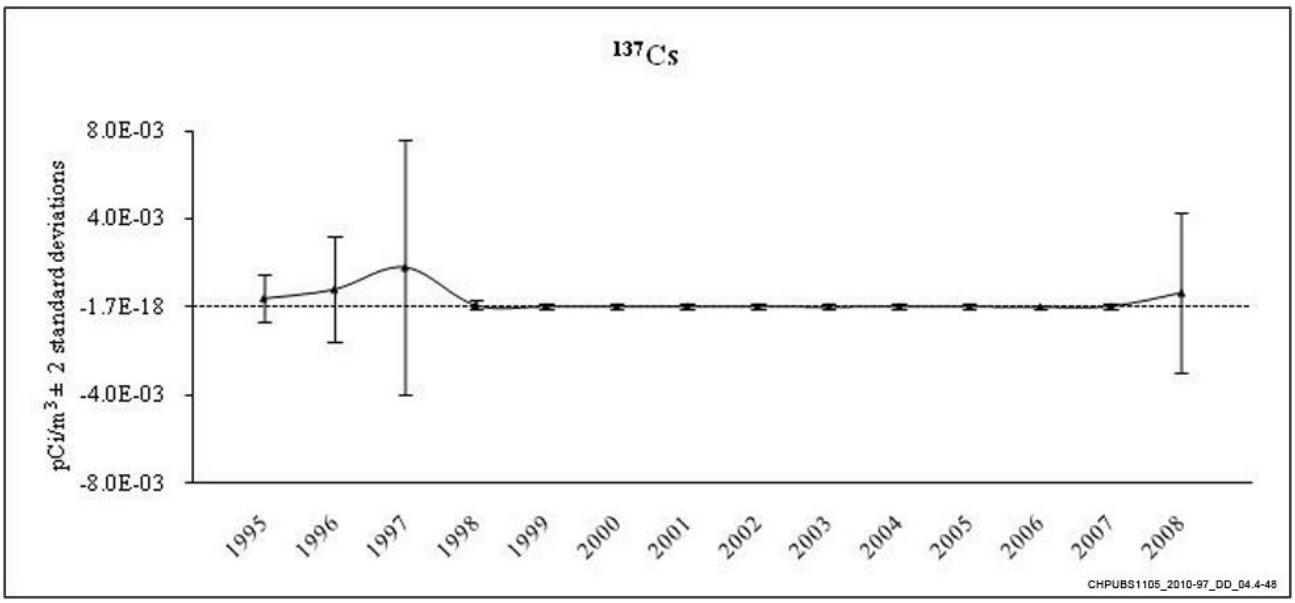

Figure 4-53. Monitoring Results for Cesium-137 Radionuclides at 100-K in 2008

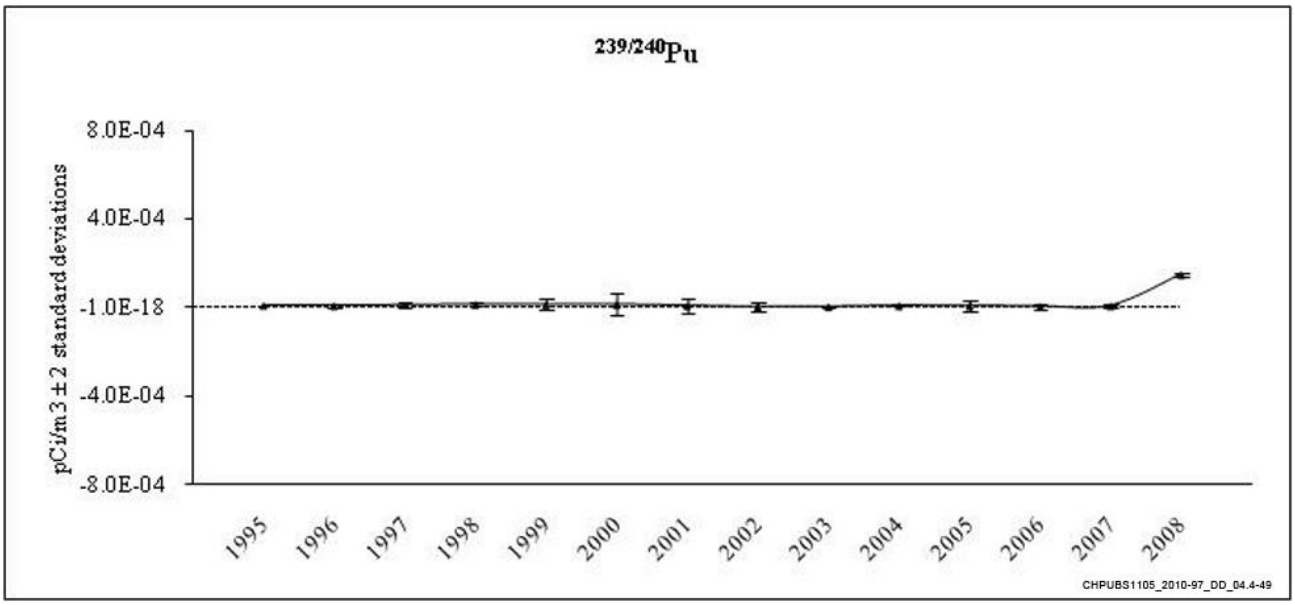

Figure 4-54. Air Monitoring Results for Plutonium-239/240 Radionuclides at 100-K in 2008

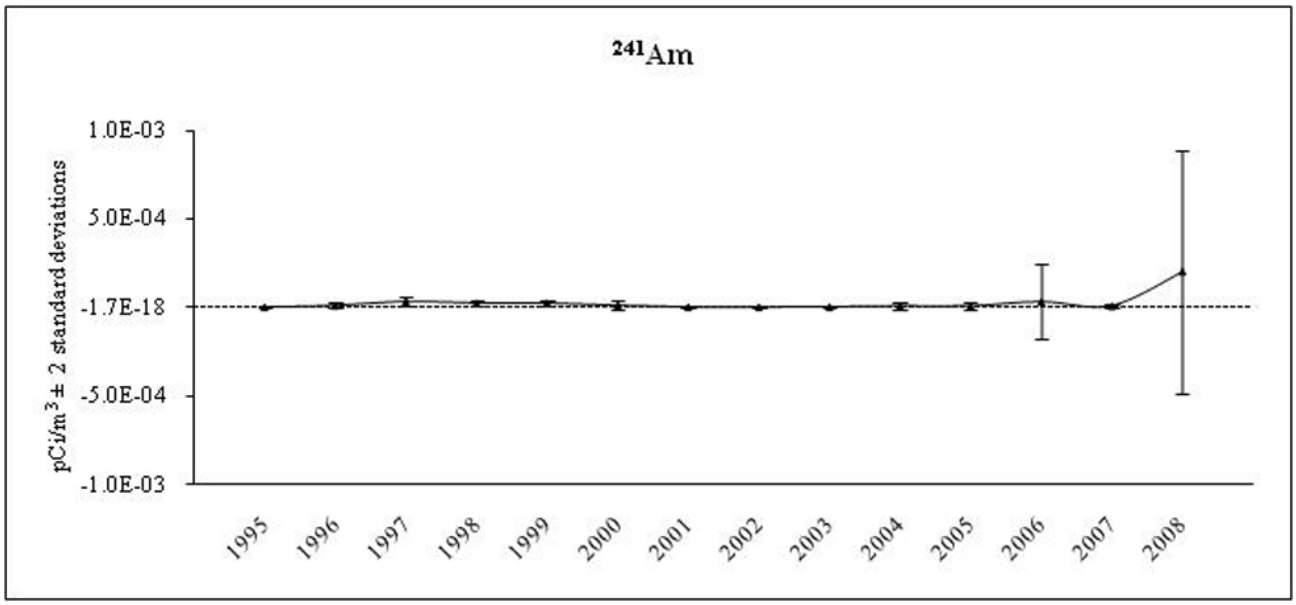

Figure 4-55. Air Monitoring Results for Americium-241 Radionuclides at 100-K in 2008

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5 Contaminant Fate and Transport

This chapter presents an evaluation of the anticipated behavior of selected contaminants in the vadose zone and groundwater at 100-K. An approach is presented for the assessment of anticipated future behavior of vadose zone contaminants that may function as secondary sources of contamination to groundwater. The approach describes how these contaminants are released into the environment to affect underlying groundwater. An analysis is also presented to describe the future behavior of contaminants (carbon-14, Cr(VI), nitrate, strontium-90, trichloroethene, and tritium) already present in groundwater at 100-K. Factors affecting the fate and transport of contaminants, modeling methods and results, and uncertainties are also discussed.

Contaminant fate and transport for the 100-K Area are summarized as follows:

- Interim remediated waste sites with CVP/RSVP and/or RI analytical data were evaluated to determine whether further remedial action may be needed for the protection of groundwater and surface water quality. Evaluation results are as follows:
  - Carbon-14 concentrations in the vadose zone associated with a group of four remediated waste sites (100-K-6, 100-K-46, 100-K-62, and 132-KE-1) were determined to pose a potential threat to groundwater and surface water, assuming infiltration rates based on a native vegetation scenario. The carbon-14 contamination at these four waste sites is associated with a co-located fifth waste site (116-KE-1) that was not completely remediated under interim action. The 116-KE-1 waste site will be evaluated further in the FS.
  - Carbon-14 and Cr(VI) concentrations in the vadose zone at the 116-K-2 waste site were determined to pose a potential threat to either groundwater or surface water assuming infiltration rates based on a native vegetation scenario. The waste site will move forward into the FS for further evaluation.
- Observed contaminant distributions in the unconfined aquifer show the tendency to migrate toward the Columbia River. However, extraction and injection wells control plume migration, directing plumes to extraction wells. Mass remains in the vadose zone for carbon-14, Cr(VI), nitrate, strontium-90, and tritium that sustains groundwater plumes for some time. Considering the effects of potential continuing vadose zone sources, the simulated results of the no further action scenario are as follows:
  - Cr(VI) persists above the MTCA (WAC 173-340) groundwater cleanup levels near the 183.1KW Headhouse through 2142.
  - Cr(VI) concentrations in groundwater discharging to the Columbia River will decrease below the surface water standard (10 µg/L) by 2063 along the river shoreline near the KW and KE area and will persist above the surface water standard (10 µg/L) along the river shoreline near northern 100-N through 2142.
  - Carbon-14 source depletion results in groundwater concentrations less than the DWS (2,000 pCi/L) by 2033.
  - Nitrate groundwater concentrations decrease to less than the DWS (45 mg/L) by 2027.
  - Tritium groundwater concentrations decrease to less than the DWS (20,000 pCi/L) by 2027.

- Strontium-90 groundwater contamination persists through 2142 above the DWS (8 pCi/L) near waste sites 116-KW-2, UPR-100-K-1, and 116-K-2. In addition, strontium-90 concentrations stay above cleanup level after 300 years of simulated time.
- Trichloroethene groundwater concentrations decrease to less than cleanup level (5 µg/L) by 2022.

5.1 Introduction

This chapter describes the key processes affecting COPCs fate and transport in 100-K environmental media and the effect these processes may have on the future COPC distribution. The following information is presented in this chapter:

- 100-K COPC environmental persistence summaries (Section 5.2)
- Maximum soil contaminant levels for COPCs in the vadose zone at 100-K protective of groundwater and of surface water under two future land use scenarios (irrigated agriculture and conservation with native vegetation), determined using a one-dimensional numerical fate and transport model (Section 5.3)
- Results of comparisons between soil COPC concentrations and modeled maximum soil COPC concentrations protective of groundwater and surface water, to determine if waste sites are secondary sources of groundwater and surface water COPCs and merit FS evaluations for groundwater and surface water protection (Section 5.4)
- A three-dimensional groundwater fate and transport numerical model suitable for evaluating groundwater COPCs under baseline conditions (assuming no further remedial action is taken) and under the remedial alternatives evaluated (Section 5.5)
- Groundwater fate and transport model results for the future evolution of existing carbon-14, Cr(VI), nitrate, strontium-90, tritium, and trichloroethene groundwater plumes, assuming no further remedial action is taken (Section 5.6)

The assumptions and model input parameters described in this chapter are important for potential future waste site remediation efforts and assessing achievement of remedial goals. The cleanup verification process, including demonstration of how remedial goals are achieved, involves comparing the waste site CSM to the generic CSM used to develop maximum soil concentrations that will be protective of groundwater and of surface water. To the extent a deviation in the two CSMs is observed, site-specific conditions can be used to evaluate the potential for a waste site to act as a source of groundwater contamination.

5.2 Contaminant Persistence

The persistence of various contaminants determines how long they remain in the environment and how long they are available for transport to potential receptors; the processes that influence this effect are collectively known as natural attenuation. If a contaminant remains in the environment for a long time and is mobile, it is more likely to be transported from the vadose zone to groundwater and eventually to surface water. Natural attenuation also determines how long it takes a contaminant to be transformed into a less toxic or less available form or how long it takes the contaminant to leave the affected area. Radionuclides undergo radioactive decay at rates specific to the individual nuclide. Chemicals may also degrade abiotically or through microbial processes. Both radionuclides and chemicals in the subsurface may be dispersed in a manner that reduces the mass and/or the concentration of the contaminant available

for transport or direct exposure. The following subsections discuss the persistence of selected COPCs detected in 100-K environmental media.

5.2.1 Nonradionuclide Chemical Constituents

The persistence or degradation of chemical constituents at 100-K is primarily driven by biological and geochemical oxidation/reduction (redox) processes, potential biological uptake, and physical processes (e.g., volatilization and water solubility). The chemical constituents identified for this discussion include Cr(VI), which is generally present as an oxyanion, volatile organic compounds (VOCs) (trichloroethene and chloroform), and nitrate. These constituents are subject to a variety of transformational processes.

Cr(VI) is relatively stable and persistent in the vadose zone and groundwater environments at 100-K (Section 4.4). Chromium is typically present at the Hanford Site in one of two oxidation states: trivalent (Cr(III)) or hexavalent (Cr(VI)). Trivalent chromium is typically precipitated in the environment as a low-solubility hydroxide molecule ($Cr(OH)_3$) and, as such, has low mobility and exhibits low toxicity. Cr(VI), however, is acutely toxic and is typically present under ambient conditions at 100-K as a soluble oxyanion ($Cr_2O_7^{-2}$ or CrO_4^{-2}), depending primarily on pH. The ionic forms of Cr(VI) are relatively stable under the aerobic conditions typically found in soil and unconfined groundwater at 100-K; as such, Cr(VI) tends to have moderate mobility under present conditions.

Chemical degradation of Cr(VI) is unlikely to be important at 100-K. The primary Cr(VI) source in the subsurface environment was the sodium dichromate dihydrate used for corrosion control in reactor cooling water. This compound is acidic in its concentrated form. However, the dichromate or chromate ion can react with other metals in the environment to form compounds of lower solubility. These compounds can include potassium dichromate (which is about one tenth as soluble as sodium dichromate dihydrate) and lead chromate (which is relatively insoluble). PNNL conducted a series of laboratory experiments assessing Cr(VI) reduction mechanisms in 100 Area sediments (PNNL-24705, *Assessment of Hexavalent Chromium Natural Attenuation for the Hanford Site 100 Area*) showing co-precipitation of Cr(VI) with calcium carbonate materials acts as a solubility controlled partitioning interaction with respect to slowing Cr(VI) transport (e.g., within the plume especially at the distal portions) while co-precipitation of Cr(VI) with calcium carbonate materials of moderate solubility may provide a continuing source of Cr(VI) (e.g., for the tail of a plume or near former source areas).The Cr(VI) ion can also undergo chemical reduction under moderately reducing conditions or on reaction with reducing agents such as ferrous iron. Ferrous iron is effective at reducing Cr(VI) to Cr(III), producing a very low solubility hydroxide molecule (EPA/600/R-07/140, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 2 Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*). Ferrous iron data are limited to well 199-K-126 for six samples: two were non-detect, two values were 20 µg/L, one value of 10 µg/L, and one value of 60 µg/L. The absence of high concentrations of ferrous iron are consistent with an oxidizing environment, and this attenuation mechanism is likely of no significance in 100-K groundwater.

A chlorinated VOC (trichloroethene) is found at relatively low concentrations in 100-K groundwater (Section 4.4.8) and degrades very slowly under the redox and dissolved oxygen conditions currently in groundwater (i.e., moderately aerobic). Natural attenuation of these compounds can occur from reductive dechlorination via facultative[1] and obligate[2] anaerobic microorganisms under anoxic conditions or undergo abiotic transformation (EPA 600/R-09/115, *Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water*). Trichloroethene may volatilize from the land surface or surface water directly to the atmosphere. Trichloroethene dissolved in soil moisture or groundwater can partition to soil gas and then migrate to the atmosphere; however, gas exchange from the deep vadose zone (e.g., deeper than a few meters bgs) or from groundwater accounts for only a small potential loss. Once in the atmosphere, trichloroethene can be destroyed through photodegradation (sunlight). The potential for volatilization and abiotic or biologically mediated degradation is dependent on the specific physical and chemical properties of the constituent, diversity and population of microorganisms, and geochemical characteristics of the subsurface environment.

Nitrate is a relatively stable oxyanion of nitrogen and oxygen. Nitrate is highly water-soluble and remains stable in vadose zone soil, groundwater, and surface water under oxidizing conditions typically encountered at 100-K. Nitrate is subject to chemical or biological reduction to nitrite or ultimately to diatomic nitrogen by soil and water microorganisms under low-oxygen conditions not currently found at 100-K. Reduction of nitrate to diatomic nitrogen generally results in removal of the nitrogen from the soil/water system.

5.2.2 Radionuclide Constituents

Radionuclide persistence is controlled by the radioactive decay process that transforms the original radioisotope either into another isotope of the same element or into another element. The daughter product of radioactive decay may be a radionuclide or a stable isotope. Exclusive of their relative mobility in the environment, radionuclides with relatively long half-life are typically more of an environmental concern than radionuclides with shorter half-lives. This is due to the potential for constituents with longer half-lives to remain in the environment after release and to present a potential for exposure to human and ecological receptors either through direct exposure at or near the point of release, or through migration to distant exposure points.

[1] Can survive in both aerobic and anaerobic conditions.

[2] Can survive only in anaerobic conditions.

5.3 Vadose Zone Fate and Transport Modeling

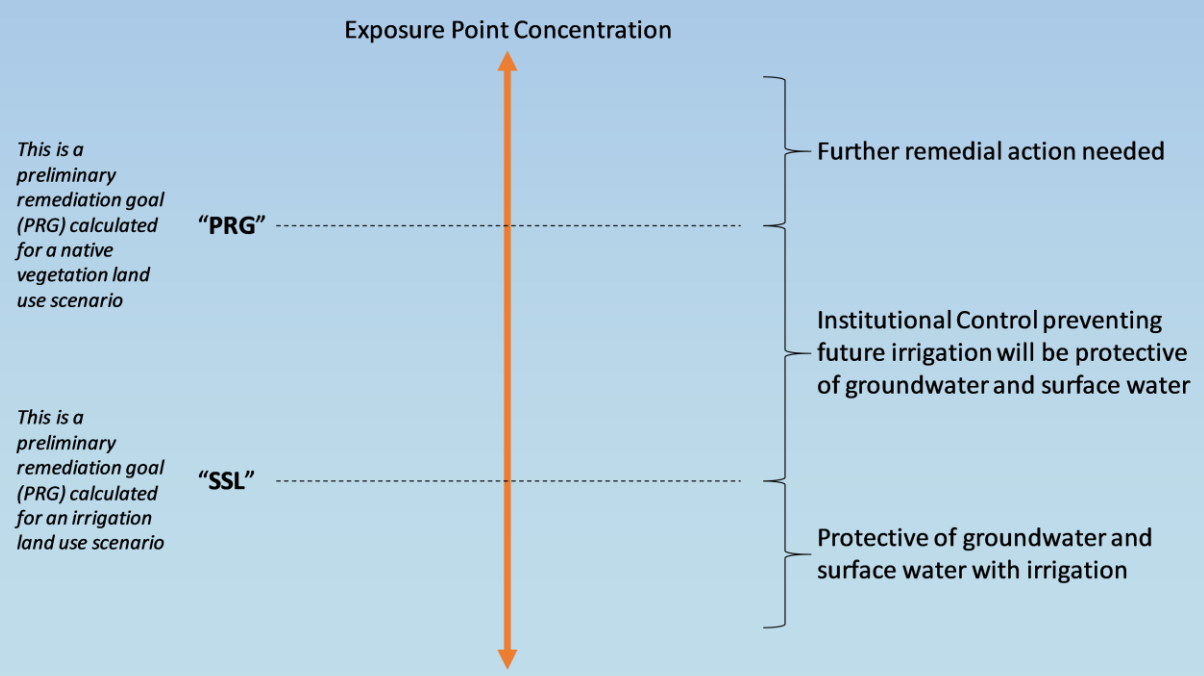
SSL and PRG Terms

In Chapter 5, two threshold values are calculated for residual soil contamination that are used to evaluate EPCs. These values are denoted as the "soil screening level" (SSL) and the "preliminary remediation goal" (PRG).

Both SSL and PRG values are, in fact, PRGs calculated for two different land uses: conservation with native vegetation and irrigation. The purpose of calculating these two values is to determine if an EPC is low enough to be protective under irrigation. If it is not, then the EPC is subsequently compared to the second value to determine if an institutional control (IC) to preclude irrigation would be protective of groundwater and surface water.

Use of these terms has resulted from an evolving, negotiated process that needs to be understood by the reader in the following context:

- The term "SSL" in this Chapter refers to a PRG value calculated for irrigation land use.
- The term "PRG" in this chapter refers to a PRG value calculated for conservation with native vegetation land use.



Vadose zone fate and transport modeling simulated future COPC behavior and concentrations to assess potential threats to human health and the environment following an evaluation process. Results from the vadose zone fate and transport modeling were used to calculate SSLs and PRGs protective of

groundwater and surface water quality for the conditions simulated. The SSL and PRG values are calculated in the same way, with the only difference being that SSL values are calculated for a future irrigation use scenario as a bounding infiltration rate condition, whereas PRG values are calculated using a native vegetation scenario that represents conservation land use in the 100 Area (i.e., conservation activities that do not include intensive irrigated agriculture). The model calculated SSLs and PRGs are inherently dimensional values that depend on the extent of the contaminated soil in the direction of groundwater flow. Hence, unit-length SSL and PRG values are provided that are readily scalable to the length of each waste site in the general direction of groundwater flow. Subsequent application of the unit-length SSLs and PRGs to the 100-K waste sites identified waste sites requiring future consideration in the FS for groundwater and surface water protection.

The vadose zone transport simulations were performed using the Subsurface Transport Over Multiple Phases (STOMP) computer code (PNNL-11216, *STOMP Subsurface Transport Over Multiple Phases: Application Guide*; PNNL-12030, *STOMP Subsurface Transport Over Multiple Phases: Theory Guide*; PNNL-15782, *STOMP Subsurface Transport Over Multiple Phases: Version 4.0: User's Guide*). The STOMP code was selected to perform the simulations because it can adequately simulate the vadose zone features, events, and processes (FEP) relevant to the SSL and PRG calculations for the 100 Area while satisfying the criteria for numerical model code selection described in DOE/RL-2011-50. The model development approach used to support this RI is documented in SGW-50776, *Model Package Report: Vadose Zone Model for the River Corridor*. The numerical approach for calculation of the unit-length SSLs and PRGs is described in ECF-100KR1-17-0087, *Determination of Unit-Length Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Units* (included in Appendix F).

Conceptually, the model simulation represents a column of sediments that comprise the vadose zone underlain by an aquifer. Recharge-driven flow moves downward through the vadose zone, where it encounters contaminated soil that releases soluble contaminants for transport towards the underlying aquifer, across which a hydraulic gradient drives horizontal groundwater flow. At the start of each vadose transport simulation, the vadose zone is composed of a cover of clean fill with constant thickness as well as contaminated and uncontaminated sediments of varying thickness. The aquifer constitutes the base of the column with a thickness of 5 m (16.4 ft). This is consistent with the requirements for aquifer mixing zone thickness in WAC 173-340-747(5)(f)(i), which specifies that the aquifer mixing zone thickness shall not exceed 5 m (16.4 ft) in depth.

One-dimensional numerical models were constructed to represent the key facets of the conceptual model and were solved using STOMP. The STOMP-W (water) mode was used to solve the various equations that govern unsaturated water flow and dilute solute transport, respectively, under variably saturated conditions in porous media. The STOMP simulations predict contaminant concentration and the time to reach the peak groundwater concentration within the aquifer based on the assigned boundary and initial conditions, hydraulic and transport properties, and contaminant source distributions appropriate to the 100-K Area.

5.3.1 Evaluation Process for Assessment of Groundwater and Surface Water Protection

The evaluation process used to assess whether there is potential for vadose zone contaminants to affect groundwater and/or surface water quality followed a specific set of steps as shown in Figure 5-1. This process is intended to determine whether soil contaminants could migrate to the underlying groundwater and, subsequently, be discharged to surface water at concentrations that would pose a threat to human or ecological receptors. The activities associated with the evaluation process included the following:

- The available data describing the nature and extent of residual vadose zone soil contamination at a waste site were identified and assembled. This included laboratory analysis of soil samples collected from the vadose zone, field measurements of specific contaminant concentrations, qualitative and quantitative measurements of radionuclides in the vadose zone, measurements of soil physical properties (e.g., moisture or particle size distribution), and field observations made during drilling and/or excavation. These data have been generated from process knowledge and operating history, specific waste site characterization activities (e.g., LFIs and RI activities), or completion and verification measurements associated with vadose zone remedial activities.

- The available data that provide a description of residual contaminant distribution, including concentrations and horizontal and vertical distribution for each waste site, were evaluated and then compared to the generic CSM, upon which the SSL and PRG values were based. If the known waste site conditions were similar to those for the models used to develop SSL and PRG, then the evaluation followed the SSL and PRG comparison pathway.

- If known waste site conditions differ from the generic CSM, then the waste site would be evaluated using a site-specific contaminant transport simulation. Conditions that may indicate that the generic CSM is not representative include historical or persistent groundwater plumes associated with a specific waste site or operating area or contaminant distribution within the vadose zone that is not consistent with the default distribution for that contaminant. Waste sites that are not represented by the default simulation scenarios would be evaluated individually.

- EPCs for each COPC were calculated based on site-specific data (see Section 6.2.2) for previously defined decision units (see Section 4.2.1). The EPC was calculated using either a 95% UCL on the mean or a maximum observed concentration (if insufficient data were available to derive a UCL).

- EPCs for each contaminant at a waste site were then compared to the relevant SSL for each contaminant. The SSLs represent a conservative groundwater and surface water protection value for a waste site based on the assumption of a long-term irrigation recharge scenario. If the EPC was less than the SSL, then that contaminant was identified for no further action and the assessment moved to the next contaminant.

- If the site-specific contaminant EPC was greater than the SSL for a waste site, then the EPC was subsequently compared to the PRG for that contaminant. The PRG represents a groundwater and surface water protection value for a waste site based on conservation activities that do not include irrigated agriculture. If the EPC was greater than the SSL but less than the PRG at a particular waste site, then the affected waste site was identified for potential application of ICs in the FS that will prevent irrigation in the future at the waste site. If the EPC was also greater than the PRG, then the COPC at the waste site is carried forward into the FS for identification of other appropriate remedial alternatives to mitigate risks to groundwater and surface water posed by the vadose zone contamination.

If waste site conditions were not adequately represented by the generic CSM used for SSL and/or PRG development simulations, then the waste site and its affected contaminants would be evaluated using a site-specific vadose zone transport simulation. This simulation would use the same general fate and transport modeling approach used for SSL and PRG development, except that site-specific conditions would be substituted where appropriate. The simulations would include recharge estimates with and without the assumed application of irrigation. When site-specific simulations are necessary, the results would be evaluated as follows:

- The site-specific transport simulation results for the specified contaminant would be prepared and evaluated.
- The site-specific results under the irrigation recharge scenario would be evaluated to determine whether the waste site conditions result in an exceedance of the contaminant-specific groundwater or surface water protection criteria (e.g., DWS or AWQC). If the waste site conditions did not cause an exceedance of any of the criteria, then the site would be identified for no further action with respect to protection of groundwater and protection of surface water requirements.
- If the waste site conditions do cause an exceedance of any criteria, then site-specific results under a native vegetation recharge scenario would be evaluated next to determine whether waste site conditions result in exceedance of the groundwater or surface water protection criteria. If site conditions did not cause an exceedance of the groundwater or surface water protection criteria, then the waste site would be identified for application of ICs that prevent future irrigation at the site. If site conditions cause an exceedance of groundwater or surface water protection criteria, then the affected waste site would be carried forward into the FS for identification of appropriate remedial alternatives to mitigate risks to groundwater and surface water posed by the vadose zone contamination.

The result of the site-specific evaluation is an assessment of the overall site conditions and if those conditions result in an unacceptable threat to groundwater or surface water.

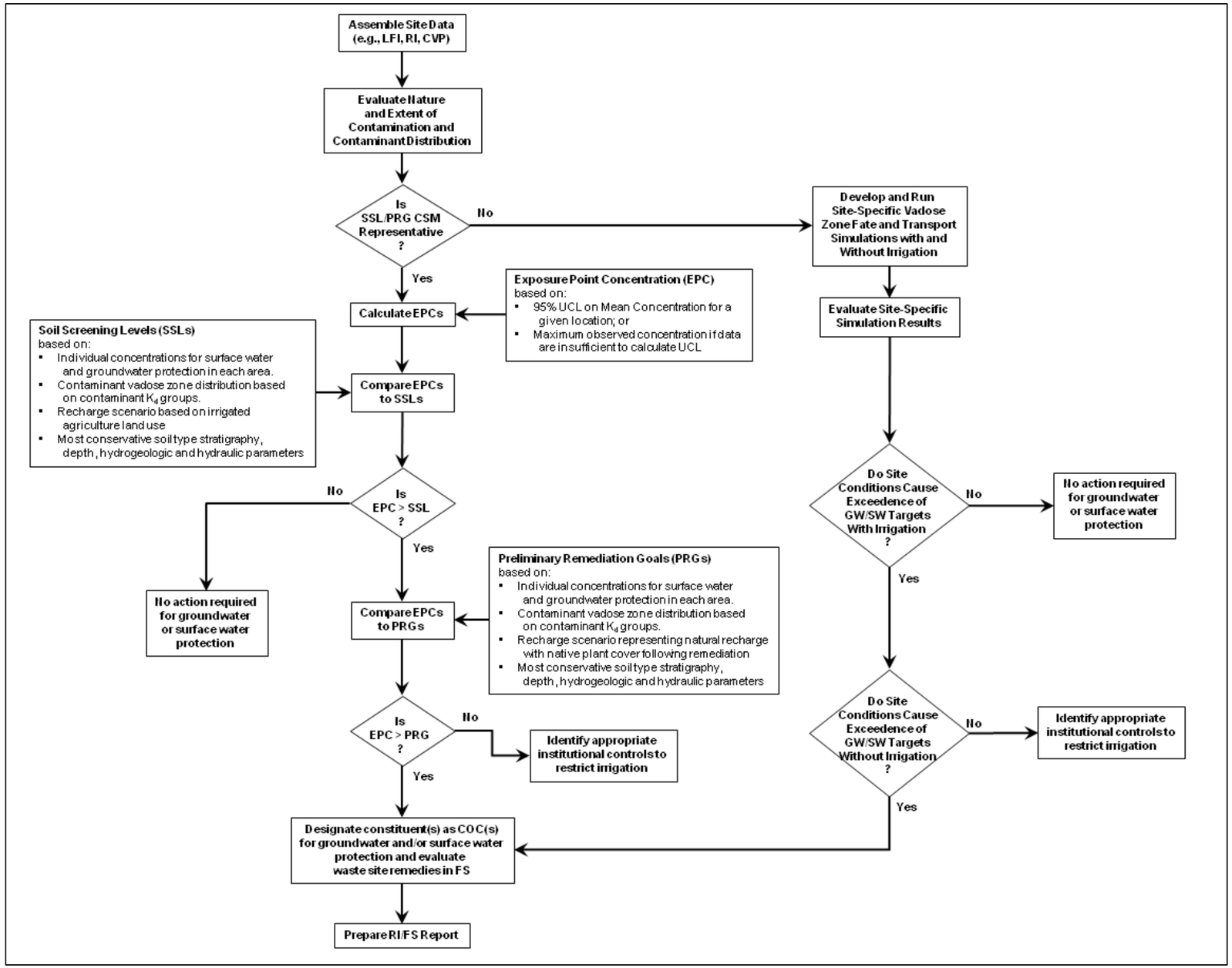


Figure 5-1. Screening Process for Groundwater/Surface Water Protection at Sites with Measurement Data Describing Site Conditions

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5.3.2 Construction and Parameterization

Table 5-1 provides a summary of the model domain and specified input parameters used for the simulations to account for the range of conditions observed or measured at representative locations within 100-K. The information listed in Table 5-1 is described in more detail in the following subsections.

Table 5-1. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-KR-1 and 100-KR-2 Operable Units

Input	Input Value			
Simulation Duration				
Simulation to establish initial hydraulic conditions (yr)	Calendar years 1 to 2010 (arbitrary long period to reach a steady state)			
Simulation to predict contaminant transport (yr)	Calendar years 2010 to 3010			
Upper Boundary Condition: Recharge (Deep Percolation) by Recharge Scenario (Stepwise Constant)				
Input	**Phase**			**Recharge (mm/yr)**
Native vegetation recharge scenario	Pre-Settlement (<1880)			4.0
	Historic Irrigation (1880 to 1944)			72.4
	Hanford Operations (1944 to 2010)			63.0
	Bare Soil (2010 to 2015)			63.0
	Cheatgrass (2015 to 2020)			31.5
	Developing Shrub-Steppe (2020 to 2050)			8.0
	Mature Shrub-Steppe (after 2050)			4.0
Input	**Phase**			**Recharge (mm/yr)**
Irrigation recharge scenario	Pre-Settlement (<1880)			4.0
	Historic Irrigation (1880 to 1944)			72.4
	Hanford Operations (1944 to 2010)			63.0
	Bare Soil (2010 to 2015)			63.0
	Irrigation I (2015 to 2045)			76.4
	Irrigation II (after 2045)			72.4
Lateral Boundary Condition: Hydraulic Gradient (Saturated Portion)				
Hydraulic gradient (m/m)	0.00389			
Hydraulic Parameters				
	Vadose Zone			**Saturated Zone**
	Backfill	**Hanford formation**	**Ringold Formation unit E**	**Ringold Formation unit E**
n_T total porosity (m^3/m^3)	0.276	0.280	0.293	0.293

Table 5-1. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-KR-1 and 100-KR-2 Operable Units

Input	Input Value			
Hydraulic Parameters				
	Vadose Zone			**Saturated Zone**
	Backfill	**Hanford formation**	**Ringold Formation unit E**	**Ringold Formation unit E**
n_D diffusive porosity (m^3/m^3)	0.262	0.247	0.267	0.267
α van Genuchten water retention function inverse air entry matric potential (1/cm)	0.019	0.117	0.083	0.083
n van Genuchten water retention function exponential fitting parameter (dimensionless)	1.400	1.332	1.345	1.345
s_r residual saturation (dimensionless)	0.103	0.021	0.013	0.013
$K_{s,h}$ saturated horizontal hydraulic conductivity (m/d) [a]	0.517	59.36	35.25	5.64
$K_{s,v}$ saturated vertical hydraulic conductivity (m/d) [a,b]	0.517	5.936	3.525	0.564
ρ_p particle density (g/cm^3)	*Calculated from bulk density and porosity;* $\rho_p = \rho_b/(1-n_T)$			
ρ_b bulk density (g/cm^3)	1.94	1.91	1.90	1.90
m Mualem relative permeability function fitting parameter (dimensionless)	$m = (n-1)/n$			
B Mualem relative permeability function exponential term	0.5			
Transport Parameters				
D_m molecular diffusion (m^2/s)	0 (diffusion neglected; conservative assumption with regard to peak concentration)			
α_L longitudinal dispersivity (m)	0 (dispersivity neglected; conservative assumption regarding peak concentration)			
α_T/α_L dispersivity anisotropy ratio (dimensionless)	Not applicable (one-dimensional model)			
K_d partition coefficient (mL/g)	Contaminant of potential concern specific			

Note: The selection basis for all parameters in this table are found in Appendix F (ECF-100KR1-17-0087, *Determination of Unit-Length Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Units*).

a. Saturated hydraulic conductivity for backfill was assumed to be isotropic.

b. Saturated vertical hydraulic conductivity values were computed based on assumed anisotropic ratio of 0.1 to saturated horizontal hydraulic conductivity consistent with the convention used in SGW-44022, *Geohydrologic Data Package in Support of 100-BC-5 Modeling* and SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*.

5.3.2.1 Model Domain

Within the 100-KR-1 and 100-KR-2 OUs, the lithology of both vadose and saturated zones is composed of Hanford formation and Ringold Formation unit E soils in varying amounts. These are represented in the model by layers of discrete materials defined by hydraulic and mechanical properties (Table 5-1). The contact between the Ringold Formation unit E and the RUM unit forms the bottom of the aquifer in the 100-KR-1 and 100-KR-2 OUs.

Thickness and lithologic composition of the vadose and saturated zone sediments were determined using borehole data from the Hanford Environmental Information System (HEIS) borehole database. Boreholes from 100-K were divided into groups that represent the range of vadose zone thicknesses and lithologic composition. The objective was to create a limited number of representative stratigraphic columns so that the number of STOMP simulations could be managed while maintaining fidelity with the hydrostratigraphic conditions observed in the field. This was accomplished by grouping the 100-K boreholes into ten different intervals of vadose zone thickness and then identifying one representative lithologic composition for each interval, as given in Table 5-2 and shown in Figure 5-2. A conservative (thinner) estimate of vadose zone thickness was calculated by taking the difference between ground surface elevation and the June 2008 water table elevations (or similar water year if boreholes did not have data for June 2008), which is representative of the seasonal high-water table elevation. In 100-K, vadose zone thickness ranges between 7 and 25 m (22.9 to 82.0 ft) with an average of 18.2 m (59.7 ft), whereas saturated zone thickness ranges between 7.1 and 25.0 m (23.3 to 82.0 ft), with an average of 18.2 m (59.7 ft). Each column was assumed to contain clean backfill to represent conditions following interim remediation of a waste site.

The model coordinate system is pseudo two dimensional Cartesian, with the vertical (z) axis aligned with the direction of gravitational acceleration and the horizontal (x) axis aligned with the direction of groundwater flow. The y axis is represented numerically by the STOMP simulator but is not used (i.e., no flow or transport occur in this direction of the model).

The model domain consists of a vertical one-dimensional column of grid blocks intersected by a water table. Grid blocks above the water table comprise the vadose zone. Grid blocks below the water table comprise the saturated zone. The location of the water table is assigned in the initial configuration of the model and does not move up or down during simulations. Dimensions of the model grid blocks were selected to capture the hydrostratigraphy and minimize the model run time and unwanted numerical effects. Grid blocks were uniformly 0.25 m (0.8 ft) in height and 10 m (32.8 ft) in length throughout the model domain, with an arbitrarily assigned thickness of 1 m (3.3 ft) along the unused y axis. For implementation into the STOMP model, the thickness of the representative hydrostratigraphic units listed in Table 5-2 was rounded to the nearest multiple of 0.25 m (0.8 ft) to accommodate the model gridding. The thickness of the saturated zone was set to 5 m (16.4 ft) in all models to represent a 5 m (16.4 ft) monitoring well screen (representing the mixing zone).

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Table 5-2. 100-K Representative Lithostratigraphic Columns

Representative Column Index	Representative Vadose Zone Thickness (m)	Representative Vadose Zone Composition	Thickness of Backfill in Vadose Zone (m)	Thickness of Hanford in Vadose Zone (m)	Thickness of Ringold E in Vadose Zone (m)	Corresponding Wells	Thickness of Backfill (m)	Thickness of Hanford (m)	Thickness of Ringold E (m)	Thickness of Ringold Upper Mud (m)	Actual Vadose Zone Thickness (m)	Assigned Saturated Zone (Aquifer) Thickness (m)
Column 1	25	18% Backfill 34% Hanford 48% Ringold E	4.5	8.5	12	199-K-173	0.3	10.4	42.5	2.0	25	5
						199-K-158	0.6	17.7	16.9	(N/P)		
						199-K-167	0.3	10.4	1.8	(N/P)		
Column 2A	16	28% Backfill 42% Hanford 34% Ringold E	4.5	1.5	10	199-K-32B	1.2	9.8	30.5	12.2	16	5
						199-K-32A	6.1	3.4	11.6	(N/P)		
						199-K-144	0.6	2.7	26.2	3.1		
						199-K-178	0.3	7.3	32.9	0.2		
						199-K-181	0.6	5.5	33.8	1.5		
						199-K-190	(N/P)	4.0	36.6	5.8		
						199-K-210	(N/P)	5.2	30.2	1.9		
Column 2B	18.5	20% Backfill 42% Hanford 34% Ringold E	4.5	7.75	6.25	199-K-163	0.9	11.3	21.3	1.1	18.4	5
						199-K-154	0.9	11.3	18.9	1.8		
Column 3	22.75	20% Backfill 53% Hanford 27% Ringold E	4.5	12	6.25	199-K-109A	11.7	(N/P)	35.5	3.9	22.6	5
						199-K-189	0.0	11.0	36.0	1.5		
						199-K-202	12.8	(N/P)	33.8	2.2		
						199-K-186	1.8	12.8	34.7	1.5		
Column 4	20.75	22% Backfill 18% Hanford 60% Ringold E	4.5	3.75	12.5	199-K-111A	9.0	(N/P)	38.3	9.1	20.6	5
						199-K-157	0.9	7.3	34.1	1.3		
Column 5A	25	18% Backfill 29% Hanford 53% Ringold E	4.5	7.25	13.25	199-K-165	0.3	8.5	44.9	1.3	25	5
						199-K-166	0.3	7.9	42.4	1.4		
						199-K-137	0.9	17.4	14.8	(N/P)		
						199-K-108A	9.1	(N/P)	19.4	(N/P)		
Column 5B	23	20% Backfill 9% Hanford 72% Ringold E	4.5	2	16.5	199-K-106A	6.1	0.3	43.1	8.4	23.1	5
						199-K-107A	5.8	(N/P)	23.2	(N/P)		
						199-K-34	1.1	5.0	21.5	(N/P)		
						199-K-139	0.3	7.9	24.8	(N/P)		
Column A1	15.5	29% Backfill 32% Hanford 39% Ringold E	4.5	5	6	199-K-138	0.3	8.8	20.7	(N/P)	15.6	5
						199-K-132	0.2	8.1	18.6	(N/P)		
						199-K-33	7.6	(N/P)	12.5	(N/P)		
						199-K-32B	1.2	9.8	30.5	12.2		

Table 5-2. 100-K Representative Lithostratigraphic Columns

Representative Column Index	Representative Vadose Zone Thickness (m)	Representative Vadose Zone Composition	Thickness of Backfill in Vadose Zone (m)	Thickness of Hanford in Vadose Zone (m)	Thickness of Ringold E in Vadose Zone (m)	Corresponding Wells	Thickness of Backfill (m)	Thickness of Hanford (m)	Thickness of Ringold E (m)	Thickness of Ringold Upper Mud (m)	Actual Vadose Zone Thickness (m)	Assigned Saturated Zone (Aquifer) Thickness (m)
Column B1	7	64% Backfill 36% Ringold E	4.5	(N/P)	2.5	199-K-144	0.6	2.7	26.2	3.0	7.1	5
						199-K-145	1.2	2.4	32.3	1.7		
						199-K-162	0.6	8.5	29.9	1.7		
						199-K-120A	0.9	(N/P)	28.3	1.5		
Column C1	8.5	53% Backfill 9% Hanford 38% Ringold E	4.5	0.75	3.25	199-K-117A	0.3	4.0	16.5	1.5	8.4	5
						199-K-125	0.5	4.1	18.3	0.9		
						199-K-118A	1.2	4.6	17.2	1.7		
						199-K-116A	1.2	5.2	20.1	1.5		
						199-K-115A	1.2	3.7	11.6	2.1		

Hanford = Hanford formation
N/P = Not present
Ringold E = Ringold Formation unit E

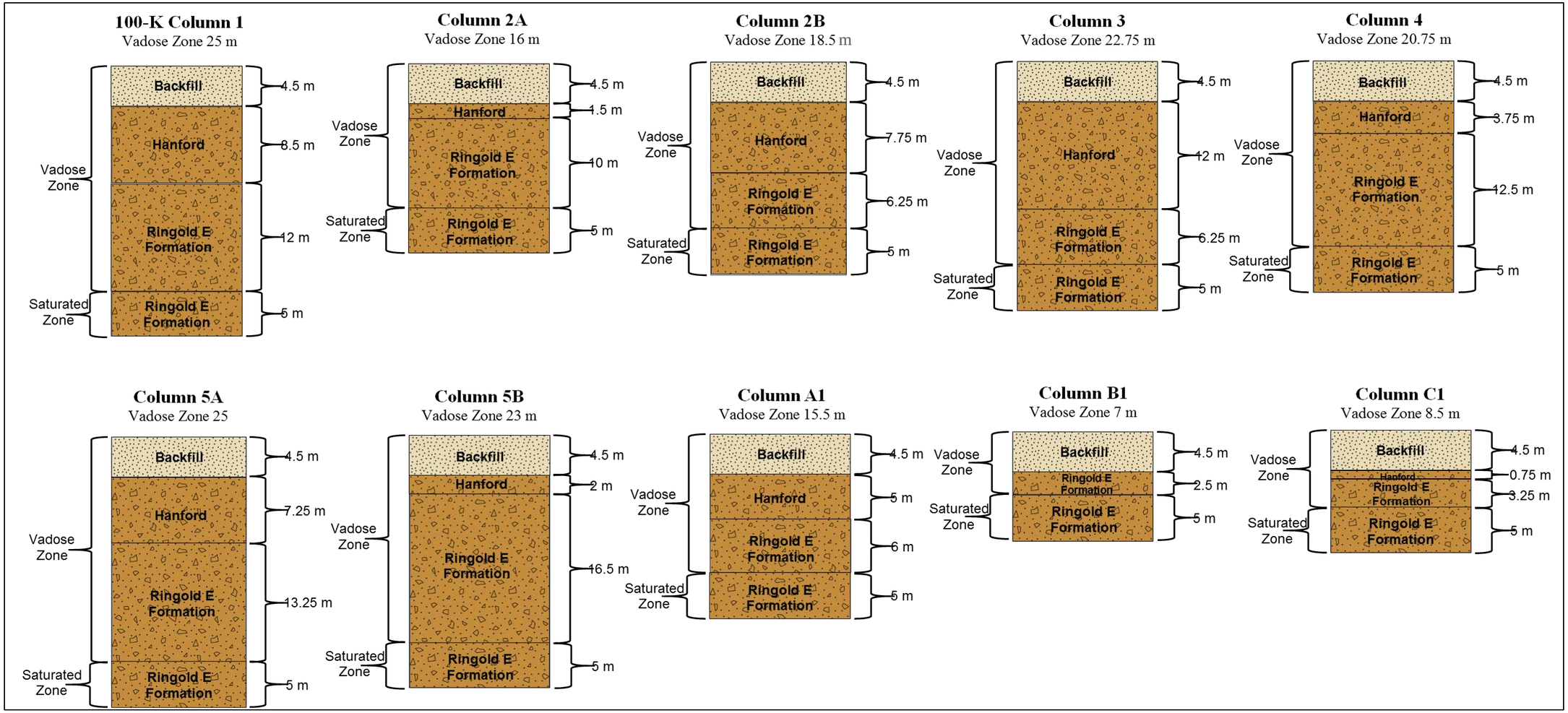

Figure 5-2. Representative Lithostratigraphic Columns for 100-K Source Areas

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The grid block length of 10 m (32.8 ft) was selected to minimize potential numerical artifacts (dispersion) in simulated concentrations within saturated grid blocks. Numerical dispersion is a modeling artifact that can arise when the advective transport distance exceeds the grid block size within a single model time step. Numerical dispersion can be mitigated by setting limits on the minimum grid block size or minimum model time step. Choosing limits that yield a Courant number value on the order of unity will minimize numerical dispersion (Huyakorn and Pinder, 1983, *Computational Methods in Subsurface Flow*). The Courant number is the dimensionless ratio of advective transport distance, defined as the product of groundwater velocity and the model time step, to grid block size (Huyakorn and Pinder, 1983). All simulations used the STOMP Courant limitation scheme, which automatically subdivides transport time steps within flow solution time steps, to ensure that the Courant number for each grid block does not exceed unity throughout the computational mesh. However, the tenfold increase in the grid block length increased the source term area from a unit value to a value of 10. Therefore, the simulated contaminant aqueous concentration values were divided by 10 to give values appropriate for a unit-length SSL and PRG calculation (ECF-100KR1-17-0087).

5.3.2.2 Hydraulic Properties

The hydraulic properties of the stratigraphic units are key in controlling the flow of water through the porous media in both the vadose zone and unconfined aquifer. Hydraulic properties for both the vadose zone and simplified unconfined aquifer, which were required for the fate and transport modeling, were defined to the extent possible by OU specific hydraulic parameter values.

Based on previous Hanford studies, the movement of water through the unsaturated vadose zone stratigraphic units can be defined by the van Genuchten, 1980, "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," moisture retention constitutive relation and the Mualem-van Genuchten relative permeability constitutive relation (Mualem, 1976, "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media"). Assuming these two relationships, the following hydraulic properties are required to be specified in STOMP for each stratigraphic unit:

- n_T total porosity (volume/volume)
- n_D saturated volumetric water content (volume/volume), called diffusive porosity in STOMP
- van Genuchten fitting parameter α (1/length), proportional to the inverse of the air entry matric potential
- van Genuchten exponential fitting parameter n (dimensionless)
- s_r residual saturation (dimensionless), equal to the residual volumetric water content divided by the saturated volumetric water content
- K_s saturated hydraulic conductivity (length/time)

Table 5-3 presents Mualem-van Genuchten parameters for Hanford formation and Ringold Formation unit E soils in the 100 Area based on RPP-RPT-35222, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report*. These form the basis for estimates of Mualem-van Genuchten used in this calculation. Hydraulic parameters used in this calculation are shown in Table 5-4 followed by discussion of the basis of the parameters.

Table 5-3. Mualem-van Genuchten Hydraulic Parameters for the 100 Area Vadose Zone [a]

Sample	HSU	Source Area	Well Number	Depth (m)	% Gravel	θ_s *Saturated Volumetric Moisture Content* (cm^3/cm^3)	θ_r *Residual Volumetric Moisture Content* (cm^3/cm^3)	α van Genuchten Inverse Air Entry Head Fitting Parameter (1/cm)	n van Genuchten Exponential Fitting Parameter (-)	Fitted K_s Fitted Saturated Hydraulic Conductivity [b,c] (cm/s)
2-1307	Ringold	100-HR-3	199-D5-14	18.90	43	0.236	0.0089	0.0130	1.447	0.000129
2-1308	Ringold	100-HR-3	199-D5-14	30.64	58	0.120	0.0208	0.0126	1.628	0.0000697
2-1318	Hanford	100-HR-3	199-D8-54A	15.54	60	0.124	0.0108	0.0081	1.496	0.000167
2-2663	Hanford	100-BC-5	199-B2-12	8.20	61	0.135	0.0179	0.0067	1.527	0.0000673
2-2664	Ringold	100-BC-5	199-B2-12	24.84	73	0.125	0.0136	0.0152	1.516	0.000112
2-2666	Hanford	100-BC-5	199-B4-9	21.49	71	0.138	0.00	0.0087	1.284	0.000102
2-2667	Hanford	100-BC-5	199-B4-9	23.93	75	0.094	0.00	0.0104	1.296	0.00014
3-0570	Hanford	100-KR-1	116-KE-4A	3.50	60	0.141	0.00	0.0869	1.195	0.0206
3-0577	Hanford	100-FR-3	199-F5-43B	7.16	66	0.107	0.00	0.0166	1.359	0.000249
3-0686	Hanford	100-FR-1	116-F-14	6.49	55	0.184	0.00	0.0123	1.600	0.000593
3-1702	Hanford	100-DR-2	199-D5-30	9.78	68	0.103	0.00	0.0491	1.260	0.0013
4-1086	Ringold	100-K	199-K-110A	12.77	65	0.137	0.00	0.1513	1.189	0.0583
4-1090	Hanford	100-K	199-K-111A	8.20	50	0.152	0.0159	0.0159	1.619	0.000405
4-1118	Hanford	100-K	199-K-109A	10.30	66	0.163	0.00	0.2481	1.183	0.0389
4-1120	Ringold	100-K	199-K-109A	18.90	63	0.131	0.0070	0.0138	1.501	0.000285

References: RPP-RPT-35222, *Far-Field Hydrology Data Package for the RCRA Facility Investigation (RFI) Report;* van Genuchten, 1980, "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils."

a. Moisture retention data were measured on the non-gravel sediment fraction (<2 mm size) and corrected for gravel fraction.

b. Assumed to represent vertical hydraulic conductivity

c. Hydraulic conductivities were measured on the bulk samples that included the gravel fraction using the constant-head permeameter method for saturated hydraulic conductivity (Ks) and the unit gradient method for unsaturated hydraulic conductivity.

HSU = hydrostratigraphic unit

Table 5-4. Hydraulic Parameters used for 100-K Source Areas

Geographic Area	Zone	Unit	n_T	n_D	α	n	s_r	$K_{s/h}$	$K_{s/v}$
			Total Porosity (cm^3/cm^3)	Diffusive Porosity (cm^3/cm^3)	van Genuchten Air Entry Fitting Parameter (1/cm)	van Genuchten Exponential Fitting Parameter (-)	Residual Saturation (-)	Horizontal Saturated Hydraulic Conductivity (cm/s)	Vertical Saturated Hydraulic Conductivity (cm/s)
100-K	Backfill	Hanford	0.276 [a]	0.262 [a]	0.019 [a]	1.400 [a]	0.103 [a]	0.000598 [a]	0.000598 [a]
	Vadose	Hanford	0.280 [b]	0.247 [b]	0.117 [c]	1.332 [c]	0.021 [c]	0.0687 [d]	0.00687 [d]
	Vadose	Ringold E	0.293 [e]	0.267 [e]	0.083 [f]	1.345 [f]	0.013 [f]	0.0408 [g]	0.00408 [g]
	Saturated	Ringold E	0.293 [e]	0.267 [e]	0.083 [f]	1.345 [f]	0.013 [f]	0.00653 [h]	0.000653 [h]

References: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*.

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report.*

SGW-40781, *100-HR-3 Remedial Process Optimization Modeling Data Package*.

a. Arithmetic mean of hydraulic parameters for backfill calculated for six samples that were collected within the Hanford Site (hydraulic conductivity assumed isotropic for backfill) reported in PNNL-18564, Table A.12 (these are also the sitewide values for backfill listed in PNNL-14702, Table 4.5).

b. PNNL-18564, Tables 6.3 and 6.4, values for total and effective porosity for Hanford gravelly sand, sitewide. Note the saturated volumetric moisture content values listed in Table 5-3 were determined by applying a gravel correction factor to the values determined in the laboratory on the <2 mm fraction. However, these values appeared to be underestimated and were inconsistent with the high K_s values estimated, so this sitewide estimate was used.

c. Computed arithmetic mean of values for three Hanford formation samples from 100-K (Table 5-3, samples 3-0570, 4-1090 and 4-1118).

d. Computed geometric mean of values for three Hanford formation samples from 100-K (Table 5-3, samples 3-0570, 4-1090 and 4-1118) for vertical value; horizontal value computed based on assumed anisotropic ratio of 0.1.

e. PNNL-18564, Tables 6.3 and 6.4, values for total and effective porosity for Ringold gravel, sitewide.

f. Computed arithmetic mean of values for two Ringold Formation unit E samples from 100-K (Table 5-3, samples 4-1086 and 4-1120).

g. Computed geometric mean of values for two Ringold Formation unit E samples from 100-K (Table 5-3, samples 4-1086 and 4-1120); horizontal value computed based on assumed anisotropic ratio of 0.1.

h. Vertical saturated hydraulic conductivity for saturated zone units was calculated as the geometric mean of aquifer test measurements for the Ringold Formation unit E in the 100-K areas of data reported in SGW-40781, Table 7-1.

The Mualem-van Genuchten hydraulic properties for the Hanford formation in the vadose zone were estimated for each geographic area by averaging the individual parameter values for all samples collected from those respective geographic areas:

- Two Ringold Formation unit E samples from boreholes 199-K-109A and 199-K-110A were selected to provide mean properties for the 100-K OU.
- Three Hanford formation samples from boreholes 116-KE-4A, 199-K-111A, and 199-K-109A (Table 5-3) were selected to provide mean properties for the 100-K OU for the Hanford formation (Table 5-4).

Vertical saturated hydraulic conductivity of the Hanford formation and Ringold Formation unit E were obtained by using the geometric mean of the selected measurements, whereas the other parameters were averaged using the arithmetic mean of the applicable measurements. Horizontal hydraulic conductivity was calculated by assuming an anisotropy ratio of 0.1.

In the absence of more site-specific data, Hanford-wide mean parameter values for the backfill were used. Mean hydraulic parameters for six samples of backfill that were collected within the Hanford site (PNNL-18564) were selected to represent these units within the 100 Area. The backfill parameters used for the 100 Area simulations were also used in flow and transport simulations under variably-saturated conditions at other waste sites, such as the 200-MW-1 and PW-1/3/6 waste sites in the 200 Area (Table 8 in ECF-200MW1-10-0080, *200-MW-1 Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2008-38 Decisional Draft*; Table 11 in ECF-200PW1/3/6-10-0326, *200-PW-1/3/6 Screening Process and Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2007-27 Draft B*).

The van Genuchten m fitting parameter was assumed to be fixed and equal to $(n - 1)/n$ and the Mualem β exponent was assumed to be fixed at 0.5 (Mualem 1976; RPP-RPT-35222). Hanford formation units and Ringold Formation unit E are well to poorly sorted sandy gravels or sandy silty gravels, whereas the backfill consists of poorly sorted sand and gravel with varying fractions of eolian loess and silt (RPP-RPT-35222; SGW-44022, *Geohydrologic Data Package in Support of 100-BC-5 Modeling*; SGW-46279; PNNL-18564). Within the 100-K source OU, the Hanford formation tends to be coarser grained than the Ringold Formation unit E. The former tends to contain larger gravel clasts than the latter, and the Ringold Formation unit E in the 100-K vadose zone consists of semi-indurated clay, silt, fine- to coarse-grained sand, and pebble to cobble-size gravel (SGW-46279). Where present, the RUM was assumed to act as a lower bound (aquitard) for the aquifer (SGW-46279) and so was not directly included in the STOMP simulations.

OU-specific values for several Mualem-van Genuchten hydraulic parameters were obtained for the Hanford formation from data packages SGW-44022 (applicable to the 100-BC and 100-D/H Areas) and SGW-46279 (applicable to the entire 100 Area). The first data package cites the data table for the unsaturated hydraulic properties of 15 samples of sandy gravels from the 100 Area OUs, which were originally described in RPP-RPT-35222. These 100 Area sediments are dominated by the gravel fraction (>2 mm size), with gravel clasts accounting for 43% to 75% of the total sample mass (RPP-RPT-35222). Moisture retention data were measured on the non-gravel sediment fraction (<2 mm size) and corrected for gravel fraction, whereas hydraulic conductivities were measured on the bulk samples that included the gravel fraction using the constant-head permeameter method for saturated hydraulic conductivity (K_s) and the unit gradient method for unsaturated hydraulic conductivity (RPP-RPT-35222). The fitted K_s estimates were assumed to represent vertical hydraulic conductivity.

The horizontal K_s for Ringold Formation unit E in the saturated zone was calculated as the geometric mean of aquifer test measurements for the Ringold Formation in the 100-K areas of data reported in SGW-40781, Table 7-1. Following convention for Hanford sediments (SGW-44022; SGW-46279), an anisotropy ratio of vertical to horizontal saturated hydraulic conductivity of 0.1 was applied to obtain vertical hydraulic conductivity values from the horizontal values discussed above.

5.3.2.3 Boundary and Initial Conditions

Solving the governing equations for variably saturated flow and transport requires stipulation of boundary and initial conditions. A complete set of boundary and initial conditions must be stipulated for each governing equation for input to STOMP. The boundary condition specifications for this model discussed in this subsection are graphically summarized in Figure 5-3. Note that in discussing the boundaries, the directions east, west, north, and south are conventions used in the STOMP code. For this model, these direction references do not (necessarily) align to cardinal directions for any given actual waste site. Rather, the east-west dimension in this STOMP representation is intended to align to the direction of groundwater flow for any waste site.

Upper Boundary Conditions. For water flow, a time-varying Neumann-type (specified water flux) boundary condition was applied at the top surface [Figure 5-3(a)] to represent net infiltration (destined to become recharge). The net infiltration into the vadose zone, which is used in the model to represent the recharge into the aquifer, is driven by the competition between precipitation (including snow), potential evaporation, transpiration, run-off, and run-on. In an arid or semiarid climate, the net downward flux that results from these fluxes are episodic and usually infrequent. This effect is typically damped towards a nearly constant rate with increasing depth as soil moisture variability with depth measured at Hanford Site lysimeters show (PNNL-17841). This is the basis for representing recharge in the vadose zone model using a constant rate applicable to a given soil type and vegetation cover (DOE/RL-2011-50). Several studies have been carried out at the Hanford Site to ascertain representative long-term averages of the episodic fluxes (i.e., recharge rates, such as those compiled in PNNL-14702) for the 100 Areas. The 100 Area specific recharge rates reported in PNNL-14702 vary with surface soil type, providing an estimate of the range of possible recharge rates for various land uses. The three surface soil types relevant to the 100-K waste sites were the Ephrata sandy loam or stony loam, Burbank sandy loam, and Rupert sand. Additionally, PNNL-14702 also provides recharge rates for disturbed soil conditions; the disturbed soil rates representing backfill were selected for use in calculation of SSLs and PRGs for 100-K.

Each calculation of a unit-length SSL or PRG with STOMP requires a pair of simulations. The first is a simulation of water flow only for historic recharge conditions, needed to obtain the soil moisture conditions throughout the model domain at the start time for the second simulation. The second is a coupled simulation of water flow and contaminant transport with the initial moisture distribution provided by the first simulation. Calendar year 2010 was set as the time when the first, historic (pre-2010) simulation ends and the second, predictive (post-2010) simulation begins. Recharge rates were assumed to change over time in step-function fashion, based on changing soil cover.

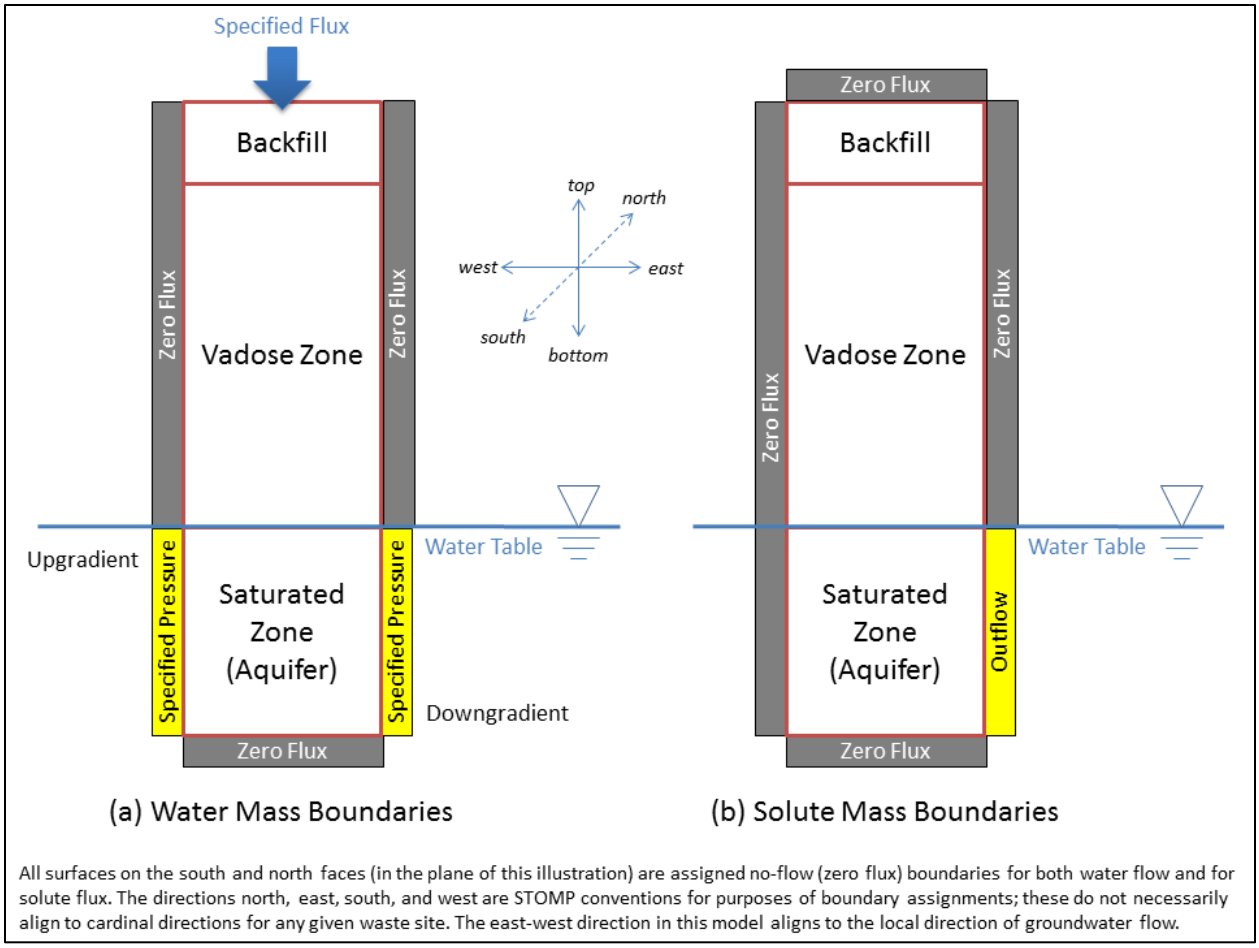


Figure 5-3. Boundary Conditions for (a) Water Mass and (b) Solute Mass Conservation Equations

The long-term natural driving force for contaminant transport through the vadose zone is the downward movement of water. This movement is expressed as follows (PNNL-17841):

- Infiltration refers to water usually resulting from precipitation that enters the ground. Enhanced infiltration may result where surface depressions act as terminuses for overland flow.
- Deep percolation or deep drainage refers to water that has percolated or drained below the zone of evaporation and the influence of plant roots.
- Recharge is water that flows to the water table and is the primary mechanism for transporting contaminants through the vadose zone to groundwater.

Direct measurement of naturally occurring recharge attributed to surface infiltration at the Hanford Site is not practical. Therefore, the measurement is made indirectly because the thickness of the vadose zone and the time scale required for water to travel from the surface to the water table would require long periods of observation. In place of direct measurements of recharge at the water table, measurements and analyses of deep drainage in the unsaturated zone are used to approximate recharge. The terms can be equated, as long as the climate, land use, and land cover remain the same. Consequently, the terms deep percolation or deep drainage are often used synonymously with recharge.

There is ample evidence that revegetation of the disturbed land at the Hanford Site occurs both with and without human intervention. For examples of revegetation with human intervention, refer to annual issues of the River Corridor Contractor Revegetation and Mitigation Monitoring Report (e.g., WCH-288, *2008 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*; WCH-362, *2009 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*; WCH-428, *2010 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*; WCH-512, *2011 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*; and WCH-554, *2012 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*). Data collected from the Prototype Hanford Barrier in the 200 East Area indicates that the sagebrush community begins to reduce net infiltration very soon after planting with sagebrush following an experimental disruption by fire. The western and northern side slopes of the barrier were not planted with sagebrush, but also revegetated without human intervention. The species richness of the plant community on the Prototype Hanford Barrier dropped from 35 in 1997 to 12 in 2007. The dominance of *Artemisia tridentata* (sagebrush) on the surface may continue to reduce the species richness on the surface (Figure 5-4).

Grass cover has decreased from initial levels on the barrier surface and continued decreasing from 2004 to 2007. Cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola kali*) are nearly nonexistent on the barrier surface. The western and northern side slopes of the barrier, which were not planted with sagebrush, show less plant cover but higher species diversity than the barrier surface. This may be due to the influence of windblown material and seeds from adjacent land or the lack of shrubs competing for resources. Insects and small mammals infest the barrier surface, which indicates that the restored barrier surface is beginning to function like a recovering ecosystem.

Numerous studies have estimated recharge rates for the vadose zone at the Hanford Site under various surface cover conditions (as summarized in PNNL-14702; see also PNNL-17481). One such study (PNL-10285, *Estimated Recharge Rates at the Hanford Site*) cites the results of radioisotopic tracer studies that were used to estimate recharge rates under various covers. This included an evaluation of the Ephrata sandy loam and Ephrata stony loam soils, similar to those present at 100-K, where a chlorine-36 tracer study indicated a recharge rate of 2.6 mm/yr (0.1 in./yr) under shrub and bunchgrass cover. The same report describes estimated recharge rates of 4.9 mm/yr (0.2 in./yr) and 17.3 mm/yr (0.7 in./yr) for cheatgrass and bare ground, respectively.

The recharge rate affects the flow velocity/volume of water through the vadose zone. The flow velocity in the vadose zone is expected to have been greatest beneath the retention basin, French drains, trenches, and cribs during the operational period when percolation was greatest. The velocity of downward movement is expected to have decreased after the waste disposal ceased, as the subsurface water content profile began to equilibrate to new (bare soil) surface conditions. After waste disposal operations ended, alterations to the surface cover (including excavation of contaminated soil, backfilling the excavation with clean fill, revegetation, and stabilization) began to alter and reduce the net infiltration rate to the vadose zone.

Reference: PNNL-17176, *200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Years 2005 Through 2007*.

Note: The two photographs show different perspectives of the barrier cover.

Figure 5-4. Prototype Hanford Barrier Cover in 2007 Dominated by Tall Sage (*Artemisia tridentata*) Covering Most of the Soil Surface, 13 Years After Plant Community Establishment

For the historic (pre-2010) simulations, land use and recharge rates were assumed to transition from native vegetation (mature shrub-steppe) during pre-settlement conditions to a historic irrigation period for 1880 to 1944 and a Hanford Site operational period with bare soil from 1944 to 2010. The pre-settlement phase was assumed to begin in CY 1, an arbitrary date that was selected merely to ensure that steady-state moisture conditions are achieved in the solution for the applicable recharge rate by the 1880 year of transition to historic irrigation (1880). Historic irrigation is included in the historic period because multiple land areas in the 100-K OU were used for irrigated agriculture prior to construction of the Hanford Site. The historic irrigation period is conservatively assumed to commence in 1880 and is further conservatively assumed applicable to all waste sites in 100-K. The Hanford Site operational period is conservatively assumed to consist of bare soil conditions, maintained vegetation free, for all waste sites. The recharge rates for each historic phase (pre-settlement with native vegetation, historic irrigation, and Hanford operations) are applied to the top boundary as a constant rate within each phase.

For the predictive simulations (post-2010), two different recharge scenarios were evaluated, representing different future land uses. The native vegetation recharge scenario represents land use that includes restoration and maintenance of a native shrub-steppe plant community. The irrigation recharge scenario represents a bounding condition of irrigated agriculture.

The native vegetation recharge scenario (Table 5-5 and Figure 5-5) is used for calculation of PRG values. The scenario comprises three historic phases discussed previously and four future phases that represent recharge rates changes corresponding to postulated future land use/cover transitions. The first future phase (2010 to 2015) represents the period of continued bare soil cover. The second future phase (2015 to 2020) represents an invasive cheatgrass cover. The third phase represents grasses and developing shrubs as vegetation matures during a 30-year transition (transition period duration from DOE/RL-2011-50). The final phase is mature shrub-steppe that lasts for the remainder of the 1,000-year simulation. Recharge rates diminish in each successive phase for this scenario. Revegetation of waste sites following remediation is assumed in this scenario, consistent with revegetation that is occurring in the 100 Areas accordance with DOE/RL-96-32. Revegetation has been successfully conducted in the 100 Area following other remediation activities (e.g., refer to annual issues of the River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report, including WCH-288, WCH-362, WCH-428, WCH-512, and WCH-554).

The irrigation recharge scenario (Table 5-6 and Figure 5-6) is used for calculation of SSL values. This recharge scenario represents an upper bound, based on recharge rates from irrigated agriculture land use. This recharge scenario comprises transition from bare soil conditions to long-term irrigation farming, and is used here to represent an upper bound on recharge rates for screening purposes. The bounding nature of this recharge scenario is reinforced further by the assumption that irrigated agriculture commences 5 years in the future, much sooner than is reasonable given that Hanford Site remediation activities are expected to continue for decades to come and constrain land use accordingly.

Table 5-5. Native Vegetation Recharge Scenario Phases and Recharge Rates (mm/yr)

Surface Soil Type	Historic Simulation (pre-2010) (Calculation of Initial Hydraulic Conditions)			Predictive Simulation (post-2010) (Calculation of Peak Groundwater Concentrations)			
	Pre-Settlement (<1880)	Historic Irrigation [a] (1880-1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Cheatgrass (2015-2020)	Developing Shrub-Steppe (2020-2050)	Mature Shrub-Steppe (>2050)
Hanford Sand, Disturbed	4.0 [b]	72.4 [c]	63.0 [d]	63.0 [d]	31.5 [e]	8.0 [f]	4.0 [g]

Reference: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments.*

a. Irrigated agriculture was present adjacent to and slightly overlapping the 100-K Area prior to Hanford Site construction; irrigation was conservatively assumed applicable to all 100-K sites from calendar years 1880 through 1944.

b. PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; shrub-steppe.

c. Recharge rates for historic irrigation phase are from the long-term irrigation rate (Irrigation II) under the irrigation recharge scenario (Table 5-6).

d. PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

e. PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; cheatgrass.

f. PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; young shrub-steppe.

g. PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; shrub-steppe.

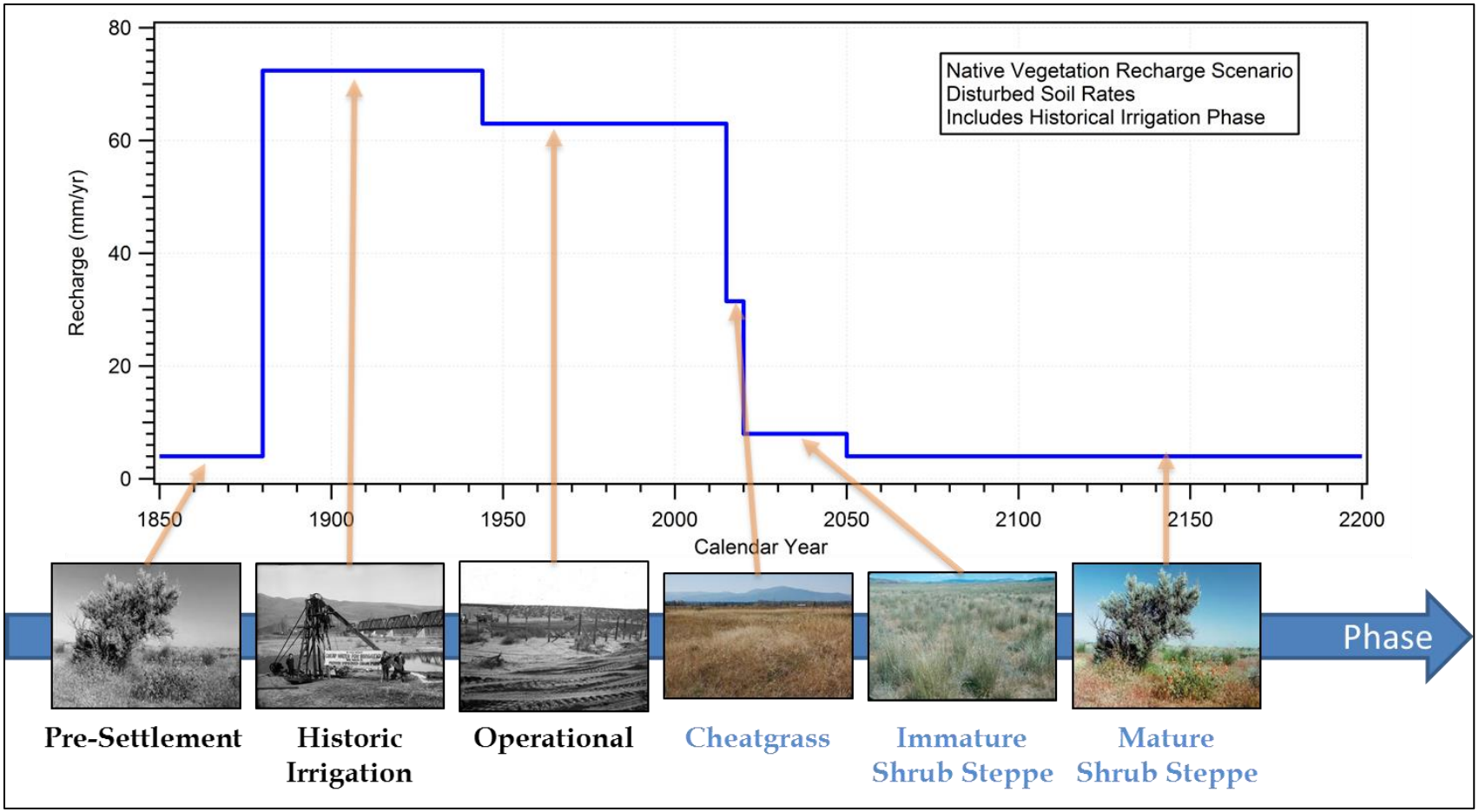


Figure 5-5. Native Vegetation Recharge Scenario

Table 5-6. Irrigation Recharge Scenario Phases and Recharge Rates (mm/yr)

Surface Soil Type	Historic Simulation (pre-2010) (Calculation of Initial Hydraulic Conditions)			Predictive Simulation (post-2010) (Calculation of Peak Groundwater Concentrations)		
	Pre-Settlement (<1880)	Historic Irrigation [a] (1880-1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Irrigation I (2015-2045)	Irrigation II (>2045)
Hanford Sand, Disturbed	4.0 [b]	72.4 [c]	63.0 [d]	63.0 [d]	76.4 [e]	72.4 [e]

References: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments.*

WDOH/320-015, *Hanford Guidance for Radiological Cleanup.*

a. Irrigated agriculture was present adjacent to and slightly overlapping the 100-K Area prior to Hanford Site construction; irrigation was conservatively assumed applicable to all 100-K sites from calendar years 1880 through 1944.

b. Source: PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; shrub-steppe.

c. Recharge rates for historic irrigation phase is that from the long-term irrigation rate (Irrigation II phase).

d. PNNL-14702, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

e. Recharge rates for future irrigation phases represent incremental increases over corresponding undisturbed native vegetation recharge rates, based on WDOH/320-015. The recharge increment attributable to irrigation alone is 68.4 mm/yr. This increment is added to the corresponding rate for immature shrub-steppe (8.0 mm/yr) and mature shrub-steppe (4.0 mm/yr) phases of the native vegetation recharge scenario (Table 5-5) to obtain the total recharge rate.

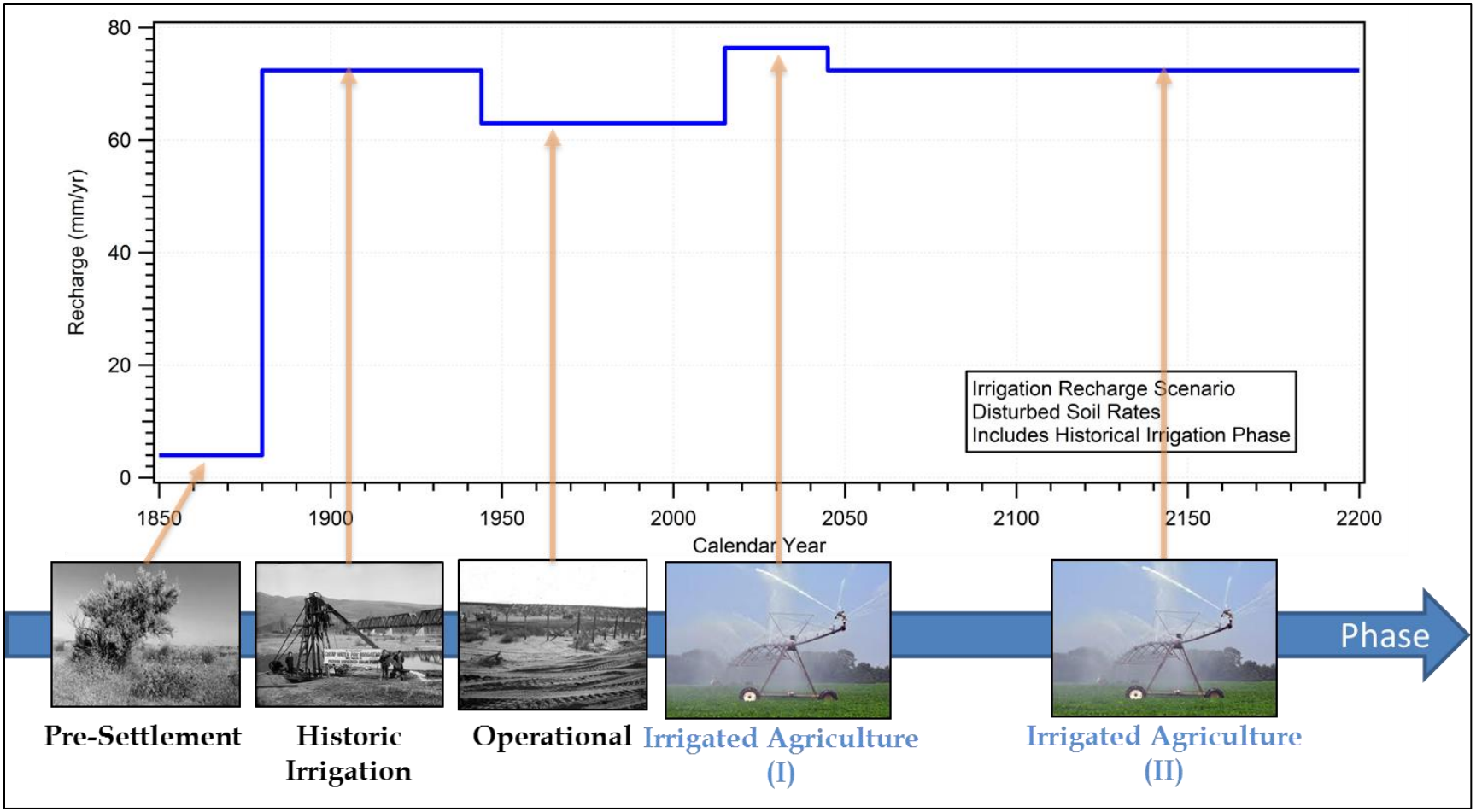


Figure 5-6. Irrigation Recharge Scenario

Recharge rates for the irrigation phases of this scenario were estimated using the same approach used to assess interim remediation at 100 Area waste sites (DOE/RL-96-17) following Washington State Department of Health guidance (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). These previous site assessments used RAGs calculated from RESidual RADiation (RESRAD) computer program simulations that assumed total recharge was a combination of irrigation and native vegetation recharge scenario rates. As the recharge rates used in the RESRAD simulations differ from those adopted for the native vegetation recharge scenario (PNNL-14702), the RESRAD equation for total recharge was back solved to ascertain the recharge rate attributable to irrigation alone.

According to the RESRAD manual, total recharge rate is a function of precipitation, evapotranspiration, runoff, and applied irrigation. As the recharge rates used in the RESRAD simulations were different from those adopted from PNNL-14702, the RESRAD equation for total recharge was solved to determine the rate attributable to irrigation alone. Based on that approach, the calculated nonirrigation total recharge rate was 11.6 mm/yr (0.5 in./yr), and the recharge attributable to irrigation alone was 68.4 mm/yr (2.7 in./yr). This resultant irrigation rate was added to the native soil recharge rate (Table 5-5) to determine a recharge rate for the irrigation scenario for each soil type in the SSL simulations. The resulting recharge rates for each soil type for the irrigation phases are shown in Table 5-6.

For solute transport under both native vegetation and irrigation recharge scenarios, a specified zero contaminant flux boundary was applied at the top of the model domain, so no contaminant source will be introduced across the upper boundary of the model [Figure 5-3(b)].

Lower Boundary Conditions. The bottom of the model domain is assigned a constant zero flux boundary condition for both water mass and contaminant mass (solute) transport (Figure 5-3). This boundary condition limits the aquifer representation in this model to the appropriate thickness and restricts groundwater flow and solute transport in the aquifer to the lateral (horizontal) direction only.

Lateral Boundary Conditions. For the portion of the model domain in the vadose zone [Figure 5-3(a)] a constant zero-flux lateral boundary condition for both water transport and solute transport was assigned to restrict flow in the vadose zone to one-dimensional vertical flow. This is a conservative representation with respect to the arrival time and the magnitude of the peak groundwater concentrations.

For the portion of the model domain in the saturated zone, a constant Dirichlet type (specified head) boundary condition is specified at the upgradient (western) and downgradient (eastern) edges aligned with the assumed direction of groundwater flow to represent the water table and to impose the desired hydraulic gradient. The hydraulic gradients used for the simulations were based on Automated Water Level Network (AWLN) data obtained from HEIS. Hydraulic head data from March 2008 were used to calculate the hydraulic gradient for the 100-K OUs. Triangulated irregular networks (TINs) were fitted to the wells using ArcGIS®[3] and hydraulic gradients were computed for each TIN. The median, a measure of the central tendency of the computed gradients, was selected as a representative value, yielding hydraulic gradients of 0.00389 m/m for 100-K. The details on the method for calculating hydraulic gradients is reported in ECF-HANFORD-14-0028, *Median Hydraulic Gradient Calculation to Support Development of Soil Screening Levels and Preliminary Remediation Goals in the 100 Area*. The summarized results from the 100-K hydraulic gradient study are found in SGW-50776 in Table 4-3.

Aquifer conditions are dynamic in the 100 Area; the hydraulic gradient, saturated thickness, and in many cases, direction of flow vary throughout the year. The use of median gradients is intended to provide a broadly representative value for use in calculation of unit-length SSLs and PRGs that will be applicable for the range of locations in each geographic area. This gradient is applied to a model stratigraphy that is

[3] ArcGIS is a registered trademark of the Environmental Systems Research Institute, Redlands, California.

based on high-river stage conditions for minimizing the vadose zone thickness as a bounding condition to minimize transport time.

For solute transport, the upgradient edge of the model domain in the aquifer was assigned zero-flux boundary condition while the downgradient edge was assigned an outflow solute boundary condition [Figure 5-3(b)]. The outflow solute boundary condition for transport of solute out of the model domain but does not allow solute to enter the domain.

Initial Conditions. For hydraulic initial conditions, an arbitrary value was assigned as the initial pressure at the start of the historic (pre-2010) flow simulations. A value of 86,656.7 Pa, approximately equivalent to −1.5 m (−4.9 ft) matric potential, was assigned to the nodes in the vadose zone, whereas the aquifer grid blocks were assigned values that matched the boundary condition pressures. Final pressures from the historic (pre-2010) simulations were used as the initial pressures for the predictive (post-2010) coupled flow and transport simulations.

5.3.2.4 Transport Properties

The contaminant transport parameters required by STOMP are the particle and bulk density of the backfill and stratigraphic units, the dispersion coefficients, the half-life radioactive decay term for each radiological COPC, and the soil/water distribution coefficient for each COPC.

The particle density (ρ_p) values of the backfill, Hanford formation, and Ringold Formation unit E are presented in Table 5-1. Bulk density is needed for retardation scaling factor calculations. Estimates of bulk density for Hanford formation and Ringold Formation unit E were obtained from PNNL-14702, which gave 1.91 g/cm^3 (119.2 lb/ft^3) for the Hanford formation and 1.90 g/cm^3 (118.6 lb/ft^3) for the Ringold Formation unit E. The bulk density estimate of 1.94 g/cm^3 (118.6 lb/ft^3) for backfill was obtained from PNNL-18564.

Hydrodynamic dispersion was conservatively assumed negligible; therefore, values for both the mechanical dispersion terms and molecular diffusion were set to zero. By ignoring the hydrodynamic dispersion, the reduction of the COPC concentrations due to spreading during transport is not incorporated and thus yields higher peak groundwater concentrations than would be obtained using non-zero values. This, therefore, is a conservative assumption with respect to SSL and PRG values.

A key component to the retardation scaling factor is the soil/water distribution coefficient, or K_d value. The K_d values for all COPCs (both radionuclides and non-radionuclides except uranium) were obtained from ECF-HANFORD-12-0023 and are listed in Tables 5-7 and 5-8. The K_d value for uranium was selected by simulating transport in the soil column at well 199-K-222. Any other well location within the 100-KR-4 OU was not considered for the site-specific K_d study as the reported soil concentrations at these boreholes were less than the detection limit. Additionally, it should be noted that the selected K_d value for Cr(VI) in ECF-HANFORD-12-0023 was derived from the site-specific analysis for the 100 Area presented in ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.*

STOMP accounts for contaminant first order radioactive decay in the solute mass conservation equation. Half-life values for the radionuclide COPCs were obtained as described in ECF-100KR1-17-0087, and are listed in Table 5-8. Chain radioactive decay was not incorporated into the simulations because no radionuclide COPC has significant daughter products.

Biodegradation is neglected in this calculation, which is generally a conservative assumption because the result is to overstate the persistence of a COPC by neglecting its biodegradation. However, in some circumstances, this may be nonconservative where biodegradation products are also COPCs.

For example, COPCs such as chloroform can degrade to methylene chloride and chloromethane, which have higher cancer slope factors. Dichloroethylene can eventually degrade to vinyl chloride, which has a higher cancer slope factor than dichloroethylene.

Volatilization and gas phase transport are conservatively neglected in this calculation to maximize the peak groundwater concentration predicted by the model.

5.3.2.5 Contaminant Source Term

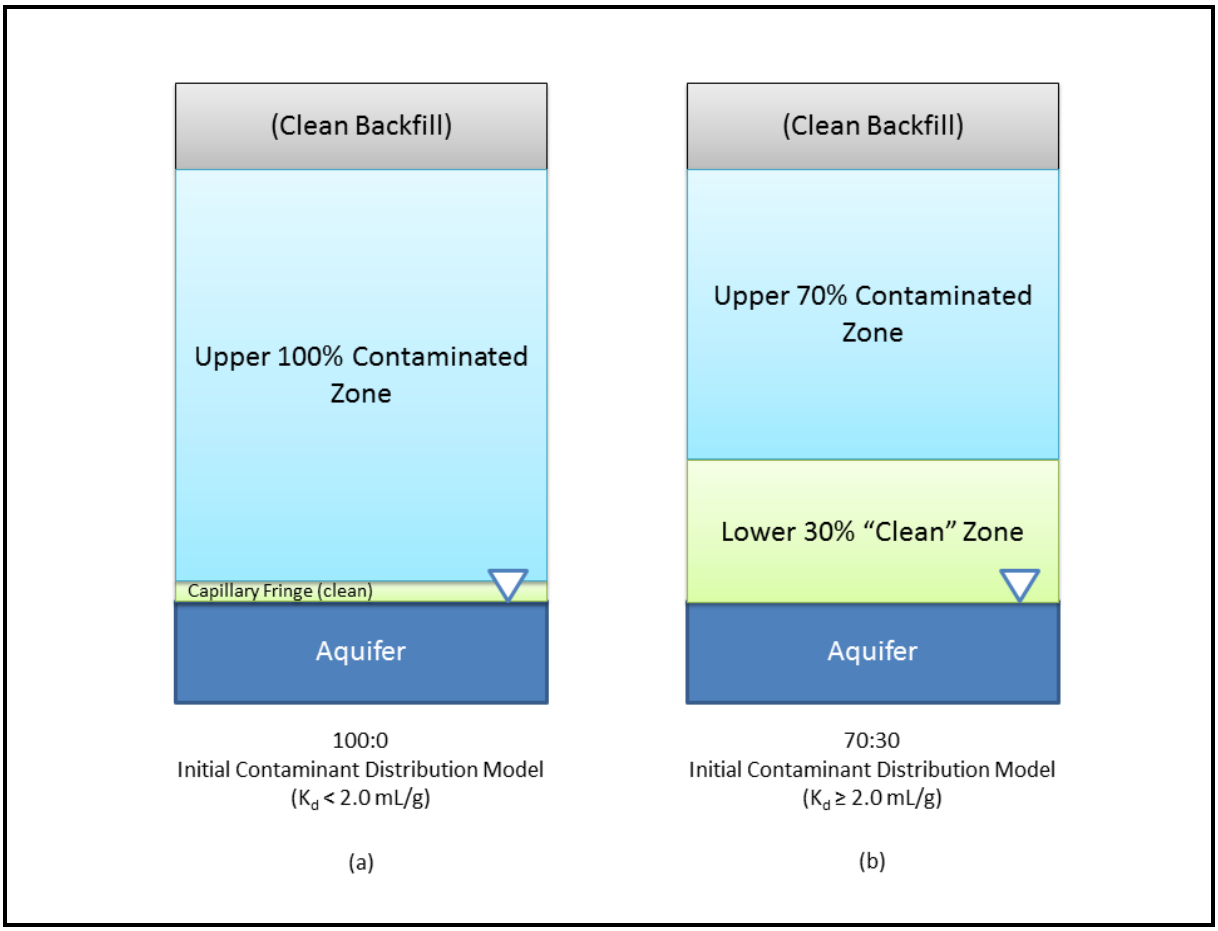
Based on observations of contaminant distribution made using laboratory analysis of soil samples collected from RI borings and wells, the spatial distribution of contaminants was identified for use in the initial flow and transport simulations. Numerous contaminants were found to be distributed across the full vadose zone thickness, while others exhibited limited vertical distribution (Section 4.2). Based on this observation, contaminants were grouped into two categories. The first category included contaminants with low K_d (<2 mL/g) values, while the second category included contaminants with high K_d (≥2 mL/g) values. The process used for identifying low K_d and high K_d range contaminants is presented in SGW-51818, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*.

The initial contaminant distribution in the vadose zone fate and transport models was imposed to calculate peak groundwater concentrations resulting from a uniform concentration over an appropriate vertical depth range of the vadose zone. For the lower K_d contaminants (K_d<2 mL/g), the entire vadose zone thickness, from below the clean backfill down to 0.5 m (1.6 ft) above the water table was assumed to be contaminated. This is termed the 100:0 initial source distribution [Figure 5-7(a)]. Contaminant mass was not assigned in the 0.5 m (1.6 ft) zone above the water table due to the capillary fringe and water table, which could result in unrepresentative large peak releases in the simulation start because of the extreme concentration gradients created by the application of this initial condition.

For the higher K_d contaminants (K_d ≥2 mL/g), the conservative assumption of contamination throughout the full thickness of the vadose zone was modified. For these contaminants, the upper 70% of the vadose zone below the clean backfill was assumed to be contaminated, while the lower 30% was treated as uncontaminated; this is termed the 70:30 initial source distribution [Figure 5-7(b)]. The 70:30 initial source distribution assumption is deemed conservative for the high K_d contaminants, with respect to peak groundwater concentration, based on observed limited vertical extent of such contaminants within the vadose zone.

A notable exception to the K_d based assignment of an initial source distribution was made for the COPC strontium-90. Field data revealed that strontium-90 is distributed throughout the vadose zone (Section 4.2), despite its relatively high K_d value, for reasons having to do with historical discharge practices that no longer dominate the subsurface. As a result, use of a 70:30 initial source distribution for this COPC would clearly be nonconservative; thus, the 100:0 initial source distribution will be utilized for strontium-90 at all waste sites.

For each transport simulation, whether low K_d or high K_d, the initial concentration distribution applied across the relevant portions of the vadose zone was a unit concentration (1 mg/kg for nonradionuclide COPCs or 1 pCi/kg for radionuclide COPCs). The use of the unit-concentration source is a common practice in the simulation of multi-contaminant transport in a system where transport is controlled by K_d.



Note: Strontium-90 (K_d = 25 mL/g) is an exception, simulated with 100:0 model; see text for explanation.

Figure 5-7. 100:0 and 70:30 Initial Contaminant Distribution Models

The transport simulation results for individual contaminants can then be readily scaled in the SSL and PRG calculation.

5.3.3 Vadose Zone Model Results

The initial contaminant concentrations were assigned based on the 100:0 or 70:30 source configuration at the start of year 2010. The predictive (post-2010) STOMP simulations were then conducted with a maximum duration of 1,000 years, as per Tri-Party agency agreement.

For each COPC, with its respective K_d value and radioactive decay half-lives, 20 simulations were conducted. These 20 simulations were a product of the 10 lithostratigraphic columns, and two recharge scenarios.

COPC concentrations in the groundwater are calculated at the downgradient boundary over the 1,000-year simulation time frame. This concentration represents mixing in the top 5 m (16.4 ft) of the aquifer consistent with the requirements for aquifer mixing zone thickness in WAC 173-340-747(5)(f)(i).

For each recharge scenario, the resulting time varying groundwater concentration for each COPC was evaluated, and the peak groundwater concentration within the 1,000-year simulation period were selected as the basis for calculating the unit-length SSL (assuming the irrigation recharge scenario) or PRG (assuming the native vegetation recharge scenario).

Table 5-7. Summary of Chemical Unit-Length SSLs and PRGs Protective of Groundwater and Surface Water Calculated with STOMP

Chemical Abstracts Service No.	Analyte	K_d Value used to Calculate SSL and PRG [a] (mL/g)	Required Detection Limit [b] (mg/kg)	Groundwater			Surface Water		
				Groundwater Standard [c] (µg/L)	Unit-Length GW SSL [d,e] (mg/kg)·m	Unit-Length GW PRG [d,e] (mg/kg)·m	Surface Water Standard [c] (µg/L)	Unit-Length SW SSL [d,e] (mg/kg)·m	Unit-Length SW PRG [d,e] (mg/kg)·m
83-32-9	Acenaphthene	4.9	0.330	960	2,620	81,300	--	NA	NA
67-64-1	Acetone	0.000575	0.020	7,200	207	279	--	NA	NA
7429-90-5	Aluminum	1,500	--	16,000	NR	NR	87	NR	NR
7440-36-0	Antimony	45	0.600	6.00	186	154,000	--	NA	NA
120-12-7	Anthracene	23.5	0.330	4,800	67,300	389,000	--	NA	NA
12674-11-2	Aroclor-1016	107	0.017	0.5	99.6	NR	0.014	2.79	NR
11097-69-1	Aroclor-1254	131	0.017	0.044	15	NR	0.014	4.77	NR
11096-82-5	Aroclor-1260	822	0.017	0.044	NR	NR	0.014	NR	NR
7440-38-2	Arsenic	29.0	10	10	173	69,700	150	2,590	389,000
7440-39-3	Barium	41	2	2,000	53,700	389,000	--	NA	NA
56-55-3	Benzo(a)anthracene	358	0.015	0.88	7,670	NR	--	NA	NA
50-32-8	Benzo(a)pyrene	969	0.015	0.088	NR	NR	--	NA	NA
205-99-2	Benzo(b)fluoranthene	1,230	0.015	0.88	NR	NR	--	NA	NA
207-08-9	Benzo(k)fluoranthene	1,230	0.015	8.8	NR	NR	--	NA	NA
7440-41-7	Beryllium	790	0.5	4.0	NR	NR	--	NA	NA
117-81-7	Bis(2-ethylhexyl) phthalate	111	0.33	6	1,310	NR	--	NA	NA
7440-42-8	Boron	3	2	3,200	5,380	118,000	--	NA	NA
7440-43-9	Cadmium (Diet)	6.7	0.5	5.0	18.8	801	0.72	2.71	115
7440-47-3	Chromium	1,000	1	100	NR	NR	74	NR	NR
218-01-9	Chrysene	398	0.1	88	389,000	NR	--	NA	NA
7440-48-4	Cobalt	45	2	4.8	149	123,000	--	NA	NA

Table 5-7. Summary of Chemical Unit-Length SSLs and PRGs Protective of Groundwater and Surface Water Calculated with STOMP

Chemical Abstracts Service No.	Analyte	K_d Value used to Calculate SSL and PRG [a] (mL/g)	Required Detection Limit [b] (mg/kg)	Groundwater			Surface Water		
				Groundwater Standard [c] (µg/L)	Unit-Length GW SSL [d,e] (mg/kg)·m	Unit-Length GW PRG [d,e] (mg/kg)·m	Surface Water Standard [c] (µg/L)	Unit-Length SW SSL [d,e] (mg/kg)·m	Unit-Length SW PRG [d,e] (mg/kg)·m
7440-50-8	Copper	22	1	640	8,400	389,000	9.9	130	31,500
53-70-3	Dibenz[a,h]anthracene	1,790	0.03	0.088	NR	NR	--	NA	NA
84-74-2	Di-n-butylphthalate	1.57	330	1,600	1,430	12,200	--	NA	NA
107-21-1	Ethylene glycol	0.001	0.33	16,000	463	625	--	NA	NA
206-44-0	Fluoranthene	49.1	0.33	640	23,000	389,000	--	NA	NA
86-73-7	Fluorene	7.71	0.33	640	2,830	140,000	--	NA	NA
16984-48-8	Fluoride	150	5	960	389,000	NR	--	NA	NA
18540-29-9	Hexavalent Chromium	0.8	0.5	48	6.0 [e]	6.0 [e]	10	6.0 [e]	6.0 [e]
193-39-5	Indeno(1,2,3-cd)pyrene	3,470	0.33	0.88	NR	NR	--	NA	NA
7439-89-6	Iron	25	--	11,200	167,000	389,000	1,000	14,900	389,000
7439-92-1	Lead	10,000	5	15	NR	NR	2.1	NR	NR
7439-96-5	Manganese	65	5	384	23,400	389,000	--	NA	NA
7439-97-6	Mercury (Mercuric chloride)	52	0.2	2	79.3	79,700	0.012	0.476	478
75-09-2	Methylene chloride	0.01	0.005	5	0.169	0.225	--	NA	NA
7439-98-7	Molybdenum	20	2	80	954	195,000	--	NA	NA
91-20-3	Naphthalene	1.19	0.33	160	110	645	--	NA	NA
7440-02-0	Nickel	65	4	100	6,100	389,000	52	3,170	389,000
14797-55-8	Nitrate	0	0.75	45,000	1,280	1,730	--	NA	NA
14797-65-0	Nitrite	0	0.75	3,300	93.8	127	--	NA	NA
NO2+NO3-N	Nitrogen in Nitrite and Nitrate	0	0.75	10,000	284	384	--	NA	NA

Table 5-7. Summary of Chemical Unit-Length SSLs and PRGs Protective of Groundwater and Surface Water Calculated with STOMP

Chemical Abstracts Service No.	Analyte	K_d Value used to Calculate SSL and PRG [a] (mL/g)	Required Detection Limit [b] (mg/kg)	Groundwater			Surface Water		
				Groundwater Standard [c] (µg/L)	Unit-Length GW SSL [d,e] (mg/kg)·m	Unit-Length GW PRG [d,e] (mg/kg)·m	Surface Water Standard [c] (µg/L)	Unit-Length SW SSL [d,e] (mg/kg)·m	Unit-Length SW PRG [d,e] (mg/kg)·m
129-00-0	Pyrene	68	0.33	480	32,200	389,000	--	NA	NA
7782-49-2	Selenium	5	1	50	139	4,400	5.0	13.9	440
7440-22-4	Silver	8.3	0.2	80	385	20,700	2.6	12.5	672
7440-24-6	Strontium	35	1	9,600	207,000	389,000	--	NA	NA
7440-28-0	Thallium	71	--	0.50	36.8	NR	--	NA	NA
7440-31-5	Tin	250	10	9,600	389,000	NR	--	NA	NA
TPH	Total petroleum hydrocarbons	4	--	500	1,120	29,300	--	NA	NA
TPHDIESEL	Total petroleum hydrocarbons - diesel range	--	--	--	NA	NA	--	NA	NA
TPHDIESELEXT	Total petroleum hydrocarbons - diesel range extended to C36	--	--	--	NA	NA	--	NA	NA
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	--	--	--	NA	NA	--	NA	NA
7440-61-1	Uranium	70	1	30	2,140	NR	--	NA	NA
7440-62-2	Vanadium	1,000	2.5	80	NR	NR	--	NA	NA

Table 5-7. Summary of Chemical Unit-Length SSLs and PRGs Protective of Groundwater and Surface Water Calculated with STOMP

Chemical Abstracts Service No.	Analyte	K_d Value used to Calculate SSL and PRG [a] (mL/g)	Required Detection Limit [b] (mg/kg)	Groundwater			Surface Water		
				Groundwater Standard [c] (µg/L)	Unit-Length GW SSL [d,e] (mg/kg)·m	Unit-Length GW PRG [d,e] (mg/kg)·m	Surface Water Standard [c] (µg/L)	Unit-Length SW SSL [d,e] (mg/kg)·m	Unit-Length SW PRG [d,e] (mg/kg)·m
7440-66-6	Zinc	62	1	4,800	266,000	389,000	91	5,040	389,000

References: DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area.*

ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100-Area.*

ECF-HANFORD-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area.*

a. K_d values reported here were used in calculations and may differ in precision (rounding) from values reported in ECF-HANFORD-12-0023, but were derived from the same electronic data set.

b. Reported in ECF-HANFORD-12-0023

c. DOE/RL-96-17

d. The following restrictions were applied to soil screening levels:

- "NA" was assigned where no applicable water quality standard was available.
- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative lithostratigraphic column within 1,000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 µg/L (a value set as the lower limit of numerical significance).
- Value defaults to the RDL for any analyte where the calculated value is less than the RDL.
- Value was limited to a physical upper bound of 389,000 mg/kg, based on the maximum pore space contaminant mass capacity.

e. PRGs/SSLs protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these SSLs, divide the listed value by a representative length across the waste site decision unit in the general direction of groundwater flow to obtain the SSL for evaluation use.

f. The SSL for Cr(VI) is set to 6.0 mg/kg based on the evaluation in ECF-HANFORD-11-0165; this value is not dependent on waste site size.

GW = groundwater

PRG = preliminary remediation goal

RDL = required detection limit

SSL = soil screening level

SW = surface water

Table 5-8. Summary of Radionuclide Unit-Length SSL and PRGs Protective of Groundwater Calculated with STOMP

Chemical Abstracts Service No.	Radionuclide	K_d Value used to Calculate SSL and PRG [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Required Detection Limit [c] (mg/kg)	Unit-Length Groundwater SSL [d,e] (pCi/g)·m	Unit-Length Groundwater PRG [d,e] (pCi/g)·m
14596-10-2	Americium-241	200	15	432	1	92,100	NR
14762-75-5	Carbon-14 [f]	0	2000	5,700	2	57	76.9
10045-97-3	Cesium-137	50	200	30.2	0.1	389,000	NR
10198-40-0	Cobalt-60	50	100	5.27	0.05	NR	NR
14683-23-9	Europium-152	200	200	13.5	0.1	NR	NR
15585-10-1	Europium-154	200	60	8.59	0.1	NR	NR
14391-16-3	Europium-155	200	600	4.76	0.1	NR	NR
13981-37-8	Nickel-63	30	50	100	30	19,000	NR
13981-16-3	Plutonium-238	200	15	87.7	1	NR	NR
PU-239/240	Plutonium-239/240	200	--	6,560	1	NA	NA
10098-97-2	Strontium-90 [g]	25	8	28.8	1	22,500	389,000
10028-17-8	Tritium	0	20,000	12.3	--	1,040	1,070
U-233/234	Uranium-233/234	2	--	159,000	1	NA	NA
15117-96-1	Uranium-235	2	--	704,000,000	0.5	NA	NA
7440-61-1	Uranium-238	2	--	4,470,000,000	1	NA	NA

References: DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area.*

ECF-HANFORD-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*.

EMDT-DE-0006, *Half-lives for Typical Hanford Site Radioactive Contaminants* (copy provided in Attachment D of ECF-100KR1-17-0087).

Note: PRGs/SSLs protective of groundwater and protective of surface water are provided on a unit-length basis. To apply these PRGs, the listed value is divided by a representative length across the waste site in the general direction of groundwater flow to obtain the PRG for waste site evaluation.

a. ECF-HANFORD-12-0023

b. EMDT-DE-0006

c. DOE/RL-96-17

d. The following restrictions were applied to PRGs:

- "NA" was assigned where no applicable water quality standard was available.

Table 5-8. Summary of Radionuclide Unit-Length SSL and PRGs Protective of Groundwater Calculated with STOMP

Chemical Abstracts Service No.	Radionuclide	K_d Value used to Calculate SSL and PRG [a] (mL/g)	Maximum Contaminant Level [a] (pCi/L)	Half-life [b] (yr)	Required Detection Limit [c] (mg/kg)	Unit-Length Groundwater SSL [d,e] (pCi/g)·m	Unit-Length Groundwater PRG [d,e] (pCi/g)·m

- "NR" was assigned where a non-representative result was obtained in cases where breakthrough was not simulated to occur in more than one representative lithostratigraphic column within 1,000 years, where breakthrough is defined as groundwater concentration exceeding 0.0001 pCi/m^3 (a value set as the lower limit of numerical significance).

e. Value defaults to the RDL for any analyte where the calculated value is less than the RDL.

f. Carbon-14 in liquid form (typically associated with reactor gas condensate).

g. Cleanup levels for strontium-90 are calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with Kd ≥2 mL/g were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these operable units.

PRG = preliminary remediation goal (the term "PRG" in this table refers to a preliminary remediation goal calculated for conservation with native vegetation land use)

RDL = required detection limit

SSL = soil screening level (the term "SSL" in this table refers to a preliminary remediation goal calculated for an irrigation land use scenario)

A simple calculation was then employed to compute unit-length SSL and PRG values by scaling the selected peak concentration value based on a unit-length source against the regulatory compliance criteria and the initial soil concentration. As a measure of allowable quantity of contaminant in the soil, unit length SSLs and PRGs are expressed as contaminant mass per unit mass of soil for chemicals (or as contaminant activity per unit mass of soil for radionuclides per meter) times unit distance of the waste site decision unit in the direction of groundwater flow.

The unit-length SSL for each COPC is computed as:

$$SSL_{UL} = C_I \frac{WQS}{CPK} \tag{5a}$$

where:

SSL_{UL} ≡ unit-length soil screening level $\left[\frac{\text{mg}}{\text{kg}} \cdot \text{m or } \frac{\text{pCi}}{\text{g}} \cdot \text{m}\right]$

C_I ≡ initial soil mass or activity concentration $\left[\frac{\text{mg}}{\text{kg}} \text{or} \frac{\text{pCi}}{\text{g}}\right]$

WQS ≡ water quality standard $\left[\frac{\text{mg}}{\text{L}} \text{or} \frac{\text{pCi}}{\text{L}}\right]$

CPK ≡ peak groundwater mass or activity concentration within 1,000 years down gradient of soil column with unit length in the direction of groundwater flow calculated under the irrigation recharge scenario $\left[\frac{\text{mg}}{\text{L}} \text{or} \frac{\text{pCi}}{\text{L}}\right]$

Similarly, the unit-length PRG for each COPC is computed as:

$$PRG_{UL} = C_I \frac{WQS}{CPK} \tag{5b}$$

where:

PRG_{UL} ≡ unit-length preliminary remediation goal $\left[\frac{\text{mg}}{\text{kg}} \cdot \text{m or } \frac{\text{pCi}}{\text{g}} \cdot \text{m}\right]$

C_I ≡ initial soil mass or activity concentration $\left[\frac{\text{mg}}{\text{kg}} \text{or} \frac{\text{pCi}}{\text{g}}\right]$

WQS ≡ water quality standard $\left[\frac{\text{mg}}{\text{L}} \text{or} \frac{\text{pCi}}{\text{L}}\right]$

CPK ≡ peak groundwater mass or activity concentration within 1,000 years down gradient of soil column with unit length in the direction of groundwater flow for the native vegetation recharge scenario of groundwater flow calculated under the native vegetation recharge scenario $\left[\frac{\text{mg}}{\text{L}} \text{or} \frac{\text{pCi}}{\text{L}}\right]$.

The standard values used for *WQS* are the surface water quality standards for computing the unit-length SSLs and PRGs protective of surface water, whereas the groundwater quality standards are used to compute unit-length SSLs and PRGs protective of groundwater. The water quality standards are in Appendix F, ECF-HANFORD-12-0023.

COPC breakthrough was assumed not to occur if the simulated peak groundwater concentrations within the 1,000-year simulation time frame did not exceed a value of 0.0001 µg/L for nonradionuclide COPCs or 0.0001 pCi/m^3 for radionuclide COPCs, in at least one of the representative stratigraphic columns simulated. In these instances, the results were below a level of numerical significance and were thus designated as non-representative.

The unit-length SSLs and PRGs for each COPC were calculated for the corresponding recharge scenario (i.e., irrigation recharge for SSL and native vegetation for PRG) and for each of the ten lithostratigraphic columns. The resulting unit-length SSL and PRG values were evaluated and adjusted based on the following provisions:

- If the calculated SSL/PRG value was less than the required detection limit (RDL), as provided in DOE/RL-96-17, then the RDL was selected as the final value.

- In situations where simulated peak groundwater concentrations are very small, application of Equations (5a) and (5b) yields physically impossible soil concentrations (e.g., 10 kg of aluminum per 1 kg of soil), so an upper physical bound value was derived. This calculated limit is based on considering the maximum contaminant mass that can occupy all the soil pore space within a unit mass (1 kg) of bulk soil. This maximum value was determined to be 389,000 mg per kg of soil (ECF-100KR1-17-0087 [Appendix F]). Therefore, if the calculated protective value exceeded this physical upper bound, it was limited to 389,000 mg/kg.

- ECF-100KR1-17-0087 provides quantitative evaluations of leach test results and the derivation of a conservative-basis K_d for Cr(VI) to evaluate future fate and transport of residual vadose zone contamination after interim remedial actions have been implemented for source waste sites in the vadose zone. These evaluations were based on results of leaching studies conducted on soil samples from a large number (about 200) of leach studies for vadose zone soils across the River Corridor, including both high-concentration/low-volume waste sites, low concentration effluent waste sites, and boreholes not associated with a waste site. The soil concentration data for which the K_d value was derived had a maximum value of 6.0 mg/kg; hence, there is no basis to infer greater soil cleanup levels for Cr(VI) based on the limited range of these data. These leach test data also indicate that Cr(VI) concentrations below 6.0 mg/kg are highly non-leachable. Therefore, the SSL and PRG values for Cr(VI) using the K_d recommended in ECF-Hanford-11-0165 (0.8 mg/L) are set to a soil concentration value of 6.0 mg/kg, consistent with the data range and leaching test results. This value is not scaled by the representative dimension in the general direction of groundwater flow because the bases for the K_d value are bounding results for intentionally aggressive leaching methods that showed highly non-leachable Cr(VI) concentrations below 6 mg/kg in the vadose zone, a result that is not dependent on the dimensionality of the model. The soil PRG and SSL values for protection of groundwater and surface water for Cr(VI) are not based on results of fate and transport modeling but rather on interim cleanup actions, originally based on the 100 times rule, which assigns the more restrictive value of 2.0 mg/kg.

For both protection to groundwater and surface water, a single unit-length SSL and a single unit-length PRG value were then selected for each COPC, which corresponded to the minimum value calculated from the 10 stratigraphic columns. Table 5-7 presents the selected unit-length SSLs and PRGs protective of groundwater and surface water for each chemical COPC, based on a unit-length source. Table 5-8 presents the SSLs and PRGs protective of groundwater for each radionuclide COPC, based on a unit-length source. The unit-length SSLs and PRGs for protection of surface water were not calculated for the radionuclide COPCs because federal water quality criteria for radionuclides have yet to be established. Section 5.4 applies these unit-length SSLs and PRGs to individual 100-K waste sites.

The unit-length SSL and PRG values obtained from the vadose zone models must be scaled by a representative length in the general direction of groundwater flow to obtain values for use in evaluating EPCs for a given waste site decision unit:

$$SSL_{EVAL} = \frac{SSL_{UL}}{L_{\parallel GW}} \quad \textbf{(5c)}$$

$$PRG_{EVAL} = \frac{PRG_{UL}}{L_{\parallel GW}} \quad \textbf{(5d)}$$

where:

$SSL_{EVAL} \equiv$ unit-length soil screening level for evaluation use $\left[\frac{\text{mg}}{\text{kg}} \text{ or } \frac{\text{pCi}}{\text{g}}\right]$

$L_{\parallel GW}$ representative length in the direction parallel to the direction of groundwater flow [m].

This scaling is required because the larger the waste site extends in the direction of groundwater flow, the more contamination that is contributed to groundwater. A simple example illustrates this concept. Figure 5-8(a) depicts the 1 m (3.3 ft) basis for the derivation of the unit-length SSL and PRG values in which soil is contaminated at initial concentration C_I, and the transport of this contaminant vertically downward in the vadose zone, then laterally in the aquifer, results in a peak groundwater concentration *CPK* (within 1,000 years) at the downgradient edge of the waste site. The ratio of the resulting value of *CPK* to the applicable groundwater protection level is used to determine the maximum value of C_I (using Equation 5a or 5b) that would not exceed the applicable protection level. Inherent to this construct is the dimension in the direction of groundwater flow (to which the model is intentionally aligned). The greater the length in this direction, the more contaminant mass arrives in groundwater from soil contaminated at level C_I, and the higher *CPK* becomes on the downgradient edge of the waste site. In Figure 5-8(b), this is illustrated by considering a waste site with a representative length of 5 m (16.4 m). Even though the concentration of soil contamination is the same in the 1 m (3.3 ft) and 5 m (16.4 ft) cases, the total contaminant mass arriving in groundwater is five times greater in the 5 m (16.4 ft) wide case than in the 1 m (3.3 ft) case. This results in a *CPK* value five times greater in the 5 m (16.4 ft) case, which when scaled will result in a protection level (SSL or PRG value) five times smaller than in the 1 m (3.3 ft) case. Therefore, the SSL and PRG values derived from the model are provided on a unit-length basis, so they can be directly scaled by the waste site decision unit representative length in the direction of groundwater flow. Scaling is accomplished by dividing the unit-length SSL or PRG value by the representative length in the direction of groundwater flow. Scaled values then explicitly account for the total mass arrival in groundwater, based on waste site size, and are appropriate to apply for evaluation of whether EPC values would potentially result in exceedance of protection levels. Care must also be taken to ensure that the scaled SSL or PRG values are truncated at RDL and/or background levels before comparison, in case scaling reduces these values below those thresholds.

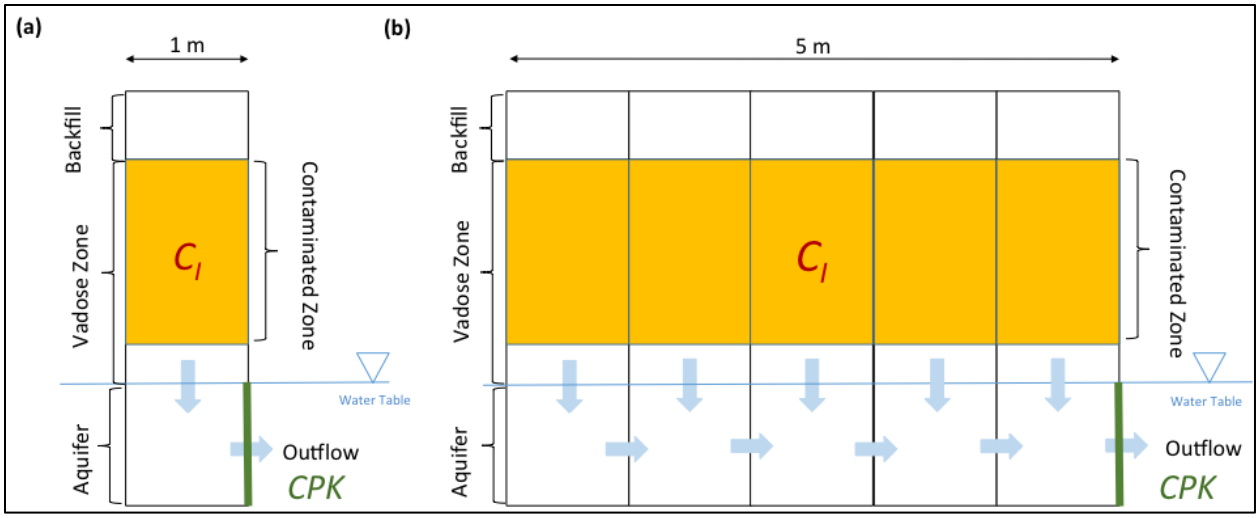


Figure 5-8. Illustration of Application of Unit-Length SSL and PRG Values

5.3.4 Uncertainty Analysis

Potential sources of uncertainty in risk assessments are primarily in the categories of (1) model uncertainties, (2) scenario uncertainties, and (3) parameter uncertainties. Model uncertainty pertaining to the equations used as numerical representations of the natural processes is expected to be relatively small (DOE/RL-2011-50).

STOMP has been shown through comparison to analytical solutions, benchmarking against other codes, and field validation to solve the governing equations it incorporates for flow and transport processes correctly, but that the representativeness of any given model implemented using STOMP is inherently limited by the accuracy of the conceptual representation and the representativeness of the parameterization.

DOE/RL-2011-50 provides a summary evaluation of the comparisons of field data and field test results to corresponding model results obtained using the STOMP code, and the evaluation indicates that the equations used in STOMP adequately simulate the natural processes. The technical basis regarding scenario and parameter selection and the evaluation of uncertainty and variability is also documented in DOE/RL-2011-50. Documentation is provided in DOE/RL-2011-50 on (1) dominant model factors, (2) model parameter values and plausible ranges of parameter values, (3) model assumptions and effects on model results, and (4) model limitations.

Application of the SSL and PRG values calculated herein requires an understanding of which assumptions and modeling choices were conservative and which were not. The following assumptions and modeling choices are conservative:

- The vadose zone is considered homogeneous in nature, without accounting for the thin, finer grained material, which can retard the downward migration of contaminants.
- Vadose zone thicknesses for the representative stratigraphic columns were minimized by using water tables from a typical high-water month when developing the stratigraphic columns for use in an average annual model; this minimizes contaminant transport time, thereby resulting in higher and earlier groundwater peak concentrations.

- The one-dimensional simulations force all water and contamination through the vadose zone down to the aquifer, whereas infiltrating water and solutes tend to migrate laterally as the wetting front redistributes following an infiltration event.
- Recharge was represented in the numerical model by uniform flux rates specified over particular periods so that vadose zone flow is always downward. In contrast, recharge in an arid vadose zone occurs only as often as the combination of precipitation and antecedent moisture conditions allow (i.e., sporadically or infrequently) so that there can be long periods when shallow vadose zone pore water movement is controlled more by evaporation and transpiration near the surface than gravity, resulting in upward movement or reduced downward seepage velocity.
- Based on current revegetation activities, revegetation of a waste site after remediation is typically occurring within one to two growing seasons. In the modeling, revegetation of the area is assumed to start after five years, with bare soil present for the first five years. This conservative assumption results in more water infiltrating to the vadose zone than may actually occur.
- Recharge rates for the native vegetation scenario used to calculate PRGs uses the highest native vegetation rates based on numerous lysimeter and tracer recharge studies (PNNL-17841).
- SSL values used for screening were calculated for bounding (highest) recharge rates postulated in the irrigation recharge scenario. A conservative treatment in this scenario is that irrigation is assumed to commence much sooner than is reasonable (within five years); this leads to earlier and higher peak groundwater concentrations under this scenario than would be the case if irrigation were assumed not to commence until perhaps a few decades later.
- The initial condition (either the 100:0 or 70:30 model) represents a bounding initial condition that effectively assumes the maximum residual soil contamination level is uniformly present over the entire applicable vadose zone thickness (a peak or maximum concentration level would not be expected to occur over the entire depth range).
- Hydrodynamic dispersion is assumed negligible, which leads to larger peak concentrations than if dispersion had been included.
- VOCs are assumed to have negligible volatilization so that the resulting peak concentrations are larger than if volatilization had been included.
- The assumption of a 5 m (16 ft) thick aquifer is conservative as 100-K has an aquifer thicknesses greater than 5 m (16 ft).
- The single aquifer hydraulic gradient value specified for all source areas is smaller than measured for the waste sites near the Columbia River. A smaller hydraulic gradient will yield lower aquifer groundwater fluxes and higher peak concentrations along with a subsequently lower SSL and PRG values.
- Groundwater is assumed to have negligible mixing with the Columbia River. In calculating the values for surface water protection, the point of compliance is assumed to occur in groundwater at the downgradient boundary of the waste site. No attenuation or decay of contaminants is assumed to occur between the downgradient boundary of the waste site and the river.

The following assumption may or may not be conservative:

- The surface cover used in development of PRGs includes a progression from bare ground through a developing shrub-steppe plant community to a long-term mature shrub-steppe community. This surface cover may be subject to specific uncertainty due to the potential for wildfire effects. Wildfires occur periodically (and can be characterized by a recurrence frequency), and the effects of these events would likely result in a net increase of the long-term recharge rate to groundwater underlying affected areas. Note, SSLs are not impacted by fire cycle effects as these are calculated for an irrigation scenario.

5.4 Application of Vadose Zone Fate and Transport Model Results

SSLs and PRGs represent a data evaluation tool that provides a technical basis for identifying whether a previously remediated waste site could pose a threat to groundwater or surface water quality. The unit-length SSLs and PRGs derived for application to 100-K waste sites are listed in Tables 5-7 and 5-8. The development of the unit-length SSLs and PRGs are documented in ECF-100KR1-17-0087 (Appendix F).

The application of these unit-length SSLs and PRGs to 100-K wastes sites requires site-specific information on the representative dimensions of the waste site decision units and the EPC for each COPC present. Table 5-9 presents a listing of 100-K waste site decision units that were evaluated. Representative waste site lineal dimensions assuming an overall northerly direction of groundwater flow for use in scaling unit-length SSL and PRG values are derived in ECF-100KR1-17-0092, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations* (Appendix F). The calculation of an EPC for each COPC present at each waste site evaluated was based on a 95% UCL. The process for calculating an EPC is discussed in Section 6.2.2 and the resulting calculated EPC values for 100-K waste sites are in ECF-100KR4-17-0081, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit* (Appendix F).

Once the waste site-specific EPCs, SSLs, and PRGs were determined for each COPC, the determination of whether a waste site could pose a threat to groundwater or surface water quality was conducted in ECF-100KR4-17-0240, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water*. These determinations are presented in the following subsections.

Table 5-9. Interim Remediated Waste Sites in 100-K Evaluated Using Scaled SSL and PRG Values

Waste Site Decisional Unit Identification			
100-K-102_Shallow_1	100-K-102_Shallow_2	100-K-102_Shallow_Focused	100-K-105_Shallow_1
100-K-105_Shallow_2	100-K-105_Shallow_3	100-K-106_Overburden_1	100-K-106_Overburden_2
100-K-106_Overburden_3	100-K-106_Overburden_Focused_2	100-K-106_Shallow	100-K-106_Shallow_Focused_1
100-K-106_Shallow_Focused_2	100-K-106_Shallow_Focused_3	100-K-106_Shallow_Focused_4	100-K-106_Shallow_Focused_5
100-K-106_Shallow_Focused_6	100-K-109_Shallow	100-K-109_Shallow_Focused	100-K-110_Shallow
100-K-110_Shallow_focused	100-K-14, 126-KE-2_Shallow	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5N	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5S
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow_Focused	100-K-29_Shallow_Focused	100-K-3, 100-K-36, 100-K-79:7_Deep
100-K-3, 100-K-36, 100-K-79:7_Shallow	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_1	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_2	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_3
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_4	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P10	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P11	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P16
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P17	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P18	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P19	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P20
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P21	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P25	100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P9	100-K-3, 100-K-36, 100-K-79:7_Shallow_P3P6
100-K-3, 100-K-36, 100-K-79:7_Shallow_P4P5	100-K-3, 100-K-36, 100-K-79:7_Shallow_Sewer	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Overburden	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_1	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_2	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_3	100-K-3_Shallow_1
100-K-3_Shallow_2	100-K-30_Shallow_Focused	100-K-31_Shallow_Focused	100-K-32_Shallow_Focused
100-K-33_Shallow_Focused	100-K-34, 100-K-102, 1607-K3_Overburden_11A	100-K-34, 100-K-102, 1607-K3_Overburden_11B	100-K-34, 100-K-102, 1607-K3_Shallow

Table 5-9. Interim Remediated Waste Sites in 100-K Evaluated Using Scaled SSL and PRG Values

Waste Site Decisional Unit Identification			
100-K-34, 100-K-102, 1607-K3_Shallow_Focused	100-K-34_Shallow	100-K-36_Shallow	100-K-36_Shallow_Focused
100-K-4_Deep	100-K-4_Shallow	100-K-46_Shallow	100-K-47, 100-K-69, 100-K-70, 100-K-71_Shallow
100-K-50, 1607-K2_Shallow	100-K-53_Shallow	100-K-55:1_Deep	100-K-55:1_Overburden
100-K-55:1_Shallow	100-K-55:1_Shallow_Focused	100-K-56:1_Deep	100-K-56:1_Shallow
100-K-56:1_Shallow_Focused	100-K-6, 100-K-46, 100-K-62, 132-KE-1_Overburden	100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2
100-K-6_Shallow	100-K-62_Shallow	100-K-63_Shallow_1	100-K-63_Shallow_2
100-K-77_Shallow	100-K-78_Shallow_Focused	100-K-84_Shallow	100-K-85_Shallow_Focused
100-K-86_Shallow_Focused	100-K-88_Shallow_Focused	100-K-89, 600-29_Shallow	100-K-89, 600-29_Shallow_Focused
100-K-90_Shallow_Focused	100-K-91_Shallow_Focused	100-K-92_Shallow_Focused	100-K-95_Shallow
116-K-1_Deep	116-K-1_Overburden	116-K-1_Shallow	116-K-2_Deep_1
116-K-2_Deep_2	116-K-2_Overburden	116-K-2_Shallow_1	116-K-2_Shallow_2
116-KE-4_Shallow	116-KE-5_Shallow_Focused	116-KW-3_Shallow	116-KW-4_Shallow_Focused
118-K-1_Overburden_12	118-K-1_Overburden_13	118-K-1_P1_Shallow_1	118-K-1_P1_Shallow_2
118-K-1_P1_Shallow_3	118-K-1_P1_Shallow_4	118-K-1_P1_Shallow_5	118-K-1_P1_Shallow_Focused_1
118-K-1_P1_Shallow_Focused_2	118-K-1_P1_Shallow_Focused_3	118-K-1_P2_Deep_2	118-K-1_P2_Deep_3
118-K-1_P2_Deep_4	118-K-1_P2_Deep_5	118-K-1_P2_Deep_6	118-K-1_P2_Deep_7
118-K-1_P2_Deep_8	118-K-1_P2_Shallow_1	118-K-1_P2_Shallow_10	118-K-1_P2_Shallow_11A
118-K-1_P2_Shallow_11B	118-K-1_P2_Shallow_11C	118-K-1_P2_Shallow_11D	118-K-1_P2_Shallow_11E
118-K-1_P2_Shallow_11F	118-K-1_P2_Shallow_11G	118-K-1_P2_Shallow_11H	118-K-1_P2_Shallow_2
118-K-1_P2_Shallow_3	118-K-1_P2_Shallow_4	118-K-1_P2_Shallow_5	118-K-1_P2_Shallow_6

Table 5-9. Interim Remediated Waste Sites in 100-K Evaluated Using Scaled SSL and PRG Values

Waste Site Decisional Unit Identification			
118-K-1_P2_Shallow_7	118-K-1_P2_Shallow_8	118-K-1_P2_Shallow_9	118-K-1_P2_Shallow_Focused_1
118-K-1_P2_Shallow_Focused_2	118-K-1_P2_Shallow_Focused_3	118-K-1_P2_Shallow_Focused_4	118-K-1_P2_Shallow_Focused_5
118-K-1_P2_Shallow_Focused_6	118-K-1_P2_Shallow_Focused_7	118-K-1_P2_Shallow_Focused_8	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Overburden_7
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Overburden_9	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow_Focused	128-K-1_Shallow_Focused
128-K-2_Shallow	128-K-2_Shallow_Focused	132-KE-1_Shallow	1607-K3_Shallow
600-29_Shallow	600-29_Shallow_Focused		

5.4.1 Comparison of Waste Site EPCs to SSLs

A comparison of the waste site-specific EPCs to the waste site-specific (scaled) SSLs protective of groundwater and surface water (based on irrigation land use) was conducted for each COPC that was found at each waste site. If the comparison indicated that an EPC was greater than the corresponding SSL, then that COPC and waste site were moved forward for comparison to the less restrictive PRG values derived for conservation land use (native vegetation). This comparison provides the FS with knowledge whether an irrigation restriction would be protective of groundwater and surface water. Regardless, all EPCs that exceed the SSL move forward to the FS for further evaluation.

The results of the comparison for protection of groundwater indicated 24 instances where 7 different COPCs had EPCs greater than the scaled SSL distributed across 22 waste site decision units. For the surface water protection comparison, results indicated 42 instances where 9 different COPCs had EPCs greater than the scaled SSL distributed across 34 waste site decision units. A description of the comparison process and a listing of the comparison results is provided in ECF-100KR4-17-0240 (Appendix F).

Table 5-10 lists the waste sites and decision units with a COPC EPC exceedance of the scaled SSL protective of groundwater. Table 5-11 lists the waste sites and decision units with a COPC EPC exceedance of the scaled SSL protective of surface water.

Table 5-10. Waste Site Decision Units with EPCs Greater than Scaled SSLs (Irrigation Scenario) Protective of Groundwater

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled SSL Protective of Groundwater* (µg/kg or pCi/g)	Is EPC > Scaled SSL Protective of Groundwater?
100-K-110_Shallow	Antimony	7440-36-0	4,420	1,390	Yes
100-K-110_Shallow	Iron	7439-89-6	33,500,000	32,600,000	Yes
100-K-110_Shallow	Selenium	7782-49-2	1,810	1,040	Yes
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	Carbon-14	14762-75-5	65.5	4.15	Yes
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2	Carbon-14	14762-75-5	139	4.15	Yes
100-K-6_Shallow	Carbon-14	14762-75-5	34.8	26.6	Yes
100-K-62_Shallow	Carbon-14	14762-75-5	20.2	4.15	Yes
100-K-63_Shallow_1	Selenium	7782-49-2	1,290	1,000	Yes
116-K-2_Deep_1	Hexavalent Chromium	18540-29-9	6,060	6,000	Yes
116-K-2_Deep_2	Carbon-14	14762-75-5	4.62	3.25	Yes
118-K-1_P1_Shallow_3	Iron	7439-89-6	33,600,000	32,600,000	Yes
118-K-1_P1_Shallow_5	Nitrate	14797-55-8	77,400	69,100	Yes
118-K-1_P2_Deep_5	Iron	7439-89-6	34,000,000	32,600,000	Yes
118-K-1_P2_Deep_8	Iron	7439-89-6	36,000,000	32,600,000	Yes
118-K-1_P2_Shallow_11A	Nitrate	14797-55-8	121,000	52,000	Yes
118-K-1_P2_Shallow_11B	Nitrate	14797-55-8	391,000	52,000	Yes

Table 5-10. Waste Site Decision Units with EPCs Greater than Scaled SSLs (Irrigation Scenario) Protective of Groundwater

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled SSL Protective of Groundwater* (µg/kg or pCi/g)	Is EPC > Scaled SSL Protective of Groundwater?
118-K-1_P2_Shallow_11C	Nitrate	14797-55-8	169,000	52,000	Yes
118-K-1_P2_Shallow_11D	Nitrate	14797-55-8	148,000	52,000	Yes
118-K-1_P2_Shallow_11E	Nitrate	14797-55-8	56,000	52,000	Yes
118-K-1_P2_Shallow_11F	Nitrate	14797-55-8	65,100	52,000	Yes
118-K-1_P2_Shallow_7	Antimony	7440-36-0	16,300	2,590	Yes
118-K-1_P2_Shallow_9	Nitrate	14797-55-8	231,000	58,200	Yes
132-KE-1_Shallow	Carbon-14	14762-75-5	14.5	11.6	Yes
600-29_Shallow	Nickel	7440-02-0	37,500	30,900	Yes

References: ECF-100-KR1-0087, *Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Unit.*

ECF-100KR1-17-0092, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations*.

ECF-100KR4-17-0240, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water*.

*The scaled SSL value is based on scaling of the unit-length SSLs, presented in ECF-100-KR1-0087 (Appendix F), by the representative length of the waste site decision unit parallel to the general direction of groundwater flow (ECF-100KR1-17-0092 [Appendix F]) and evaluated against EPCs in ECF-100KR4-17-0240 (Appendix F).

EPC = exposure point concentration

SSL = soil screening level

Table 5-11. Waste Site Decision Units with EPCs Greater than Scaled SSLs (Irrigation Scenario) Protective of Surface Water

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled SSL Protective of Surface Water* (µg/kg or pCi/g)	Is EPC > Scaled SSL Protective of Surface Water?
100-K-102_Shallow_1	Mercury	7439-97-6	5,090	200	Yes
100-K-102_Shallow_1	Selenium	7782-49-2	1,720	1,000	Yes
100-K-102_Shallow_2	Cadmium	7440-43-9	962	563	Yes
100-K-102_Shallow_2	Mercury	7439-97-6	1,210	200	Yes
100-K-109_Shallow	Selenium	7782-49-2	1,030	1,000	Yes
100-K-110_Shallow	Iron	7439-89-6	33,500,000	32,600,000	Yes
100-K-110_Shallow	Mercury	7439-97-6	431	200	Yes
100-K-110_Shallow	Selenium	7782-49-2	1,810	1,000	Yes
100-K-110_Shallow	Zinc	7440-66-6	76,500	67,800	Yes
100-K-14, 126-KE-2_Shallow	Mercury	7439-97-6	492	2	Yes
100-K-30_Shallow_Focused	Mercury	7439-97-6	17,500	476	Yes

Table 5-11. Waste Site Decision Units with EPCs Greater than Scaled SSLs (Irrigation Scenario) Protective of Surface Water

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled SSL Protective of Surface Water* (µg/kg or pCi/g)	Is EPC > Scaled SSL Protective of Surface Water?
100-K-31_Shallow_Focused	Mercury	7439-97-6	5,200	476	Yes
100-K-32_Shallow_Focused	Mercury	7439-97-6	13,700	476	Yes
100-K-33_Shallow_Focused	Mercury	7439-97-6	6,800	476	Yes
100-K-34, 100-K-102, 1607-K3_Shallow	Copper	7440-50-8	23,500	22,000	Yes
100-K-4_Deep	Selenium	7782-49-2	1,660	1,000	Yes
100-K-4_Shallow	Selenium	7782-49-2	1,510	1,000	Yes
100-K-46_Deep	Copper	7440-50-8	79,000	74,000	Yes
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	Carbon-14	14762-75-5	65.5	4.15	Yes
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2	Carbon-14	14762-75-5	139	4.15	Yes
100-K-6_Shallow	Carbon-14	14762-75-5	34.8	26.6	Yes
100-K-62_Shallow	Carbon-14	14762-75-5	20.2	4.15	Yes
100-K-63_Shallow_1	Selenium	7782-49-2	1,290	1,000	Yes
100-K-63_Shallow_2	Zinc	7440-66-6	70,100	67,800	Yes
100-K-84_Shallow	Copper	7440-50-8	24,200	22,000	Yes
100-K-84_Shallow	Mercury	7439-97-6	493	200	Yes
100-K-91_Shallow_Focused	Mercury	7439-97-6	2,700	476	Yes
116-K-2_Deep_1	Hexavalent Chromium	18540-29-9	6,060	6,000	Yes
116-K-2_Deep_2	Carbon-14	14762-75-5	4.62	3.25	Yes
118-K-1_P1_Shallow_2	Copper	7440-50-8	22,300	22,000	Yes
118-K-1_P1_Shallow_3	Iron	7439-89-6	33,600,000	32,600,000	Yes
118-K-1_P2_Deep_5	Iron	7439-89-6	34,000,000	32,600,000	Yes
118-K-1_P2_Deep_8	Iron	7439-89-6	36,000,000	32,600,000	Yes
118-K-1_P2_Shallow_10	Copper	7440-50-8	22,600	22,000	Yes
118-K-1_P2_Shallow_11E	Copper	7440-50-8	22,300	22,000	Yes
118-K-1_P2_Shallow_7	Copper	7440-50-8	22,500	22,000	Yes
118-K-1_P2_Shallow_7	Zinc	7440-66-6	77,200	70,300	Yes
118-K-1_P2_Shallow_ Focused_3	Iron	7439-89-6	34,400,000	32,600,000	Yes
128-K-2_Shallow	Copper	7440-50-8	23,700	22,000	Yes
132-KE-1_Shallow	Carbon-14	14762-75-5	14.5	11.6	Yes
600-29_Shallow	Copper	7440-50-8	26,200	22,000	Yes

Table 5-11. Waste Site Decision Units with EPCs Greater than Scaled SSLs (Irrigation Scenario) Protective of Surface Water

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled SSL Protective of Surface Water* (µg/kg or pCi/g)	Is EPC > Scaled SSL Protective of Surface Water?
600-29_Shallow	Nickel	7440-02-0	37,500	19,100	Yes

References: ECF-100-KR1-0087, *Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Units*.

ECF-100KR1-17-0092, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations*.

ECF-100KR4-17-0240, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water*.

*The scaled SSL value is based on scaling of the unit-length SSLs, presented in ECF-100-KR1-0087 (Appendix F), by the representative length of the waste site decision unit parallel to the general direction of groundwater flow (ECF-100KR1-17-0092 [Appendix F]) and evaluated against EPCs in ECF-100KR4-17-0240 (Appendix F).

EPC = exposure point concentration

SSL = soil screening level

Review of the identified COPCs for potential effects to groundwater and surface water applied the following exclusion criteria to eliminate COPCs at selected waste site decision units that are unlikely to pose a threat:

- SSL/PRG values were chosen for comparison using the soil column most representative of the waste sites under consideration rather than the bounding of a range of soil columns simulated.
- Pesticides and herbicides (e.g., endosulfan I or heptachlor) are likely from biological control activities and not a result of Hanford Site production operations. The number of detect samples is limited compared to the nondetect samples.
- Most of the detected samples for COPCs were within the concentration range naturally occurring at the Hanford Site. Thus, the EPC likely overstates the concentration at this waste site decision unit.
- Numerous COPCs had a limited number of detect samples compared to the number of nondetect samples at a waste site decision unit. Thus, the EPC represents a low potential contaminant mass and the COPC is not a potential threat.
- COPCs with laboratory data indicating data-quality issues that result in the EPC being overestimated at the waste site decision unit.

Evaluating each waste site based on the criteria listed above exempted all but five waste sites from Table 5-10 and five waste sites from Table 5-11. The exemptions are tabulated by waste site/analyte combination in ECF-100KR4-17-0240 (Appendix F). Those sites which failed the SSL comparison and were not explained after further review (five waste sites in total) were carried forward for the PRG comparison.

5.4.2 Comparison of Waste Site EPCs to PRGs

If a waste site COPC EPC exceeded the SSL for groundwater or surface water protection, and was not eliminated during the subsequent review process (total of twenty waste site decision units), it is moved forward to the PRG evaluation step. PRGs were computed for waste sites not eliminated from Tables 5-10 and 5-11; waste site decision units failing the PRG comparison are summarized in Tables 5-12 and 5-13.

This evaluation provides knowledge to the FS if an irrigation IC would be protective of groundwater and surface water.

Table 5-12. Waste Site Decision Units with EPCs Greater than Scaled PRGs (Native Vegetation Scenario) Protective of Groundwater

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled PRG Protective of Groundwater* (µg/kg or pCi/g)	Is EPC > Scaled PRG Protective of Groundwater?
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	Carbon-14	14762-75-5	65.5	5.59	Yes
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2	Carbon-14	14762-75-5	139	5.59	Yes
100-K-62_Shallow	Carbon-14	14762-75-5	20.2	5.59	Yes
116-K-2_Deep_1	Hexavalent Chromium	18540-29-9	6,060	6,000	Yes
116-K-2_Deep_2	Carbon-14	14762-75-5	4.62	4.38	Yes

References: ECF-100-KR1-0087, *Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Units.*

ECF-100KR1-17-0092, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations.*

ECF-100KR4-17-0240, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water*.

*The scaled PRG value is based on scaling of the unit-length PRGs, presented in ECF-100-KR1-0087 (Appendix F), by the representative length of the waste site decision unit parallel to the general direction of groundwater flow (ECF-100KR1-17-0092 [Appendix F]) and evaluated against EPCs in ECF-100KR4-17-0240 (Appendix F).

EPC = exposure point concentration

PRG = preliminary remediation goal

Table 5-13. Waste Site Decision Units with EPCs Greater than Scaled PRGs (Native Vegetation Scenario) Protective of Surface Water

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled PRG Protective of Surface Water* (µg/kg or pCi/g)	Is EPC > Scaled PRG Protective of Surface Water?
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	Carbon-14	14762-75-5	65.5	5.59	Yes
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2	Carbon-14	14762-75-5	139	5.59	Yes
100-K-62_Shallow	Carbon-14	14762-75-5	20.2	5.59	Yes
116-K-2_Deep_1	Hexavalent Chromium	18540-29-9	6,060	6,000	Yes

Table 5-13. Waste Site Decision Units with EPCs Greater than Scaled PRGs (Native Vegetation Scenario) Protective of Surface Water

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)	Scaled PRG Protective of Surface Water* (µg/kg or pCi/g)	Is EPC > Scaled PRG Protective of Surface Water?
116-K-2_Deep_2	Carbon-14	14762-75-5	4.62	4.38	Yes

References: ECF-100-KR1-0087, *Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Units.*

ECF-100KR1-17-0092, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations.*

EPCs in ECF-100KR4-17-0240, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective of Surface Water.*

*The scaled PRG value is based on scaling of the unit-length PRGs, presented in ECF-100-KR1-0087 (Appendix F), by the representative length of the waste site decision unit parallel to the general direction of groundwater flow (ECF-100KR1-17-0092 [Appendix F]) and evaluated against EPCs in ECF-100KR4-17-0240 (Appendix F).

EPC = exposure point concentration

PRG = preliminary remediation goal

The comparison of scaled PRGs against EPCs shows at least one COPC in five waste site decision units exceeded levels protective of groundwater and surface water. Table 5-14 summarizes the waste site decision units and their associated COPCs that will be carried forward for evaluation in the FS with the knowledge that an irrigation restriction would not be enough to be protective of groundwater and surface water.

Table 5-14. Waste Site Decision Units with COPCs to be Evaluated in the FS

Waste Site Decision Unit	Analyte	Chemical Abstracts Service No.	EPC (µg/kg or pCi/g)
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1*	Carbon-14	14762-75-5	65.5
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2*	Carbon-14	14762-75-5	139
100-K-62_Shallow	Carbon-14	14762-75-5	20.2
116-K-2_Deep_1	Hexavalent Chromium	18540-29-9	6,060
116-K-2_Deep_2	Carbon-14	14762-75-5	4.62

*Carbon-14 results are associated with the co-located 116-KE-1 Gas Condensate Crib and will be considered as part of the 116-KE-1 site in the FS.

EPC = exposure point concentration

FS = feasibility study

5.5 Groundwater Fate and Transport Model

The 100-KR-4 OU groundwater fate and transport model (GWFTM) was developed to provide the computational basis for simulation of the fate and transport of groundwater contaminants and to assist with developing remedial action alternatives. The development of the numerical model, model construction, flow and transport calibration processes are documented in CP-61711, *100-K Scale-Appropriate Fate and Transport Model* (Appendix F).

The 100-K GWFTM focuses on the fate and transport of Cr(VI), trichloroethene, tritium, nitrate, carbon-14, and strontium-90, which were at concentrations greater than drinking water standards in 2016. The 100-K GWFTM provides a consistent, mass conservative hydrogeologic framework at the scale of the OU for comparing potential remediation actions. The primary purposes of this model include the following:

- Computing groundwater head and flows to the Columbia River for use in general flow system understanding as well as potential remediation system (e.g. P&T) design/evaluation.
- Estimating future groundwater concentrations of carbon-14, Cr(VI), nitrate, strontium-90, trichloroethene, and tritium to support risk screening and remediation options evaluation.
- Estimating contaminant discharge to the Columbia River and influent concentrations for extracted groundwater.

The 100-K GWFTM was implemented using configuration managed versions of the numerical simulation codes MODFLOW-2000 (Harbaugh et al., 2000, *MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*) and MT3DMS (Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*). Use of MODFLOW-2000 and MT3DMS is in keeping with DOE direction for simulation of groundwater at the Hanford Site (Klein, 2006, "MEMO: Contract No. DE-AC06-96RL13200 – Hanford Groundwater Modeling Integration"). All software used for model implementation was used in accordance with procedures that implement quality assurance requirements of DOE O 414.1D, *Quality Assurance*, for software use.

MODFLOW-2000 was selected for implementation of the 100-K GWFTM because it is one of the more versatile and widely used software packages for models of this type, is freely available and distributed with the source code, is capable of directly simulating the principal FEPs that are relevant to the 100-K simulation requirements, and is fully documented and has been verified in applications like those at the Hanford Site. The MODFLOW-2000 software program simulates groundwater flow using a block centered, finite difference grid. A finite difference grid can simulate three-dimensional groundwater flow using one or more model layers that correspond to individual aquifers or aquitards, or that provide vertical contaminant discretization across thick aquifers and aquitards. Individual or multiple layers corresponding to aquifers can be simulated as unconfined (e.g., water table aquifers), confined, or convertible between unconfined and confined conditions.

Contaminant fate and transport was simulated using MT3DMS. MT3DMS uses the MOFDLOW-2000 derived groundwater flow velocities, along with transport properties of the aquifer and contaminants, to solve the groundwater advection-dispersion equation, yielding concentrations in time and space. MT3DMS is the most commonly applied transport simulator used with MODFLOW. A description of specific modeling software program versions utilized in developing the 100-K GWFTM is provided in CP-61711 (Appendix F).

Operation of the 116-K-2 Trench is interpreted to have created a widespread Cr(VI) plume extending into the 100-NR-2 OU. Because 100-NR-2 must address OU-specific groundwater remedial actions, a local groundwater model was developed for the area. This model was used to address Cr(VI) plumes in that area, as shown in Figure 5-9. The 100-NR-2 model is documented in CP-59563, *Model Package Report: 100-N Scale-Appropriate Fate and Transport Groundwater Model*, and is not described further.

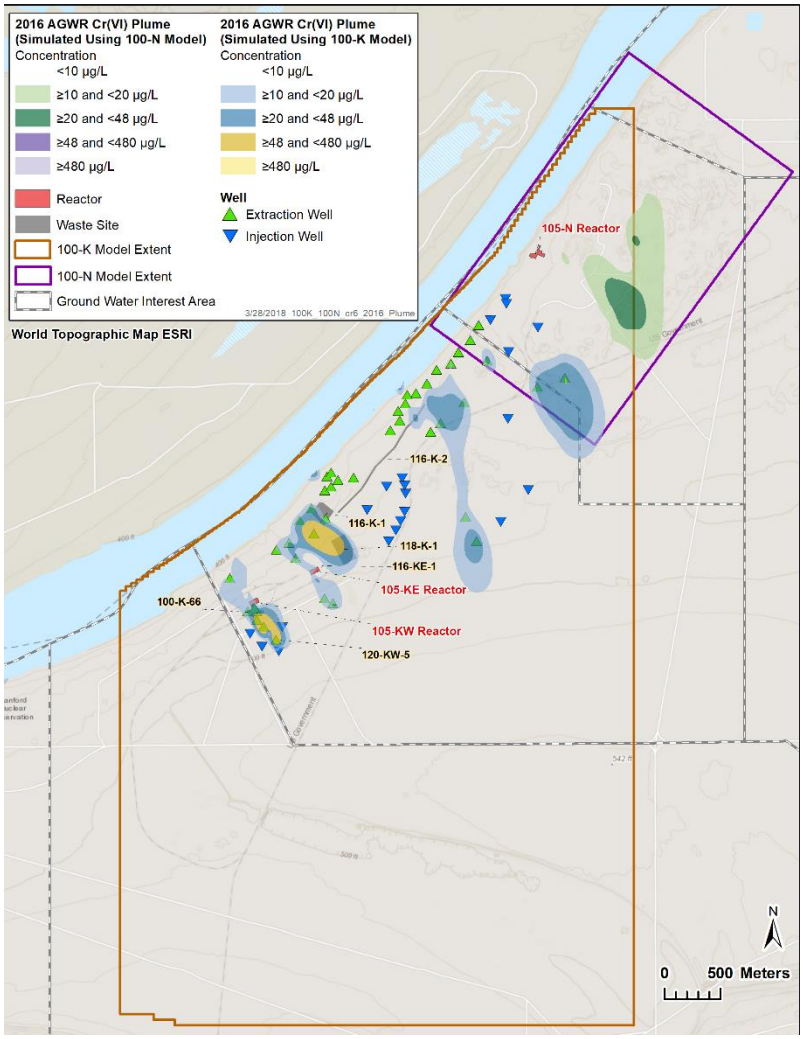


Figure 5-9. Cr(VI) Plumes Simulated in 100-K and 100-N Groundwater Models

5.5.1 Construction and Parameterization

The 100-K numerical model configurations such as temporal and spatial discretization, boundary conditions, hydraulic, and transport properties are summarized in Table 5-15. The information listed in Table 5-15 is described in more detail in the following subsections.

Table 5-15. Summary of Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for the 100-KR-4 Operable Unit

Input Parameter (units)	Input Parameter Value
Model Domain	
Grid Discretization	The model origin is at 567,450 m easting and 142,640 m northing in Washington South NAD83 HARN. 469 rows, 380 columns, and 4 layers with a minimum and maximum row/column spacing of 10 m and 50 m, respectively. A total of 712,880 cells are in the model, of which 500,848 are active.

Table 5-15. Summary of Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for the 100-KR-4 Operable Unit

Input Parameter (units)	Input Parameter Value
Simulation Duration	
Simulation of River Induced Changes to Establish Aquifer Hydraulic Properties (Used for Model Calibration)	January 2013 through December 2016 with 5-day stress periods (April to September) and 30-day stress periods (October to March).
Calibration of Interpreted COPC Plumes Migration	Calibration period was selected based on the most representative interpreted plume in between 2012 and 2015.
Simulation of Future Transport Conditions	30-day/31-day stress period length was used for 48 years beginning January 2018. March 2016 was selected as an average condition for the last 77 years computed as 77 one-year stress period.
Upper Boundary Surface	
Upper Boundary Surface	Land surface topography and Columbia River bathymetry were mosaicked together to form the upper boundary surface.
Upper Boundary Condition: Recharge	
Recharge Boundary	The RET was used to compute recharge rates both temporally and spatially. The RET uses a dictionary that contains a list of all the waste sites in the Hanford Site, their associated remediation action and date from the disposition baseline report (CP-60254) and incorporates vegetation succession over time (ECF-HANFORD-15-0019, *Hanford Site-Wide Natural Recharge Boundary Condition for Groundwater Models*). The dictionary also identifies all the years where a change in recharge rate occurs over the Hanford Site.
Lateral Boundary Conditions	
General Head Boundaries	Used to represent flow into and out of the model domain along the western, southern, and eastern boundaries of the 100-K GWFTM.
River Boundary	Boundary was developed using the steady-state water surface of the Columbia River from the Modular Aquatic Simulation System 1D surface water model (PNNL-14753, *Groundwater Data Package for Hanford Assessments*) and the K-gauge data to compute the river stage. K-gauge data were averaged over each stress period.
Lower Boundary Condition	
No Flow Boundary	The lower boundary of the model is a no flow boundary, in keeping with the stratigraphy selected to choose relatively impermeable units to serve as the lower boundary.
Sources and Sinks	
Pumping Stresses	Three P&T systems (KR4, KW, and KX) have been operational at various periods over the history of the 100-KR-2 OU.
Hydraulic Parameters	
Full Model Domain	
Specific Yield (Unitless)	0.0816
Specific Storage (1/m)	0.0000101

Table 5-15. Summary of Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for the 100-KR-4 Operable Unit

Input Parameter (units)	Input Parameter Value	
	Hanford formation	Ringold Formation unit E
K_h Saturated Horizontal Hydraulic Conductivity (m/d)	1,494	Spatially variable: varies from 1.5 to 43 within the 100-KR-4 OU and varies from 3.0 to 86 within the portion of the 100-NR-2 OU that lies inside the 100-K GWFTM
Vertical Anisotropy Ratio (K_v/K_h)	0.011	0.055
Riverbed Hydraulic Conductivity (m/d)	None	123.9
Transport Parameters		
Effective Porosity (Unitless)	0.18	
ρ_b Bulk Density (g/mL)	1.72	
Longitudinal Dispersivity	10	
Horizontal Transverse Dispersivity	1	
Vertical Transverse Dispersivity	0.1	
K_d Partition Coefficient (mL/g)	K_d Strontium-90: 12 mL/g K_d for Cr(VI), carbon-14, nitrate, tritium, and trichloroethene: 0 mL/g	

References: CP-60254, *Hanford Site Composite Analysis Technical Approach Description: Hanford Site Disposition Baseline*, Draft.
CP-61711, *Model Package Report: 100-K Scale-Appropriate Fate and Transport Model*.
ECF-HANFORD-15-0019, *Hanford Site Wide Natural Recharge Boundary Condition for Groundwater Models.*
NAD83, *North American Datum of 1983*.
PNNL-14753, *Groundwater Data Package for Hanford Assessments.*
Note: Details on the basis for all parameters in this table are found in Appendix F (CP-61711).

COPC	=	contaminant of potential concern	OU	=	operable unit
Cr(VI)	=	hexavalent chromium	P&T	=	pump & treat
HARN	=	High Accuracy Reference Network	RET	=	Recharge Estimation Tool

5.5.1.1 Model Domain

The large-scale 100 Area geologic framework model (ECF-HANFORD-13-0020, *Process for Constructing a Three-dimensional Geological Framework Model of the Hanford Site 100 Area*) was used as the starting point for developing the 100-K GWFTM geological structure. The extent of the 100-K GWFTM model domain (Figure 5-10) lies completely within the domain of the 100 Area geologic framework model. The 100-K GWFTM extends to the Columbia River on the north side of the model, and uses a general head boundary on the south, east, and west sides of the model. A small portion in the southeast corner of the model was assigned no-flow boundary where basalt outcrops above the water table. Land surface is the top of the model, and the bottom of Ringold Formation Unit E comprises the lower model boundary. The locations for the south, east, and west boundaries of the model were selected to avoid potential boundary effects on the model solution, interference with adjacent OUs, and having an unnecessarily large model.

The 100-K GWFTM comprises 469 rows and 380 columns in the lateral direction (x and y) with a spatial discretization ranging from 50 m (164 ft) to as fine as 10 m (32.8 ft) in regions where the COPC plumes were interpreted to exist (Figure 5-10). The model consists of 4 layers in the vertical direction with

the grid block thickness varying across the model domain as a function of the lateral changes in stratigraphic thicknesses. The Ringold Formation unit E is split into 4 layers; the Hanford formation only occurs in the southern part of the domain. Model layer thicknesses are dictated by the overall thickness of the 100 Area geologic framework model, with a minimum thickness of top layer (layer 1) set at 4.0 m (13.1 ft). A minimum saturated thickness of 4.0 m (13.1 ft) in layer 1 was used to avoid dry cell issues during MODFLOW simulation. The remaining saturated thickness is equally split into 3 layers. A detailed discussion of the model domain and spatial discretization is in CP-61711 (Appendix F).

5.5.1.2 Boundary Conditions and Sources/Sinks

Boundary conditions, including sources and sinks, are assigned to numerical model domains to represent interactions with potential hydraulic forces external to the groundwater system. These could include water infiltrating through the vadose zone that becomes recharge, movement to and from rivers and lakes, infiltration resulting from liquid discharges at waste sites, and extraction/injection well operations. For the 100-K GWFTM, the boundary condition type and location, defined for the model domain and shown in Figure 5-10, are discussed in the following paragraphs.

5.5.1.2.1 Recharge Boundary Condition

The RET was developed for ArcGIS®[4] using python scripts and to enable users to determine the spatio-temporal variation in recharge for their model domain and over their time period of interest. The site-specific information produced by the RET is used in the MODFLOW recharge package. The RET scripts use a dictionary which identifies all the years where a change in recharge rate occurs over the Hanford Site. This dictionary contains a list of all the waste sites in the Hanford Site, their associated remediation action and date from the disposition baseline report (CP-60254) and incorporates vegetation succession over time (ECF-HANFORD-15-0019, *Hanford Site-Wide Natural Recharge Boundary Condition for Groundwater Models*). The first RET script uses 13 spatial data sources and three tabular data sources to develop recharge estimates for the Hanford Site. This script produces a geodatabase of recharge rates over the Hanford Site for all years identified as having a change in recharge rate as listed in the dictionary. The second RET uses the user-provided model boundary (i.e., 100-K GWFTM) to identify the waste sites within the model domain and references the dictionary to identify the years over the time of interest there are changes in recharge rate. This step is repeated for all the waste sites and the list is compiled to create a comprehensive list of years for the user-provided model domain and time of interest. The RET then samples the relevant years in the geodatabase from the first RET script, clips them to the model domain, and compiles them into a new geodatabase or individual shape files as preferred by the user. Figure 5-11 shows the recharge rates that were applied to the calibration model for calendar years 2013 through 2016. The RET tool did not include some of the future estimates of the sequential recharge rates for the waste sites. This adjustment was made on the RET outputs outside the RET system processes.

[4] ArcGIS is a registered trademark of ESRI.

Figure 5-10. 100-K Groundwater Flow and Transport Model Grid with 2013 100-K Cr(VI) Plumes (Plan View)

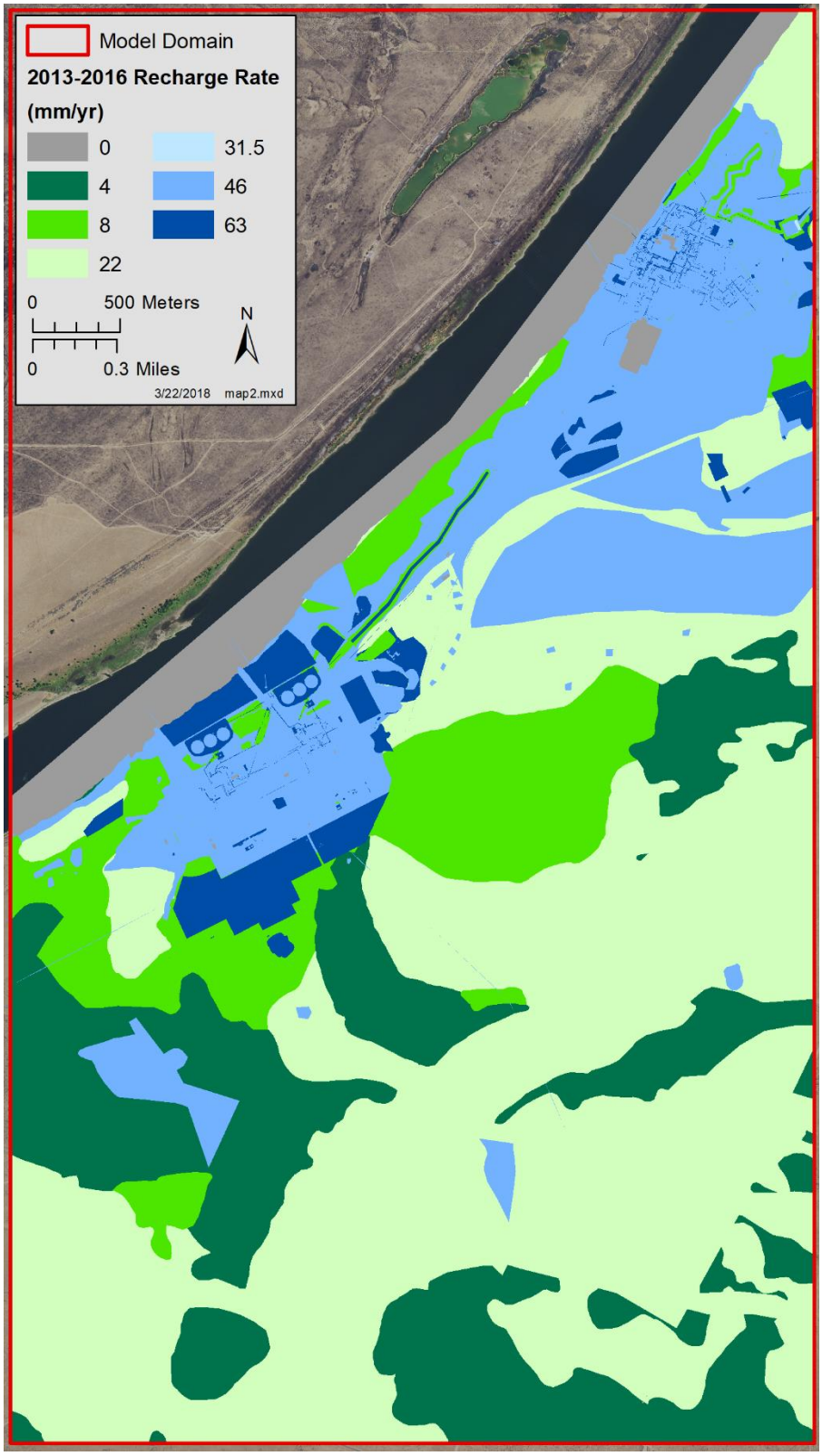


Figure 5-11. Spatial Distribution of Recharge Rates Within 100-K GWFTM Between 2013 and 2016

5.5.1.2.2 River Boundary Conditions

The northern model boundary was assigned a combination of river and drain boundary conditions dependent on the variable stage of the Columbia River. As the river stage changes over time, the submerged riverbed area also changes. A river boundary was assigned to a cell when the river stage, averaged over the MODFLOW defined stress period, was above the bottom of the cell and the cell was within the river. For grid cells where the stage is below the bottom of the cell, a drain boundary condition was substituted, and the elevation set to the land surface to emulate riverbank seeps that occur when the river stage is lowered. The process by which the transient Columbia River stage was determined and averaged over each MODFLOW stress period is described in CP-61711.

Riverbed in the Columbia River within the model domain consists of only the Ringold Formation unit E. Riverbed hydraulic conductivity (with an assumed riverbed thickness of 1 m [3.3 ft]) for Ringold Formation unit E is unknown and thus was varied during the groundwater flow model calibration process. The calibrated riverbed hydraulic conductivity value for Ringold Formation unit E was 124 m/d (407 ft/d).

5.5.1.2.3 West, South, and East Landward Boundary Conditions

General-head boundary (GHB) conditions were used at western and eastern boundaries of the 100-K GWFTM to represent the influence of the unconfined aquifer not included in the model domain. The fluctuations in the Columbia River stage are conceptualized to affect the head at these lateral boundaries with the impact of the river being largest near the river and lessening with increasing distance from the river. Active P&T systems within the 100-KR-4 OU disturb this relationship between the Columbia River and the aquifer near the P&T system. A sufficient number of wells with a long record of high frequency data outside the influence of P&T system were found to evaluate this relationship. In absence of such a relationship for 100-K model domain, the relationship between the Columbia River and the aquifer at the adjacent 100-BC OU was used for calculating GHBs at the western and eastern boundary cells. An empirical formula was developed that correlated the change in observed water levels within the aquifer to the Columbia River B-gauge stage data (SGW-59365, *Model Package Report: 100-BC Scale-Appropriate Fate and Transport Model*). Using a dampening and a time lagging parameter, the transient head at each general head boundary cell was determined to account for the regional groundwater gradient toward the river and the time required for river fluctuations to propagate through the aquifer. In this way, the effect of the natural aquifer and fluctuations and the impact of the Columbia River fluctuations was accounted for in generating the hydraulic head and hydraulic conductance values for each model grid cell along the western and eastern boundaries.

The southern boundary is 3,500 to 8,000 m from the Columbia River, where response to river fluctuation is small and wells show relatively steady water level. General-head boundary conditions with a fixed GHB are applied to the southern boundary cells.

5.5.1.2.4 Lower Boundary Condition

The lower boundary of the model is a no flow boundary, in keeping with the stratigraphy selected to choose relatively impermeable units (e.g., Columbia River basalt and RUM) to serve as the lower boundary. For the 100-K GWFTM, the lower no flow boundary corresponds to the top of the RUM.

5.5.1.2.5 Sources/Sinks

Three P&T systems have been operational at various periods over the history of the 100-KR-4 OU. Flow conditions in the 100-KR-4 OU are largely controlled by the P&T system. Over time, water-level elevations at each extraction well have generally been held constant (constant pressure constraints) while pumping rates have varied. As the interim system has been developed additional wells have been added or removed. In general, the extraction wells are located downgradient of the plumes near the river.

Along the former location of the 116-K-2 Trench, only extraction was occurring in December 2014. This P&T system is included in the 100-K GWFTM by using MNW2 package in MODFLOW.

5.5.1.2.6 Initial Head

The initial hydraulic head distribution across the model was assigned based on the 2013 water table conditions as published in the 2013 annual groundwater report (DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*).

5.5.1.2.7 Initial Concentrations

DOE publishes annual concentration plumes for each COPC for each OU for the groundwater monitoring program at the Hanford Site. These are two-dimensional (2D) concentration plumes based on interpretation using site-specific knowledge and the observed concentration over a year, irrespective of sampling depth. The plume delineation could change from one year to another if information is available from new monitoring. For contaminant transport calibration, it is important to start the model from a representative initial concentration. In addition, the calibration period needs to be as long as possible to build confidence on the calibration results. Concentration plumes in annual groundwater monitoring reports between 2012 and 2015 were used for selecting initial COPC concentrations to increase modeling confidence. The 2D annual groundwater monitoring report concentration plumes were applied to all the model layers in the 100-K GWFTM.

5.5.1.2.8 Contaminant Treatment System (CTS)

The P&T system in 100-KR-4 OU treats Cr(VI) and recirculates other COPCs into the aquifer without any treatment through the injection wells. The process of extracting high concentration plume mass from the aquifer, mixing and treatment at the P&T facilities, and re-injecting the fully/partially treated water into the aquifer need to be included in the fate and transport simulation to track the recirculating contaminant mass. A CTS module was developed and added to the standard MT3DMS software to incorporate the processes related to the P&T system.

5.5.1.3 Hydraulic Properties

The selection of hydraulic property values for the 100-K GWFTM was based on field studies conducted within the Hanford Site, specifically the 100 Area and 100-K Area. A summary of data sources is provided in CP-61711 (Table 2-1). Simulation of transient groundwater flow under unconfined conditions using the 100-K GWFTM required values for the following hydraulic properties:

- Horizontal hydraulic conductivity (K_h)
- Vertical hydraulic conductivity (K_v) based on a specified K_v/K_h ratio
- Specific storage (S_s)
- Specific yield (S_y)

A range of values for each hydraulic property was specified for the Hanford formation and the Ringold Formation unit E. During the calibration of the transient groundwater flow field, these ranges were used in assigning the parameter values to the model grid cells as described below in Section 5.5.2.1.

5.5.1.3.1 Hydraulic Conductivity

The assigned K_h for the Hanford formation was 1,494 m/d (4,900 ft/d). For the Ringold Formation unit E within the 100-KR-4 OU, the assigned K_h ranged from 1.5 to 43 m/d (4.9 to 141 ft/d). The assigned K_h for the portion of the 100-NR-2 OU inside the 100-K GWFTM ranged from 3.0 to 86 m/d (9.8 to 282 ft/d). The more transmissive Hanford formation is located near the south-western boundary and thins out with depth. The Hanford formation has minimum to no effect on the hydraulic processes at or near 100-K waste site.

Uniform values of the K_v/K_h ratio of 0.011 and 0.055 were assigned to the Hanford formation and Ringold Formation unit E, respectively. These values were multiplied by the assigned K_h to yield the corresponding K_v for each cell.

5.5.1.3.2 Specific Storage (S_s) and Specific Yield (S_y)

The S_s and S_y properties were specified as constant values for all layers and formations. The selected S_s value was 0.0000101 1/m (0.000000308 1/ft). The selected value for S_y was 0.0816.

5.5.1.4 Transport Properties

The selection of transport property values, which define the fate and transport of constituents, was based on field studies conducted within the Hanford Site 100 Area and 100-K Area. A summary of the various parameter data sources is provided in CP-61711.

The following transport properties are required to simulate the fate and transport of carbon-14, Cr(VI), nitrate, strontium-90, tritium, and trichloroethene:

- Soil-water distribution coefficient
- Radioactive decay
- Dispersivity
- Effective porosity

The selected value for each of the transport properties was assigned as a constant value uniformly across the model domain for the model grid cells representing both the Hanford formation and Ringold Formation unit E.

5.5.1.4.1 Distribution Coefficient

One of the most important properties influencing contaminant mobility is the soil:water distribution coefficient or K_d value. This parameter is dependent on several soil and water conditions such as the relative abundance of different cations and anions in soil, cation exchange capacity, and the organic carbon content of the soil matric. Several studies were performed to determine the K_d values for the COPCs present at different Hanford Site OUs. Where available, site-specific K_d values were selected for the fate and transport calculation. In absence of site-specific analysis, sitewide or generally acceptable values were selected.

PNL-10899, *Strontium-90 Adsorption-Desorption Properties and Sediment Characterization at the 100 N-Area*, characterized the adsorption and desorption of strontium-90 for the 100-NR2-OU area. Results showed K_d values from 7 to 59 mL/g, and K_d decreases with sediment particle size increases. In addition, a K_d of 15 mL/g was estimated for bulk sediments more representative of actual field conditions. A more site-specific (i.e., 100-K Area) study was performed using samples collected at UPR-100-K-1 and 116-KE-3 for evaluating leaching characteristics of strontium-90 (ECF-100KR2-16-0127). A K_d value of 12 mL/g was recommended for use in evaluating the transport of strontium-90 for the 100-KR-4 OU. The K_d value assigned for strontium-90 in the 100-K GWFTM was 12 mL/g obtained from ECF-100KR2-16-0127.

PNNL-17674 investigated the mobility of Cr(VI) in the 100 Area sediments and found that the K_d for Cr(VI) was close to zero. Thus, no adsorption of Cr(VI) was considered in the 100-K GWFTM. The remaining COPCs (i.e., carbon-14, nitrate, tritium, and trichloroethene) were found to be highly mobile (K_d of zero) (PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report).*

5.5.1.4.2 Radioactive Decay

The reduction in the COPC activity resulting from radioactive decay was incorporated into the 100-K GWFTM. The half-life values used were 5,730 years for carbon-14, 29.12 years for strontium-90, and 12.3 years for tritium.

5.5.1.4.3 Dispersivity

Dispersivity is a characteristic property of the geologic system, often found to be scale-dependent (e.g., a function of mean travel distance of solutes). Dispersivity data from the scientific literature were evaluated and appropriate dispersivity values for use in the 100-K GWFTM were selected (SGW-59365). Recommended values for longitudinal dispersivity as a function of transport distance are given in Table 5-16. Transverse horizontal and vertical dispersivities were selected based on a ratio of longitudinal to transverse horizontal dispersivity of 10 and a ratio of longitudinal to transverse vertical dispersivity of about 100, respectively.

Table 5-16. Recommended Dispersivity Values for the 100-K GWFTM

Transport Distance (m)	Longitudinal Dispersivity (m)	Horizontal Transverse Dispersivity (m)	Vertical Transverse Dispersivity (m)
500	10	1	0.1
1,000	18	1.8	0.18
5,000	60	6	0.6
7,000	82	8.2	0.82

Because groundwater contamination is caused by multiple sources located at different transport distances from the Columbia River, it was not possible to implement scale-dependent dispersivity within the 100-K GWFTM. Therefore, to minimize plume spreading but still account for the dispersion processes, the lower-end values of 10, 1.0, and 0.1 m (32.8, 3.3, and 0.3 ft) were assigned for horizontal longitudinal, horizontal transverse, and vertical transverse dispersivity parameters, respectively.

5.5.1.4.4 Effective Porosity

A range of effective porosity values for the Hanford formation based on the results of tracer tests were obtained from PNNL-21845, *Investigation of Hexavalent Chromium Flux to Groundwater at the 100-C-7:1 Excavation Site*. The estimated lower and upper bounds were 0.14 and 0.24, respectively, with a best estimate of 0.18.

5.5.1.5 Contaminant Source Term

Persistent groundwater plumes near some waste sites suggests continuing sources from the deep vadose zone to the groundwater (DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*). Based on the prior knowledge about the waste sites suspected to have contributed to groundwater contamination and groundwater concentration data at nearby wells, the following waste site locations were identified as the continuing sources that are contributing to the aquifer (SGW-60753-VA, *Overview of Soil Contamination Conditions Observed in Borings at UPR-100-K-1 and 116-KE- Crib in Vicinity of 105-KE Reactor)*:

- 183.1KW Headhouse vicinity
- 116-KW-1 Crib
- 116-KW-2 Crib

- 183.1KE Headhouse vicinity
- UPR-100-K-1
- 116-KE-1 Crib
- 118-K-1 Burial Ground (associated tritium contamination is identified as the 100-K-132 waste site)
- 116-K-1 Crib
- 116-K-2 Trench

The potential continuing source waste site extents are not well known. In addition, the plumes beneath these locations are not well defined due to limited monitoring wells around the sources. Therefore, the lateral extent of the continuing sources was adjusted only to satisfy the observed concentrations at the nearby wells.

Given the minimal deep vadose zone characterization of the suspected continuing source waste sites, a simple 1-D soil column with uniformly distributed contaminant mass was used to develop characteristic mass release rate curves for each COPC at each waste site. The characteristic mass release rate curve can be defined as the contaminant mass that reaches water table (i.e., aquifer) with time for a given contaminant source distribution in the vadose zone. These characteristic release rate curves are scaled so that the source matches the groundwater contaminant concentrations measured at the nearby monitoring wells.

The characteristic mass release rate curves representing the continuing source at each waste site were developed by using a STOMP 1-D framework like that used in the SSL/PRG calculations. STOMP simulations were performed to solve for the water flow and contaminant transport at each waste site, for each COPC, for an initial uniform concentration of contaminant. These 1-D simulations use a time varying water level boundary condition in the saturated zone to account for the water level fluctuation in the aquifer in response to the changes in Columbia River stage. The application of fluctuating water table boundary condition allows the numerical model to represent the influence of the PRZ on mass releases to the aquifer. The time varying water table at each waste site location was extracted from the calibrated 100-K GWFTM. Figure 5-12 shows the stress period averaged characteristic release rate curves at Cr(VI) continuing source locations, and for other COPCs at selected waste sites during the calibration period (i.e., 2014 through 2016). All the characteristic release rate curves show similar behavior. That is, release rate increases as the water level increases and release rate decreases as the water level decreases reflecting the assumption that residual contamination resides in the PRZ. The model mimics the observed behavior at well 199-K-189 (DOE/RL-2016-09).

The contaminant flux releases from the vadose zone to the aquifer are applied to the transport model through the MT3DMS source/sink mixing (SSM) package.

5.5.2 Groundwater Fate and Transport Model Results

The following subsections describe the methods used and adjustments made to the 100-K GWFTM for calibration of the model to the observed flow field and to the observed fate and transport of the six COPCs within the unconfined aquifer.

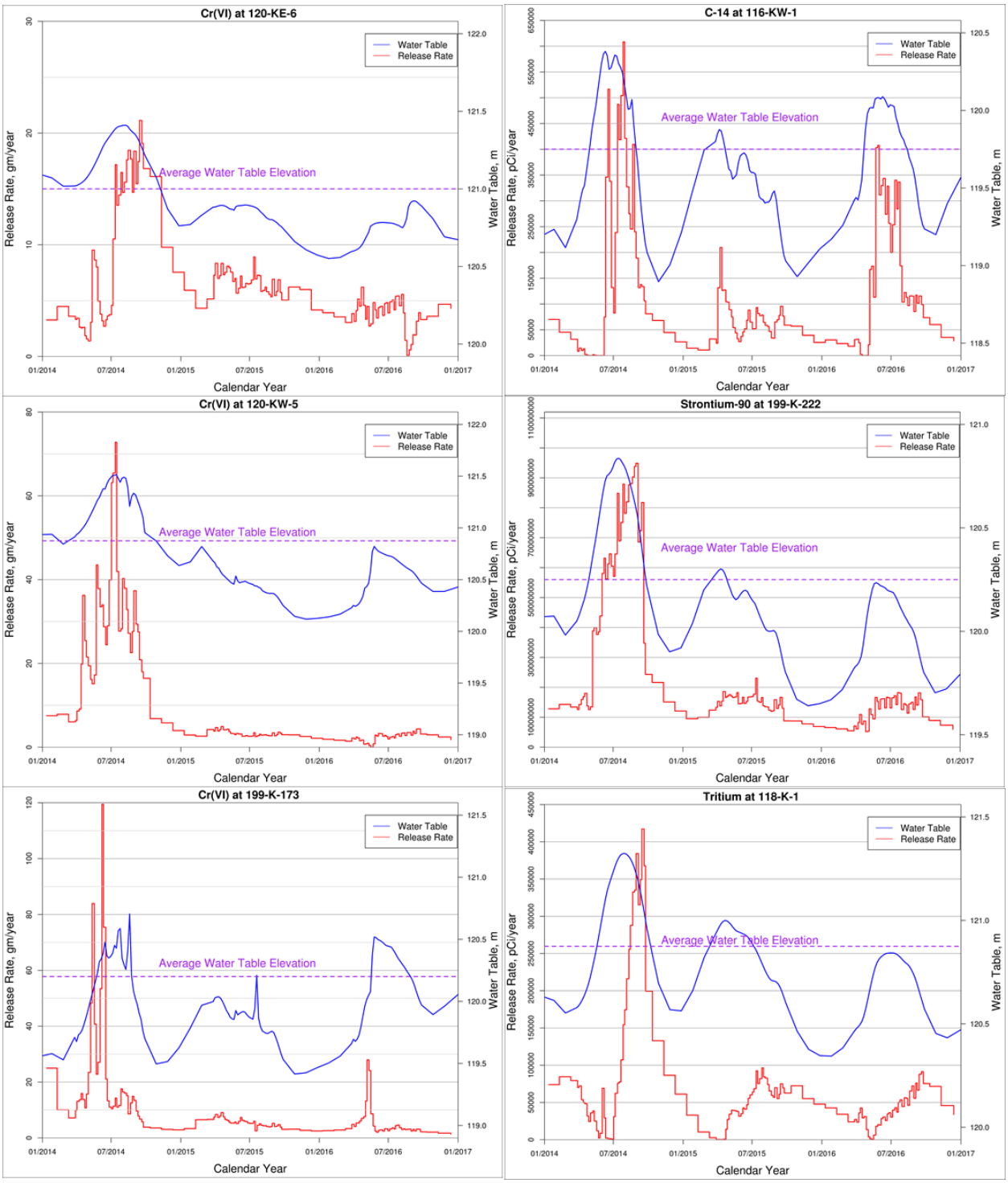


Figure 5-12. Example Characteristic Release Rate Curves at Continuing Source Locations for Cr(VI), Carbon-14, Strontium-90, and Tritium (Calibration Model)

5.5.2.1 Calibrated Flow Model

The calibration time extended from January 2013 through December 2016 with stress periods of 5 or 30 days. Temporal discretization was increased during periods of rapid river stage change to accurately capture the transient effects that provide information on hydraulic properties. Thus, a 5-day stress period length was used for April to September (i.e., rising limb to the peak river stage and falling limb from the peak river stage) of each year to capture this response, and a 30-day stress period length was used for October to March of each year.

The PEST (Doherty, 2007, *User's Manual for PEST Version 11*) parameter estimation software was used to facilitate model calibration in concert with manual adjustments. The 2013 through 2016 calibration dataset incorporated the following elements:

1. Stress-period averaged water levels from 47 AWLN wells (5,701 total data points). These AWLN wells are spatially distributed across the KW and KE areas and a portion of 100-NR-2 OU near the Columbia River. However, no AWLN well was operating in the southern portion of the 100-K GWFTM

2. Manual water-level measurements from 171 wells (2,308 data points). Wells with manual measurement data cover more area than the AWLN wells, including four wells near the southern boundary, and one well each near western and eastern boundaries. The manual measurement well list also includes the measurements from the P&T operation system.

3. Change from initial observed water level for 47 AWLN wells (5,701 total data points).

All the available observed water level data were examined and cross-referenced with nearby well data and measurement methods (i.e., AWLN versus manual measurement) prior to inclusion in the calibration dataset. The outliers or noisy data were given zero weight during calibration so that those measurements did not contribute to the objective function.

Aquifer hydraulic properties, such as hydraulic conductivity, ratio of vertical to horizontal hydraulic conductivity, specific storage, and specific yield were calibrated to minimize the deviation between observed and simulated values (i.e., hydraulic heads and deltas). A detailed description of the calibration results is in CP-61711.

The calibrated hydraulic conductivity within the 100-KR-4 OU Ringold Formation unit E varies from 1.5 to 43 m/d. These values are within acceptable range for the hydraulic conductivity in the Ringold Formation unit E and are consistent with pumping/slug test results. The calibrated hydraulic conductivity for the Hanford formation in the southern portion of the model is 1,494 m/d. The highly conductive inferred paleo-channel in the Hanford Site is interpreted to pass through the southern portion of the model domain although the extent of the channel is not known. Therefore, hydraulic conductivities of thousands of meters per day are expected in some portion of the Hanford formation.

The USGS (Theis et al., 1963, *Methods of Determining Permeability, Transmissibility and Drawdown),* present a conceptual model and analytic solution that allows estimation of hydraulic diffusivity (T/S) from the effects of river stage fluctuations in observation wells. Using this conceptual model in conjunction with the numerical model and AWLN data allowed for improved estimates of hydraulic conductivity, which controls groundwater velocity, and transport. It should be noted that fitting hydraulic head alone does not guarantee that the inferred flow direction and gradient are honored.

Figure 5-13 and Figure 5-14 present plots of observed versus simulated hydraulic head from the AWLN network and manual measurement wells. In general, the simulated head matched well with observed head. The model could capture the overall trend at well 199-K-118A, but was off by about 1.75 to 2.0 m consistently throughout the simulation period. As described in Section 3.4.2 of CP-61711, the observed higher head in this well compared to the nearby wells is known, and no further calibration was done to improve calibration at this location in absence of additional site-specific information. Similarly, well 199-K-125A, which is close to well 199-K-118A, simulates consistently lower heads. Wells 199-K-117A and 199-K-21 are located near well 199-K-118A, and the model captures the overall observed trend but could not match some lower heads during low river stage.

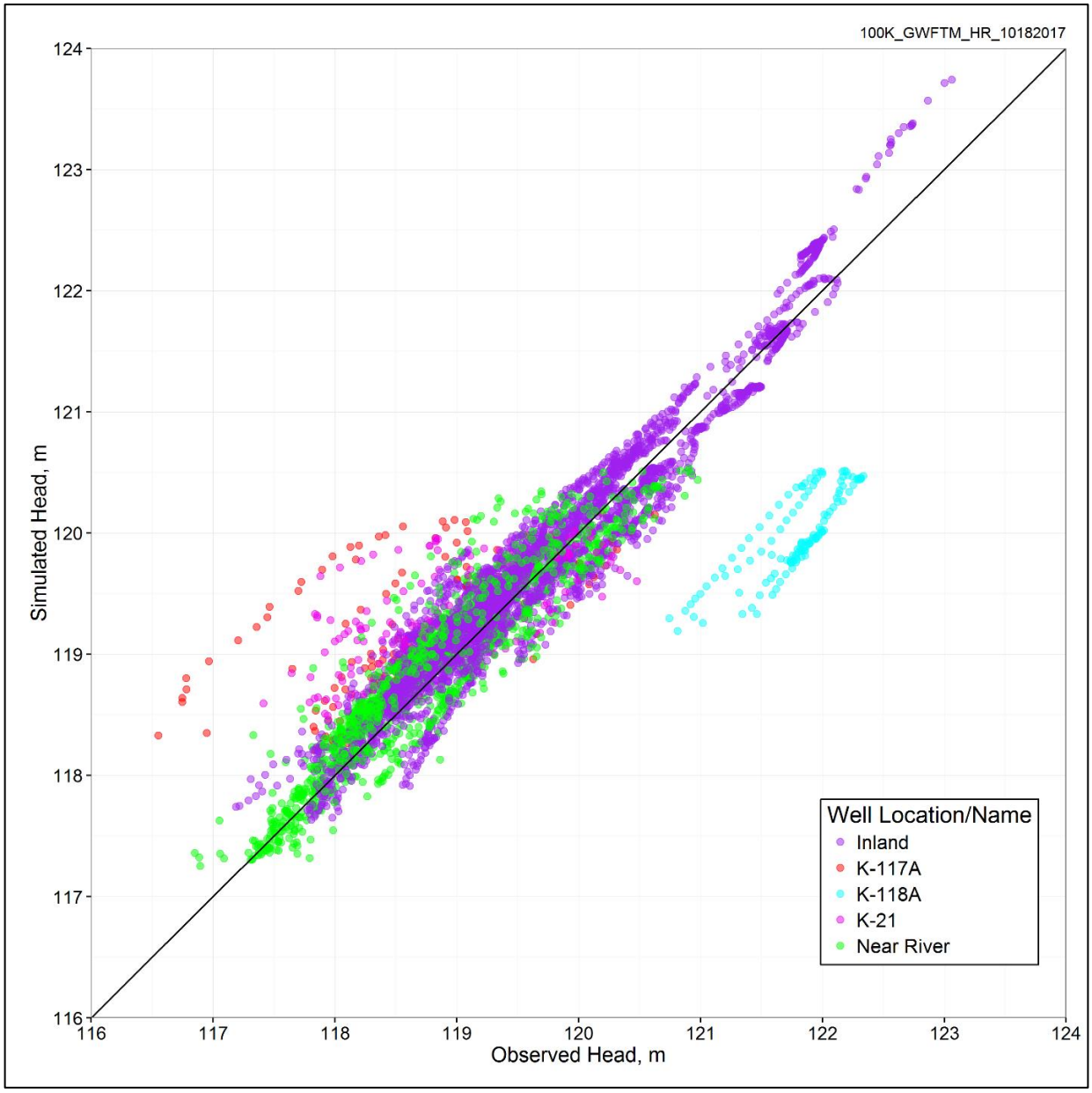


Figure 5-13. Observed Versus Simulated AWLN Heads

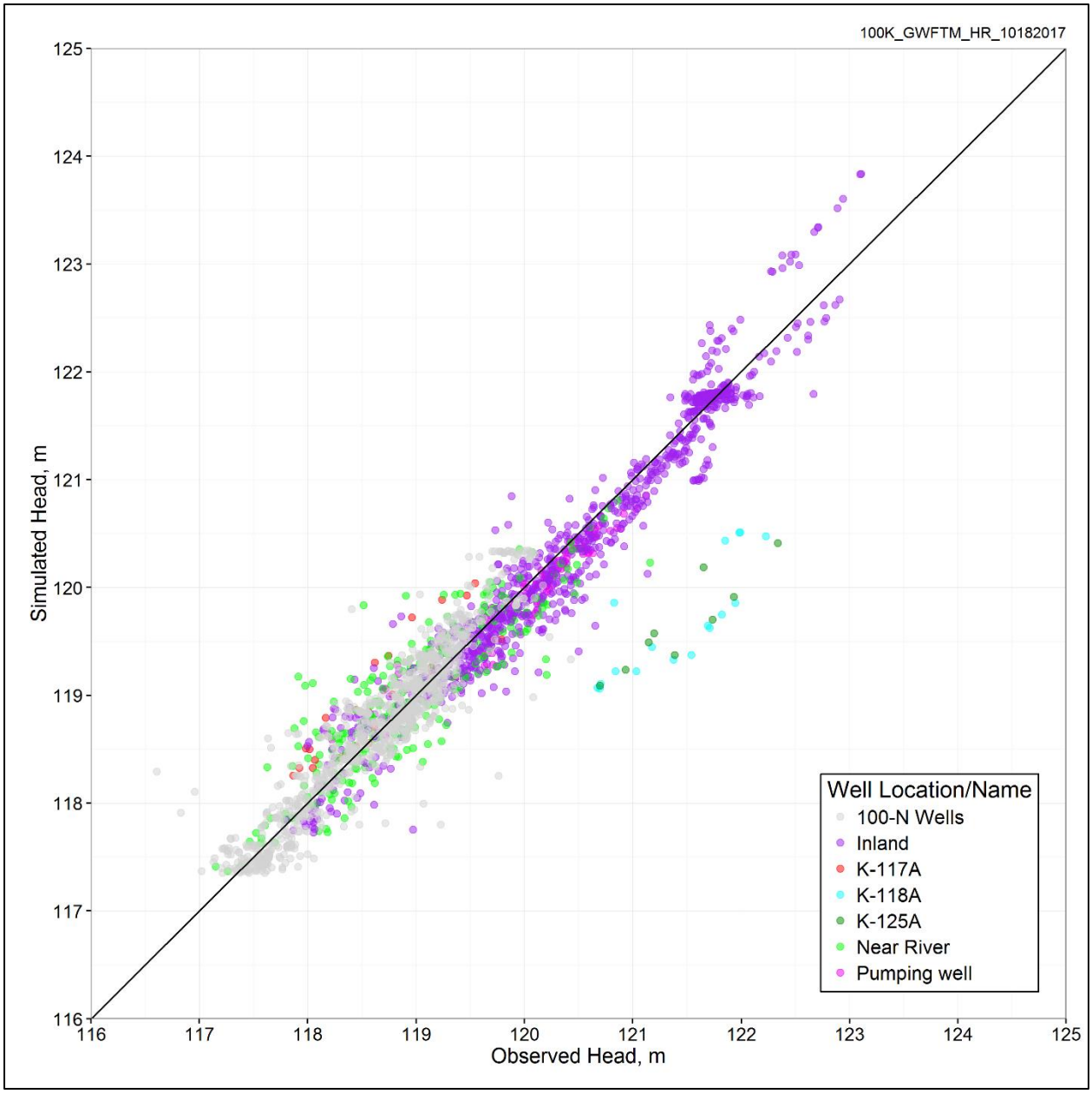


Figure 5-14. Observed Versus Simulated Manually Measured Heads

5.5.2.2 Transport Model Calibration Results

The primary objective of the transport calibration process was to estimate a mass release rate during the calibration period so that simulated concentration at the observation wells near the waste sites would be matched or overestimated for conservatism. In addition, the calibration was done so that the areal footprint of the contaminated zone at each waste site was as small as possible, so that the calibrated contaminated zone only contributed to the downgradient observation wells. The qualitative calibration of continuing sources was not meant to estimate the spatial distribution and soil concentration in the vadose zone. It was rather meant to estimate mass release required from vadose zone to the aquifer to fit the observed concentrations.

5.5.2.2.1 Calibration Results for Cr(VI)

The potential continuing sources for Cr(VI) were at or near observed high groundwater concentrations in the KW and KE areas. The KW P&T system was shut down in May 2016 to study concentration rebound near the 183.1KW Headhouse suspected source location. The observation data show a rebound at the downgradient wells after the P&T system shut down (see Section 4.4.1). The simulated concentrations at these downgradient wells continue to decline without any continuing sources. The introduction of continuing sources at the elevated concentration zones near the 183.1KW Headhouse and 190-KW Pump House helped to increase the concentration at wells 199-K-205 and 199-K-173, which are qualitatively similar to the rebound concentrations. The introduction of a continuing source at the 183.1KE Headhouse also qualitatively improved calibration at the nearby wells 199-K-36, 199-K-188, and 199-K-220. Observed high Cr(VI) concentrations near wells 199-K-111A and 199-K-207 are probably not due to the contribution from a continuing source because there were no potential sources identified at or near the 118-K-1 Burial Ground. Lack of groundwater data around the 118-K-1 Burial Ground contributed to poorly delineated plumes (used for transport initial conditions) in the annual groundwater monitoring report. Thus, the plume inferred from the annual groundwater monitoring report in this area was adjusted for this RI evaluation. The observed Cr(VI) concentration at well 199-K-111A was up to 510 µg/L and at well 199-K-207 was around 120 µg/L. The increase in concentrations in these two wells could be due to an incoming high-concentration slug from upgradient. The calibrated Cr(VI) concentrations upgradient of wells 199-K-111A and 199-K-207 were up to 2,000 µg/L. In addition, the initial Cr(VI) concentration near the 183.1KW Headhouse was changed to 1,000 µg/L from the inferred value of 450 µg/L in the annual groundwater monitoring report. Historically, the aquifer below the 183.1KW Headhouse had high concentrations based on well 199-K-195, which was decommissioned in 2011. An extraction well (199-K-205) was installed near the 183.1KW Headhouse in 2014, and measured groundwater Cr(VI) concentration after well completion was around 1,000 µg/L.

Figure 5-15 shows a qualitative comparison between the simulated and mapped chromium plume at the end of 2016. It should be noted that the Cr(VI) plume within the 100-N Area boundary was not simulated during the calibration period. The mapped 2016 plume at this location was used as the initial concentration for the predictive simulation. Figure 5-16 shows a comparison between simulated and observed concentrations over the calibration period at wells 199-K-173 and 199-K-205. 199-K-173 is a KW P&T system extraction well that operated at an approximate pumping rate of 230 L/min (60 gal/min) between 2014 and May 2016. The observed Cr(VI) concentration at this location decreased during this period. Simulated concentrations agreed with the overall observed trend. However, the model simulates some high Cr(VI) concentrations of around 175 µg/L during the summer of 2014, when the water table was higher than average. The simulated concentration agreed well with the observed high rebound concentrations at well 199-K-173. Well 199-K-205 (near 183.1KW Headhouse) is also an extraction well that started operating in September 2014 and operated at an approximate pumping rate of 454 L/min (120 gal/min) until the P&T system shut down in May 2016. Some groundwater concentration measurements during well completion was 1,000 to 3,000 µg/L, which were not included in the calibration dataset. However, the simulated concentrations during that period also show very high concentrations in response to the fluctuating high-water table. The simulated concentrations during P&T system operation agreed very well with the observation data. The model overestimates Cr(VI) concentrations during the rebound study period at this location, but correctly predicts the increasing concentration trend.

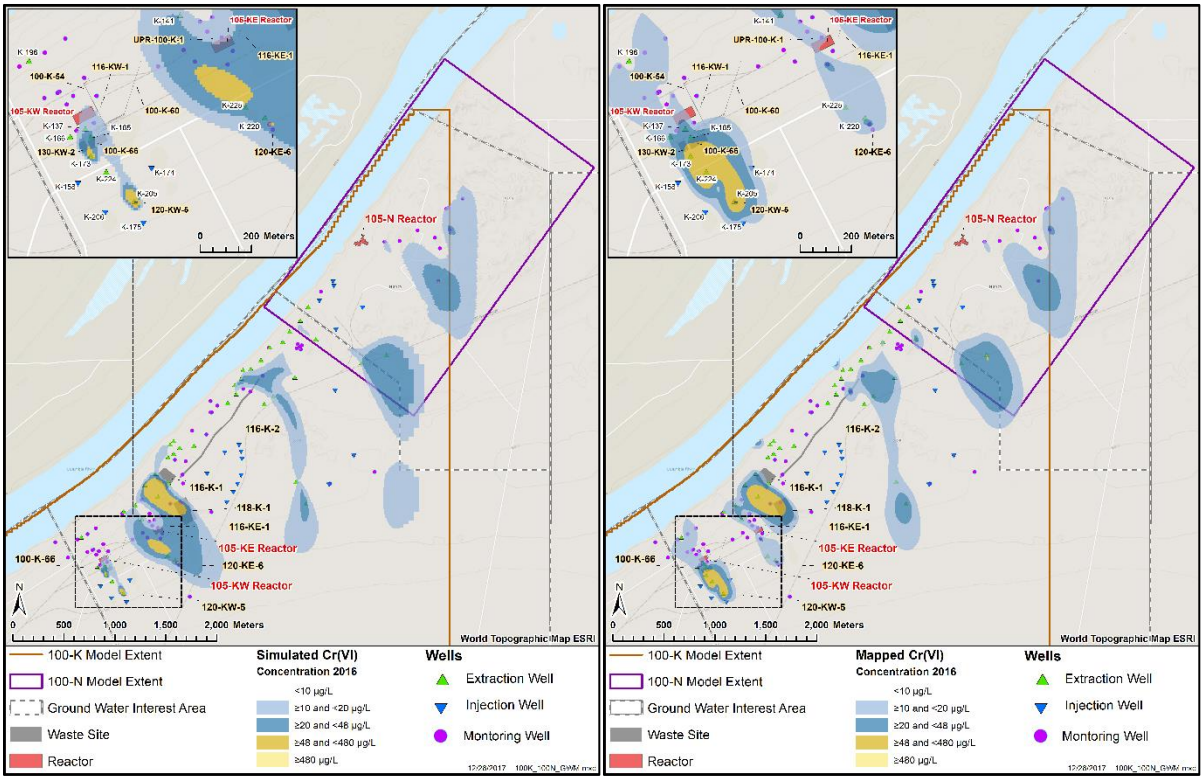


Figure 5-15. Simulated (Left) and Mapped (Right) Cr(VI) Concentrations at the End of 2016 in Layer 1 (Top of Unconfined Aquifer)

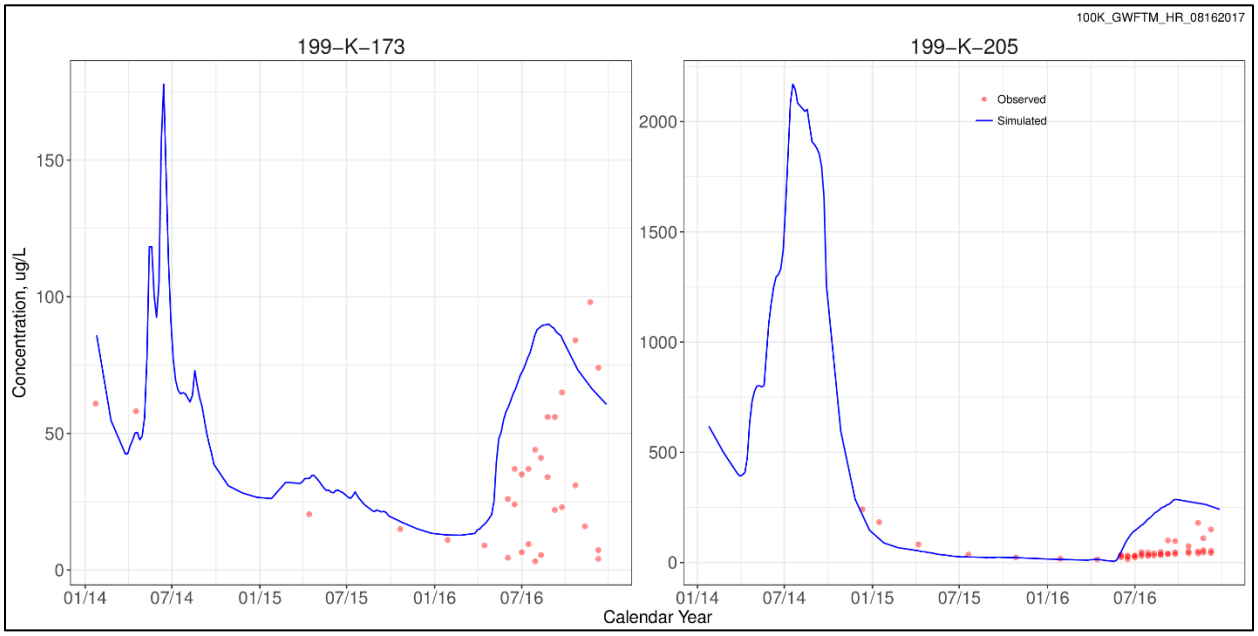


Figure 5-16. Observed Versus Simulated Cr(VI) Concentrations at Wells near the 183.1KW Headhouse

Figure 5-17 shows a comparison between simulated and observed Cr(VI) concentrations at wells 199-K-188, 199-K-220, and 199-K-36 near the 183.1KE Headhouse. Wells 199-K-188 and 199-K-36 are monitoring wells that are 25 m apart from each other. Well 199-K-220 is a KX P&T system extraction well with an approximate pumping rate of 230 L/min (60 gal/min). This extraction well about 35 m (115 ft) and 60 m (200 ft) downgradient of wells 199-K-36 and 199-K-188, respectively. Only one measurement at well 199-K-36 showed a higher Cr(VI) concentration than observed data in all three wells, and is an indication of a small localized continuing source near 183.1KE Headhouse. The calibrated continuing source zone at this location was small.

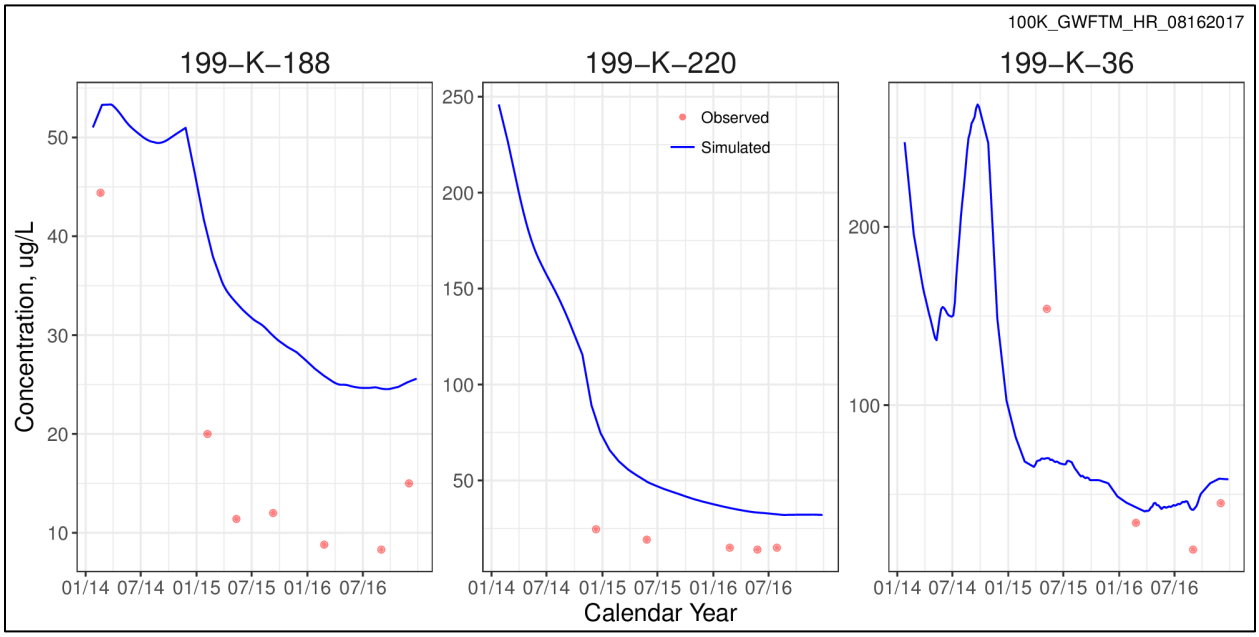


Figure 5-17. Observed Versus Simulated Cr(VI) Concentrations at Wells near the 183.1KE Headhouse

5.5.2.2.2 Calibration Results for Strontium-90

Strontium-90 has a high distribution coefficient (K_d of 12 mL/g was used for 100-K GWFTM) and is expected to transport slowly. However, the plume delineations in the annual groundwater monitoring report changed from one year to another. Therefore, transport calibration was done using the most recent initial concentration plumes (i.e., plumes from 2015 annual groundwater report [DOE/RL-2016-09]). This avoids introducing strontium-90 activity where it was not observed in the following years based on the updated interpretation. The highest strontium-90 concentrations in the 100-KR4 OU are located near the UPR-100-K-1 waste site and KE FSB in KE area. The estimated maximum concentrations in this area are >3,000 pCi/L, whereas all the observed concentrations at nearby wells 199-K-221 and 199-K-222 in 2016 were a couple of orders of magnitude lower than the initial concentrations used in the transport model. The representativeness of some of the samples was questioned after it was discovered that the samples were collected from the bottom of the well screen. As a result, reported observed concentrations were very low because all the high concentrations lie within the top 2 to 5 m of the aquifer. The sample collection method was revised later in 2016, and higher concentrations were reported. However, these numbers were still an order lower than the initial concentrations used for the transport model. Although 2017 was not part of the calibration simulation period, elevated strontium-90 concentrations at well 199-K-222 were reported for sampling in August 2017 (13,900 pCi/L) and October 2017 (15,600 pCi/L) and were used to confirm the selected transport model concentrations.

Based on prior knowledge and observed concentrations, the potential continuing sources for strontium-90 are the 116-KW-2 Crib in the KW area and UPR-100-K-1FSB, 116-K-1 Crib, and 116-K-2 Trench in the KE area.

Figure 5-18 shows a qualitative comparison between the simulated and mapped strontium-90 plumes at the end of 2016. Introducing continuing sources at 116-KW-2 Crib and at west corner of the 116-K-2 Trench increased the simulated concentrations similar to the observed high concentrations. No continuing source was used at the 116-K-1 Crib because there was no groundwater data available to support any continuing source. There are two extraction wells (199-K-144 and 199-K-208) near the 116-K-1 Crib, and all the observed concentrations at these two wells are below DWS. Depth-discrete soil concentration data at wells 199-K-221 and 199-K-222 near UPR-100-K-1/FSB were available to be used in STOMP 1D model for estimating characteristic release rate curves. As described above, the observed concentrations at these two wells in 2016 are orders of magnitude lower than the initial concentrations and in 2017 were higher than the initial concentrations. Therefore, a multiplier was used to scale the characteristic release rate curve so that simulated concentrations match the observed high concentrations. Figure 5-19 shows the simulated versus observed concentrations at wells 199-K-221 and 199-K-222 near the KE FSB. Most of the observed concentrations at well 199-K-221 are <8 pCi/L, and one recently observed data was found to be around 45 pCi/L. On the other hand, the mapped concentration in the 2015 annual groundwater report (DOE/RL-2016-09), which was used as initial concentration in the transport model, was around 400 pCi/L. The simulated high concentration at well 199-K-221 is mainly driven by the high initial concentration. A strong source was required to match the observed concentrations (15,600 pCi/L) at well 199-K-222.

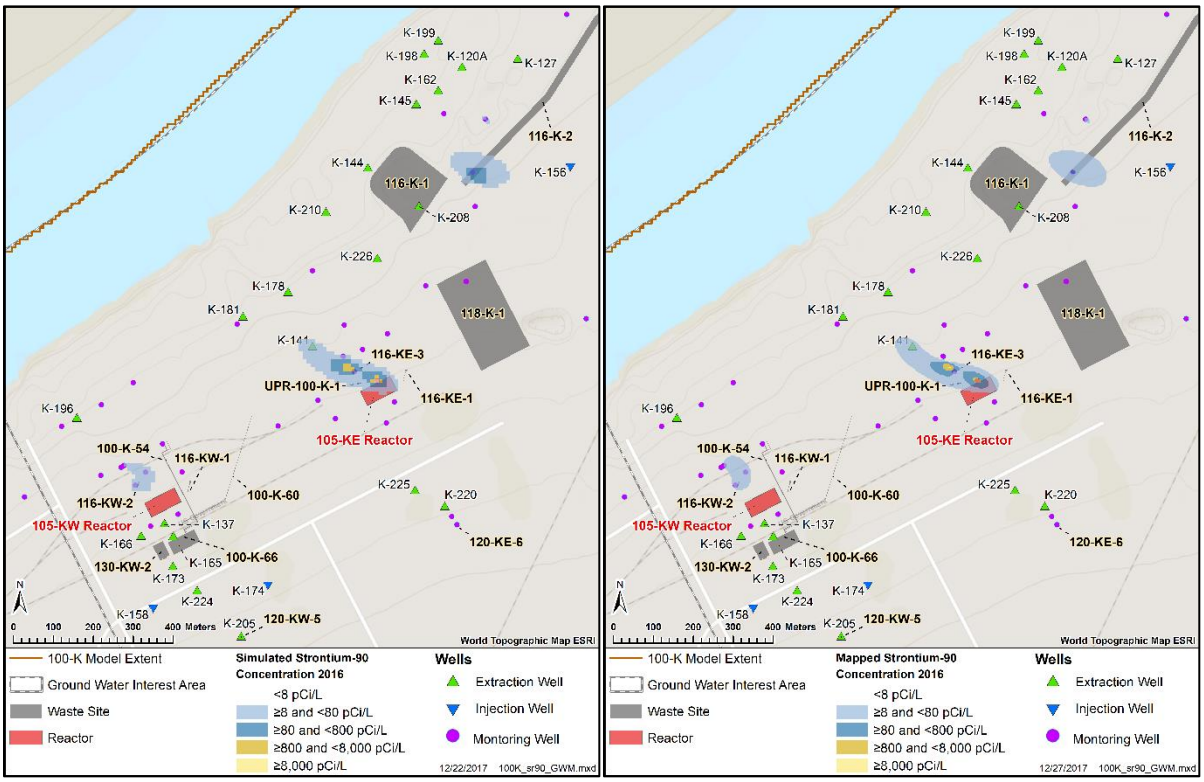


Figure 5-18. Simulated (Left) and Mapped (Right) Strontium-90 Concentrations at the End of 2016 in Layer 1 (Top of Unconfined Aquifer)

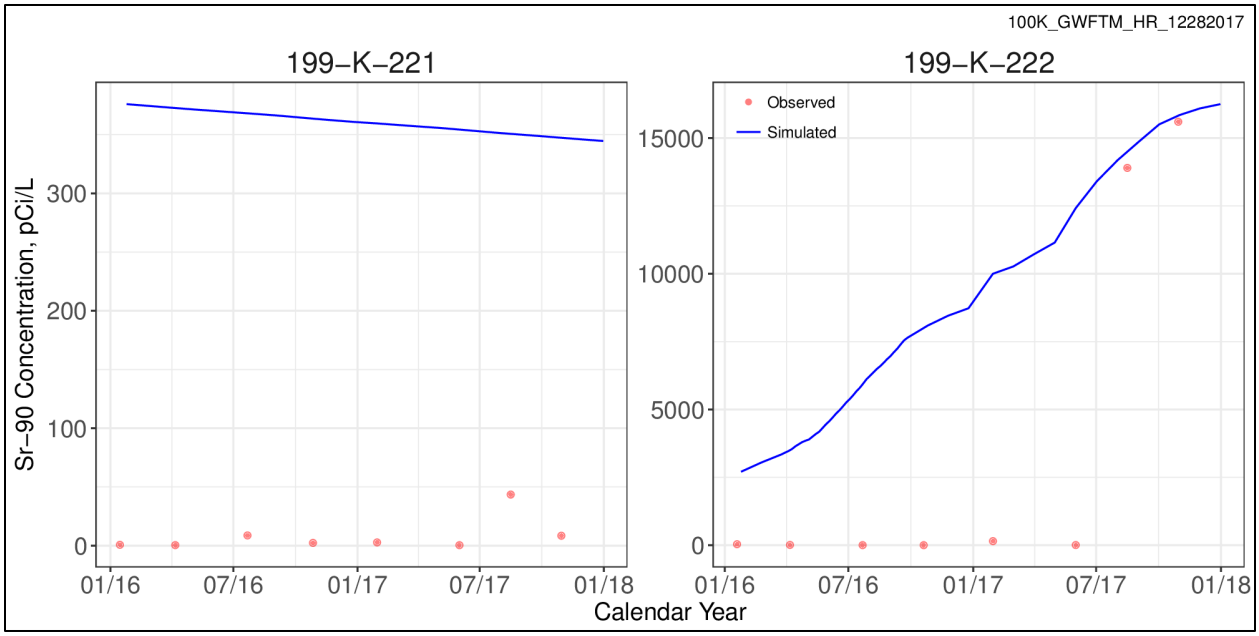


Figure 5-19. Observed Versus Simulated Strontium-90 Concentrations at Wells near KE FSB

5.5.2.2.3 Calibration Results for Carbon-14

Carbon-14 in groundwater is mostly near the 116-KW-1 and 116-KE-1 gas condensate cribs. These are also potential continuing source locations considered for the transport model calibration. Figure 5-20 shows a qualitative comparison between the simulated and mapped carbon-14 plume at the end of 2016. Figure 5-21 shows the comparison between observed and simulated carbon-14 concentrations at wells near 116-KW-1. Introducing a continuing source at the 116-KW-1 gas condensate crib increased the simulated concentrations similar to the observed high concentrations at wells 199-K-106A and 199-K-204. On the other hand, no continuing source was used near 116-KE-1 as the simulated concentrations were already higher than the observed values.

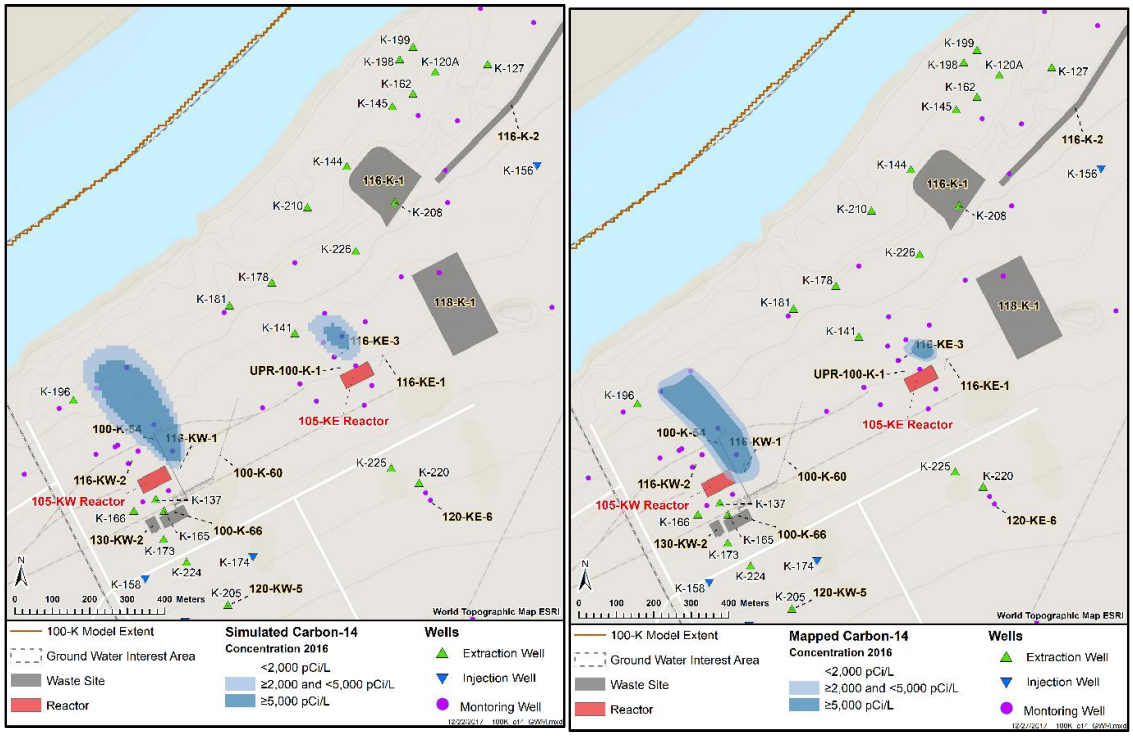


Figure 5-20. Simulated (Left) and Mapped (Right) Carbon-14 Concentrations at the End of 2016 in Layer 1 (Top of Unconfined Aquifer)

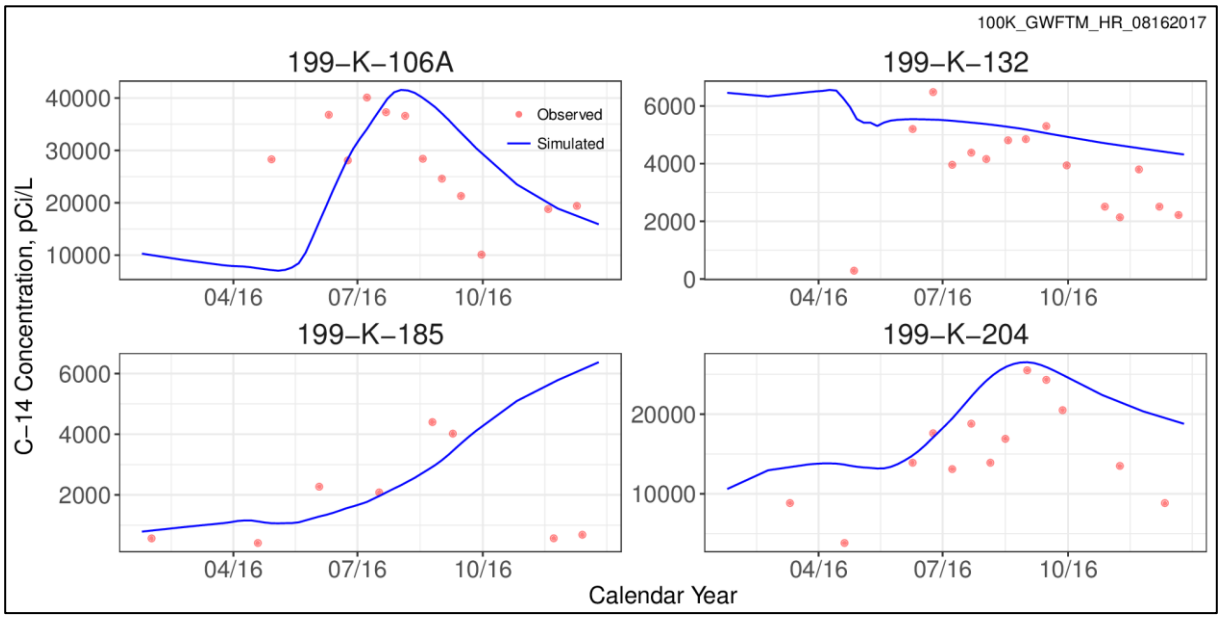


Figure 5-21. Observed Versus Simulated Carbon-14 Concentrations at Wells near the 116-KW-1 Gas Condensate Crib

5.5.2.2.4 Calibration Results for Nitrate

Nitrate in groundwater is mostly near the 116-KW-1 Gas Condensate Crib. Although both 116-KW-1 and 116-KE-1 gas condensate cribs are potential continuing sources, no calibration of a continuing source was done for 116-KE-1 due to the absence of any plume according to the 2016 data. Nitrate plume

delineations in the annual groundwater monitoring reports between 2013 and 2015 has evolved due to the plume migration and observation data. The plume delineation is dependent on well 199-K-106A, with expanded coverage provided by installing well 199-K-204 downgradient of 199-K-106A. Recent data, discussed in Section 4.6.4, showed an increase in concentration at wells 199-K-106A and 199-K-204. The data suggest a continuing source upgradient of these two wells. The nitrate plume from the 2013 annual groundwater report (DOE/RL-2014-32) was selected to provide representative initial concentrations, with transport model simulations for CYs 2014 through 2016 used for calibration. Figure 5-22 shows a qualitative comparison between the simulated and mapped nitrate plume at the end of 2016. The mapped plume extent is larger than the simulated plume. It is mainly due to the recently observed concentrations above the DWS that were lower than the DWS in the past, which were not included in the initial concentration or potential source locations. Figure 5-23 shows the comparison between observed and simulated nitrate concentrations at wells near 116-KW-1. Introducing a continuing source at the 116-KW-1 gas condensate crib increased the simulated concentrations similar to the observed concentrations at wells 199-K-106A and 199-K-204. No continuing source was used near 116-KE-1 as the simulated concentrations were already higher than the observed values.

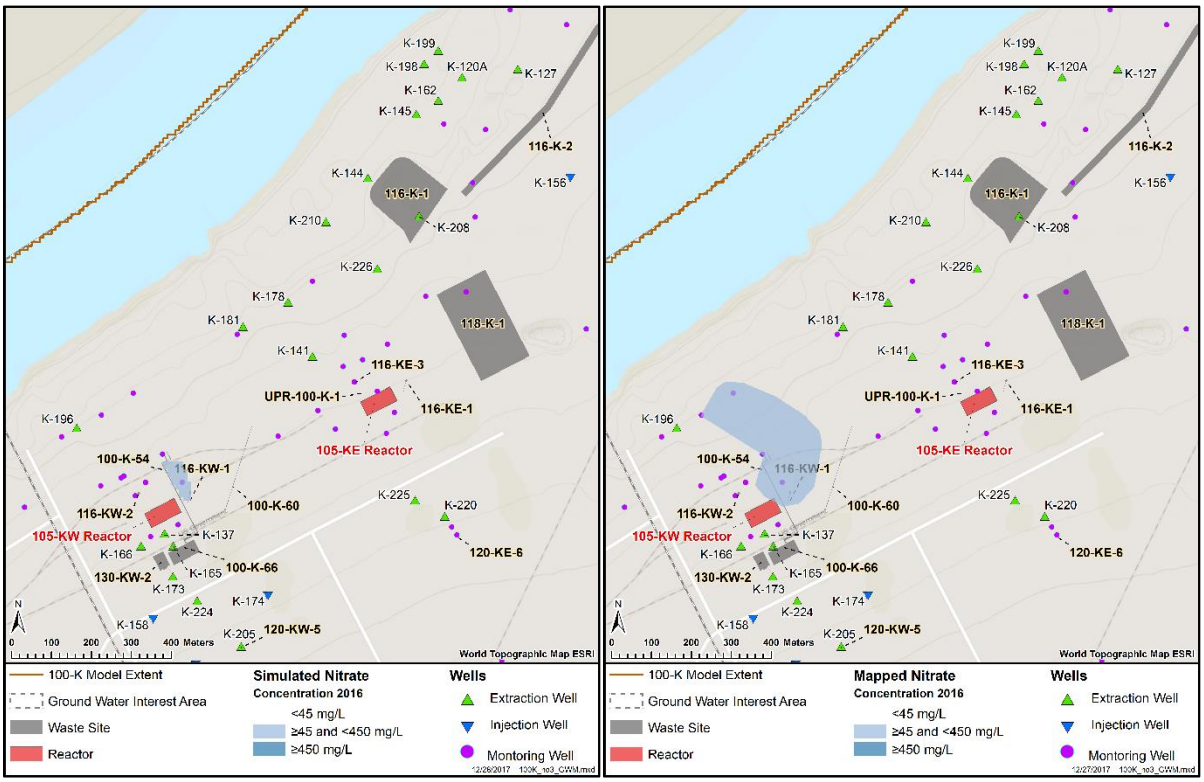


Figure 5-22. Simulated (Left) and Mapped (Right) Nitrate Concentrations at the End of 2016 in Layer 1 (Top of Unconfined Aquifer)

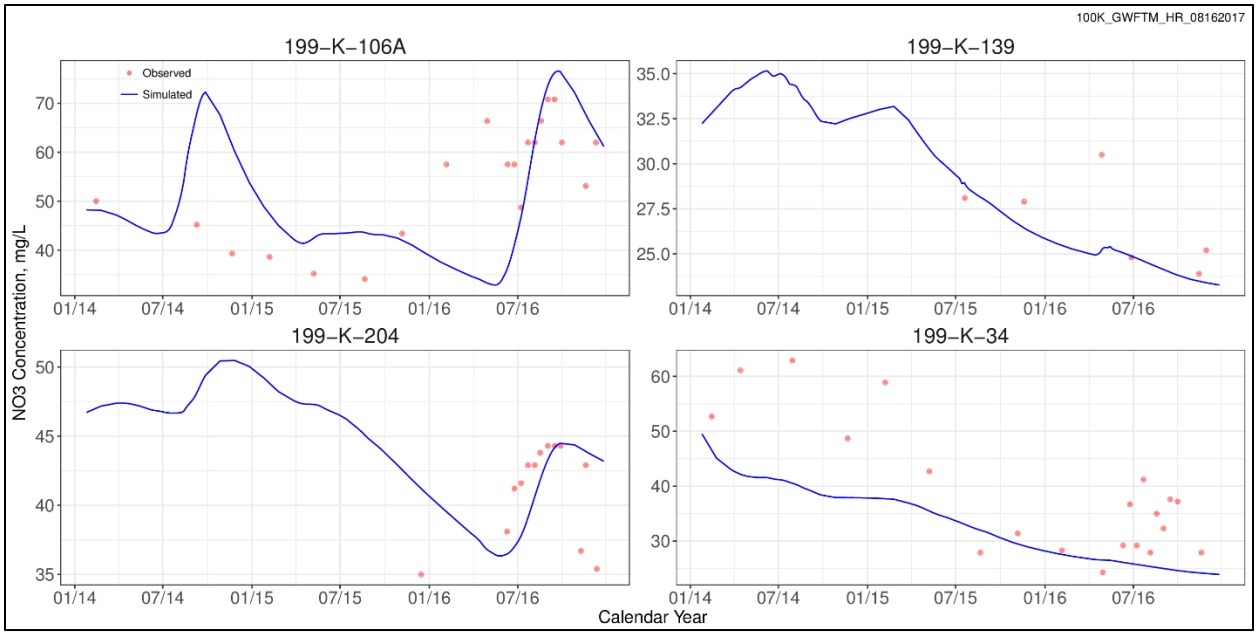


Figure 5-23. Observed Versus Simulated Nitrate Concentrations at Wells near the 116-KW-1 Gas Condensate Crib

5.5.2.2.5 Calibration Results for Tritium

Based on the prior knowledge and observed concentrations, the potential continuing sources for tritium are the 116-KW-1 and 116-KW-2 Cribs in the KW area; and the UPR-100-K-1 waste site, 116-K-1 Crib, and 118-K-1 Burial Ground in the KE area. Figure 5-24 shows a qualitative comparison between the simulated and mapped tritium plume at the end of 2016. Figure 5-25 shows the comparison between observed and simulated concentrations at selected wells near the 116-KW-1 and 116-KE-1 gas condensate cribs and the 118-K-1 Burial Ground. Introducing continuing sources near the 116-KW-1 and 116-KE-1 gas condensate cribs, and near the 118-K-1 Burial Ground, increased the simulated concentrations similar to the observed high concentrations at the nearby wells. Tritium contamination at the 118-K-1 Burial Ground is addressed as the 100-K-132 waste site, where tritium is expected to remain in the deep vadose zone even after excavating 12 m (39 ft) bgs for the interim remedial action. The monitoring wells near 116-KW-2 do not show any concentrations above the DWS. Therefore, no continuing source was assigned at this waste site. Tritium is recirculated through the P&T system; no treatment technology is available.

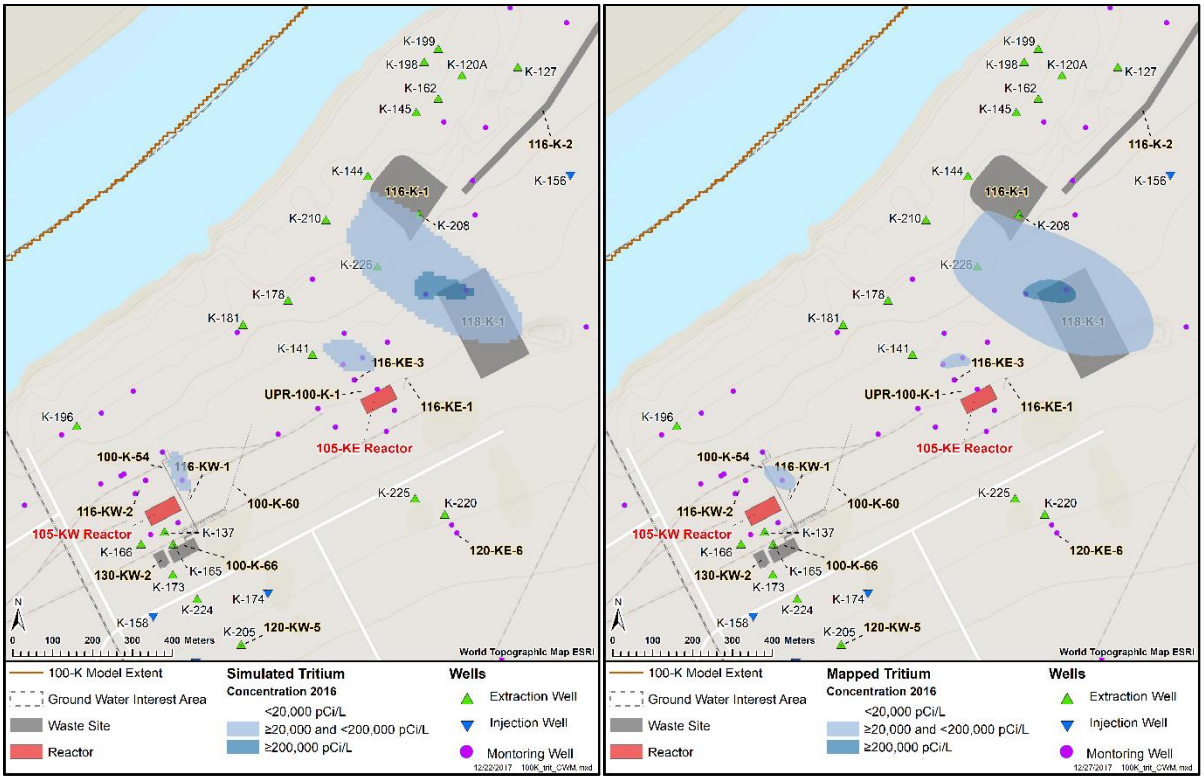


Figure 5-24. Simulated (Left) and Mapped (Right) Tritium Concentrations at the End of 2016 in Layer 1 (Top of Unconfined Aquifer)

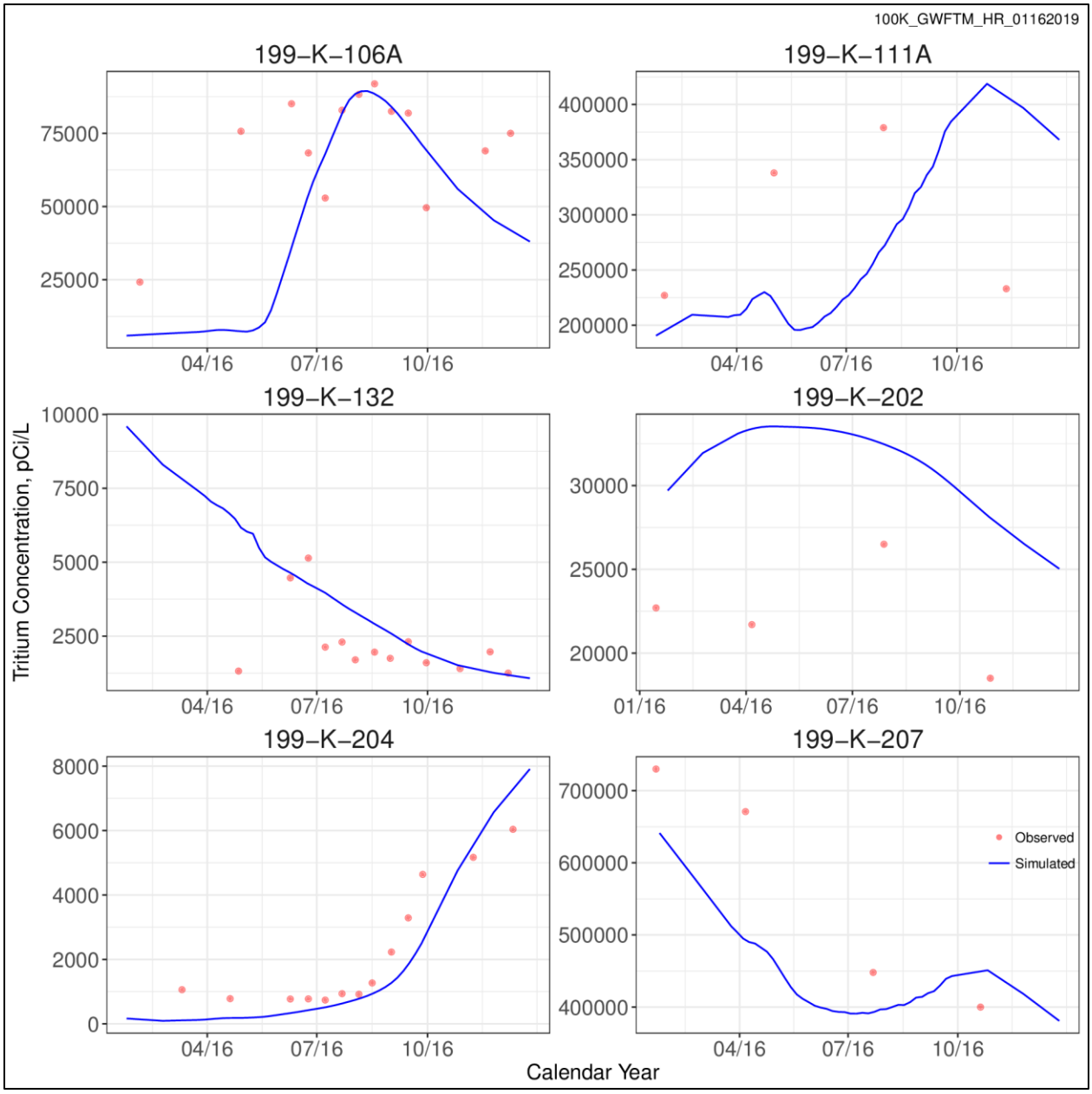


Figure 5-25. Observed Versus Simulated Tritium Concentrations at Wells near the 116-KW-1 and 116-KE-1 Gas Condensate Cribs, and 118-K-1 Burial Ground

5.5.2.2.6 Calibration Results for Trichloroethene

No continuing source has been identified for trichloroethene. Additionally, trichloroethene is not treated and is recirculated in the aquifer further obscuring interpretation. However, the plume footprint above 5 µg/L changed in 2016, suggesting a source may be present. Prediction was performed with the 2016 plume with no source (Figure 5-26).

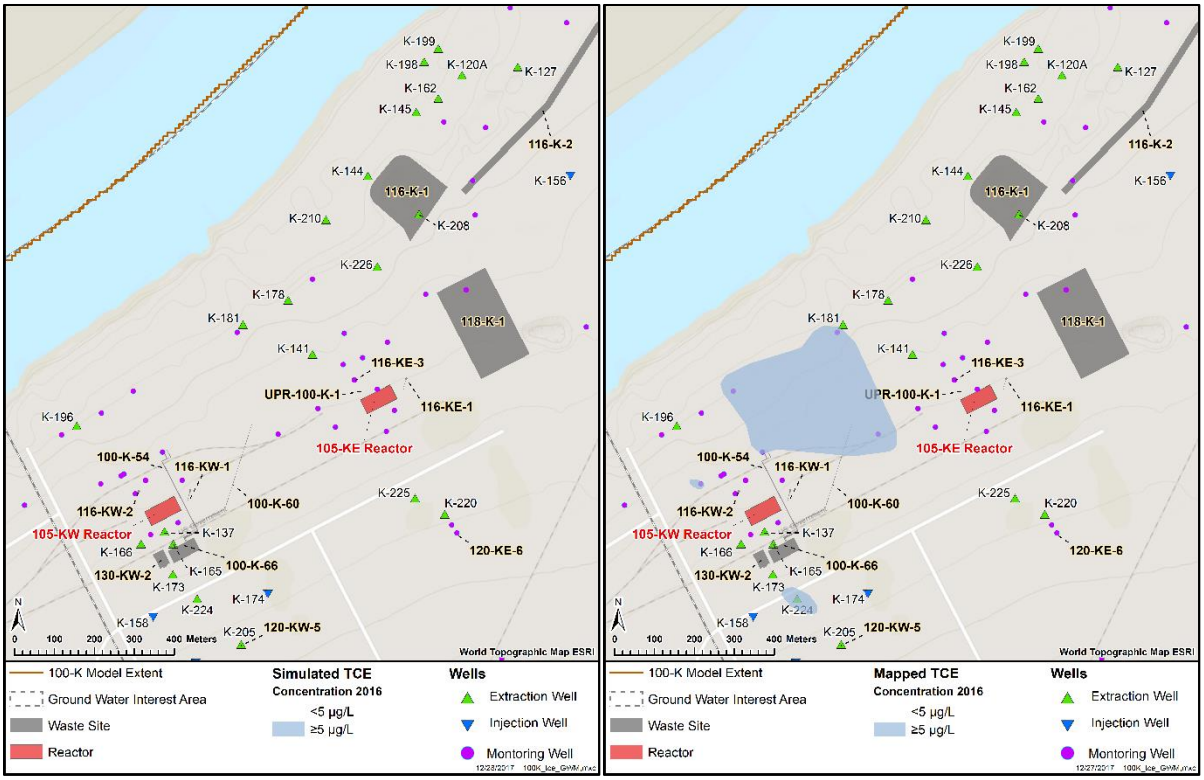


Figure 5-26. Simulated (Left) and Mapped (Right) Trichloroethene Concentrations at the End of 2016 in Layer 1 (Top of Unconfined Aquifer)

5.5.3 Uncertainty Analysis

To improve the model predictive power for evaluating decisions about groundwater contamination, many types of data were used, including hydraulic head; Cr(VI), strontium-90, carbon-14, and nitrate interpreted plume migration and individual well concentration trends; process knowledge of source areas; and groundwater discharge patterns to the river. This approach follows the general guidelines of Hill, 1998, *Methods and Guidelines for Effective Model Calibration*. Uncertainty in the 100-K GWFTM has been reduced with this approach, but is difficult to quantify. The broad location of source strengths and locations has been inferred from groundwater monitoring and historical waste site knowledge. The Cr(VI) and strontium-90 leaching coefficients have been estimated from the best available core data. However, uncertainty remains because the interval of these observations is less than the long-term forecasts required in the RI and FS process. An additional complication is the potential change in the hydrologic system from a revised Columbia River treaty with Canada. The models used in this analysis are ultimately simplifications of reality, and some difference in forecasted versus actual results is likely; models are best considered as tools to inform decisions rather than absolute predictions (EPA/100/K-09/003, *Guidance on the Development, Evaluation, and Application of Environmental Models*).

5.6 Application of Groundwater Fate and Transport Model Results

The 100-K GWFTM simulation results for the no further action case are presented in the following subsections to establish the basis for action for current groundwater contamination in 100-K. These results also provide the baseline for comparison with fate and transport simulation results for the remediation alternatives discussed in the FS (DOE/RL-2018-22).

5.6.1 Hexavalent Chromium

The no further action case is assumed to begin in January 2020, with the P&T system continuing operation as described in SGW-58690, *Remedial Process Optimization Work Plan for 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action*, until then. Figures 5-27 through 5-31 illustrate the Cr(VI) plumes from 2017 through 2117. The simulations indicate that by 2067 (Figure 5-30) the K East and K North plumes have dissipated. The KW Headhouse area source continues to generate a plume, and the K-N boundary and 100-N plumes migrate north toward the river at concentrations between 10 and 20 µg/L. Continued source depletion causes the KW plume to diminish, but not disappear, by 2117 (Figure 5-31); the 100-N plume also remains near the N Reactor and river shoreline at low concentrations.

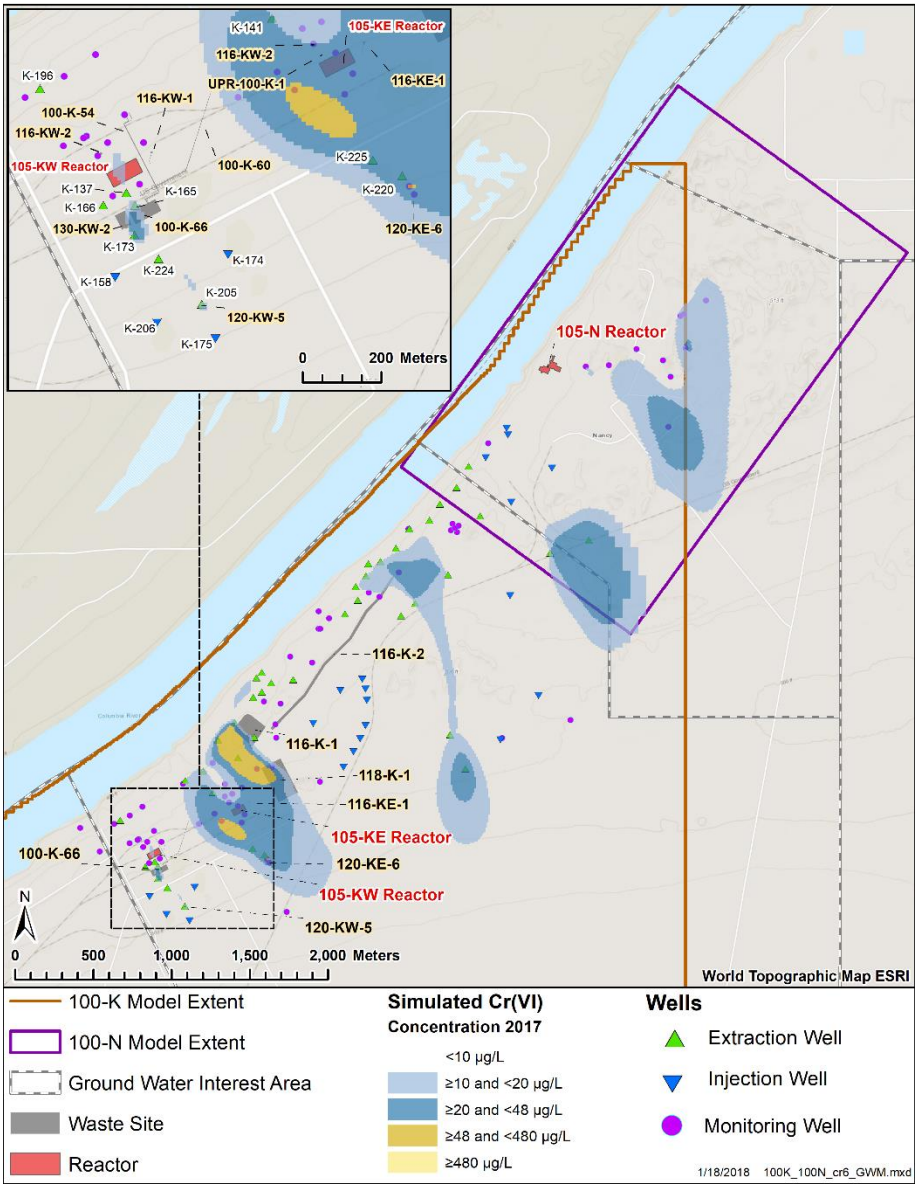


Figure 5-27. Simulated Cr(VI) Plume in 2017 at the Top of the Unconfined Aquifer

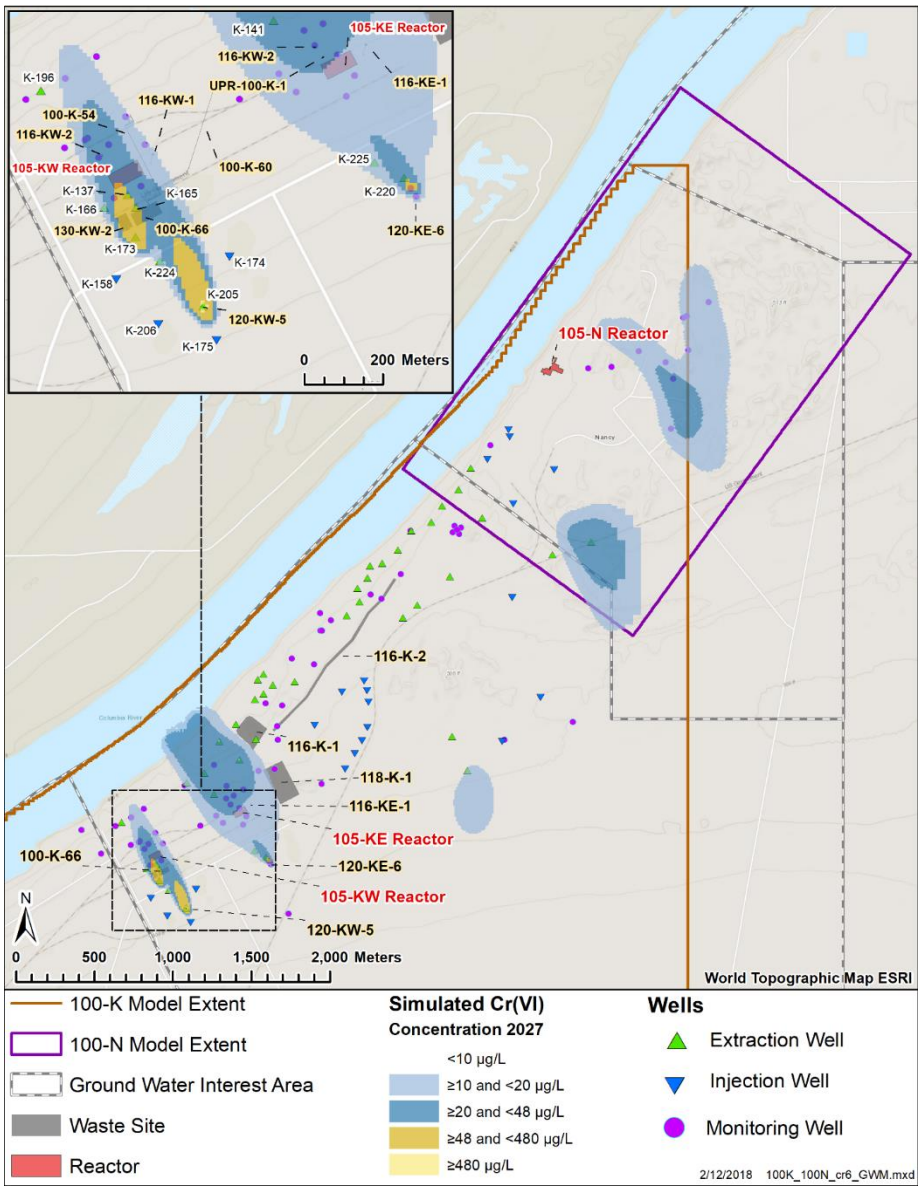


Figure 5-28. Simulated Cr(VI) Plume in 2027 at the Top of the Unconfined Aquifer

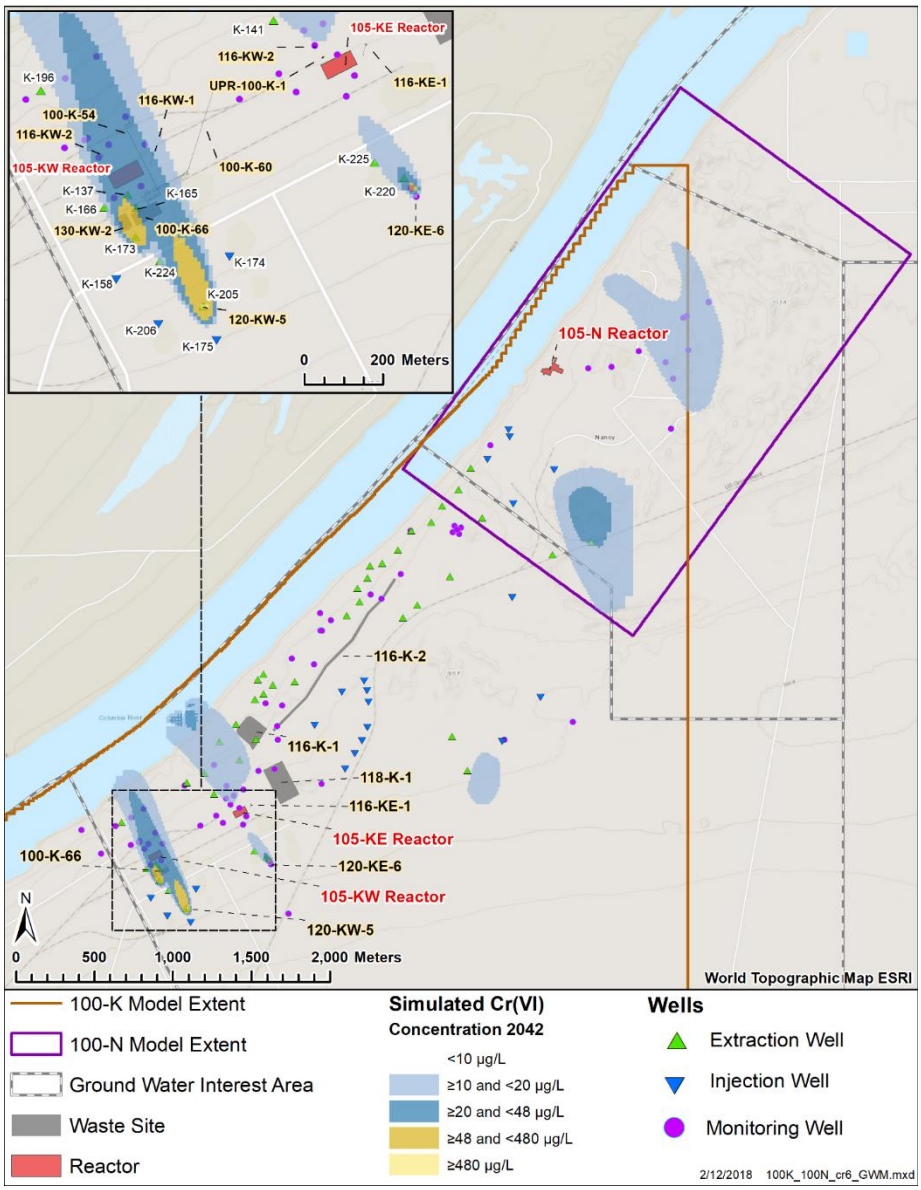


Figure 5-29. Simulated Cr(VI) Plume in 2042 at the Top of the Unconfined Aquifer

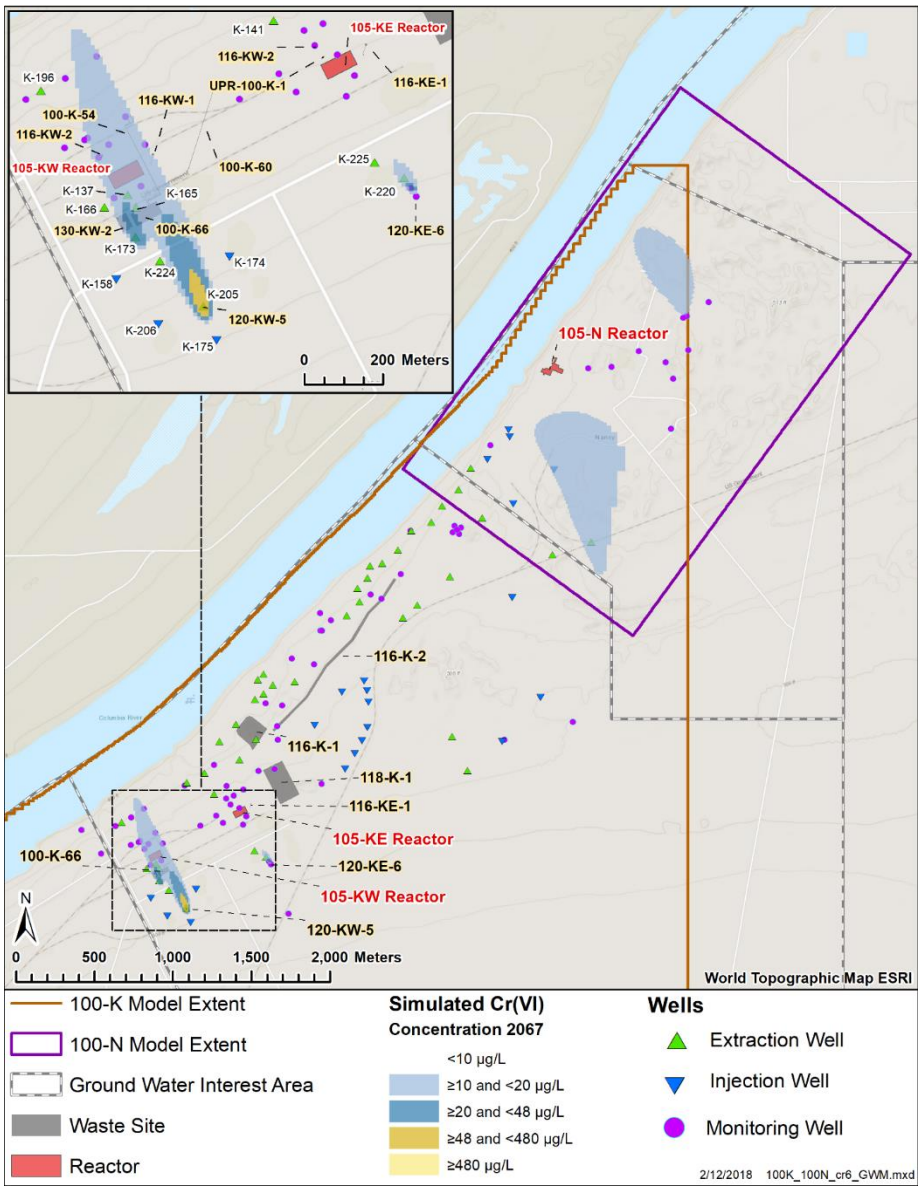


Figure 5-30. Simulated Cr(VI) Plume in 2067 at the Top of the Unconfined Aquifer

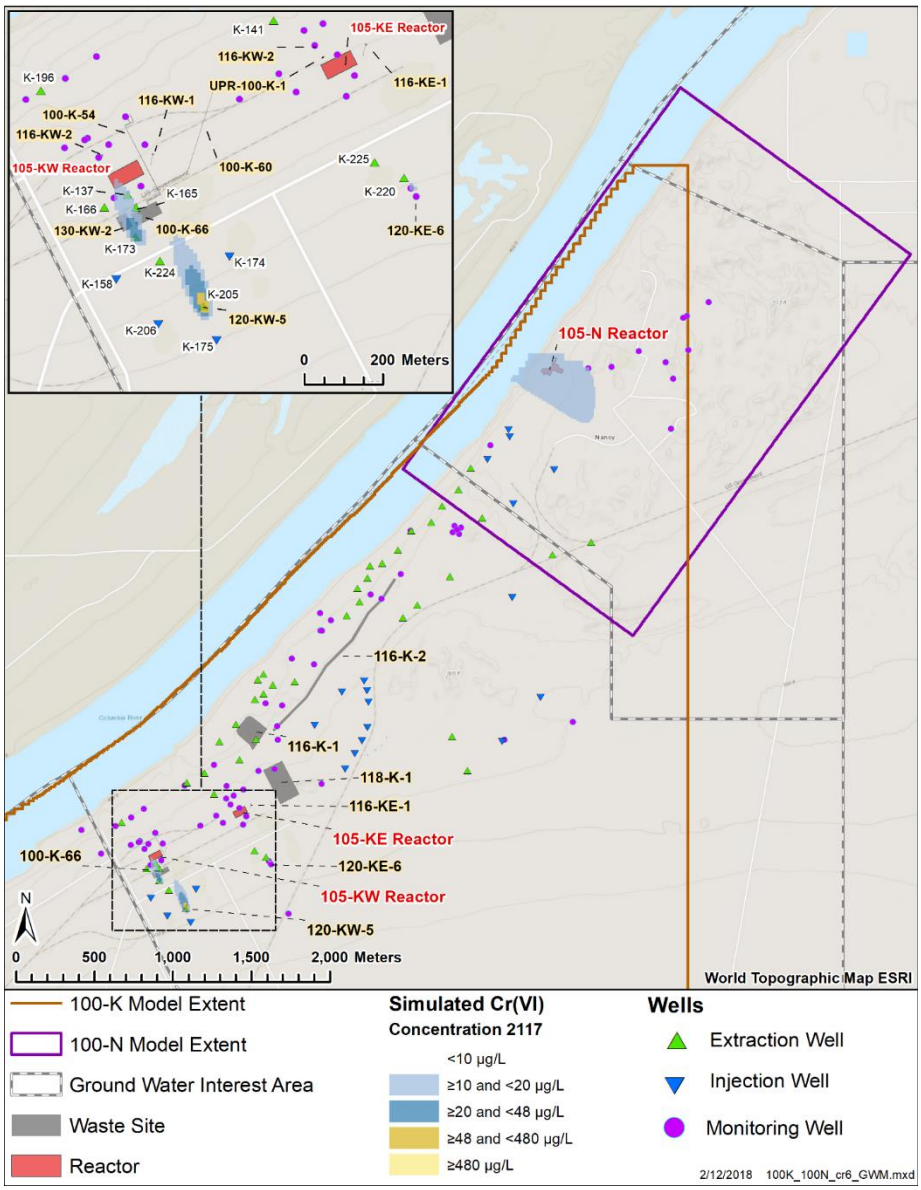


Figure 5-31. Simulated Cr(VI) Plume in 2117 at the Top of the Unconfined Aquifer

5.6.2 Strontium-90

The no further action case is assumed to begin in January 2020, with the P&T system continuing operation as described in SGW-58690 until then. Figure 5-32 shows the 2017 strontium-90 plume configurations, and Figure 5-33 shows the simulated extent 100 years later. Radioactive decay has reduced concentrations, but sources near the KW and KE Reactors, especially the 100-K-UPR-1 waste site, and high initial concentrations result in concentrations >8 pCi/L in 2117. A 300-year simulation was also performed and indicated concentrations were >8 pCi/L after 300 years.

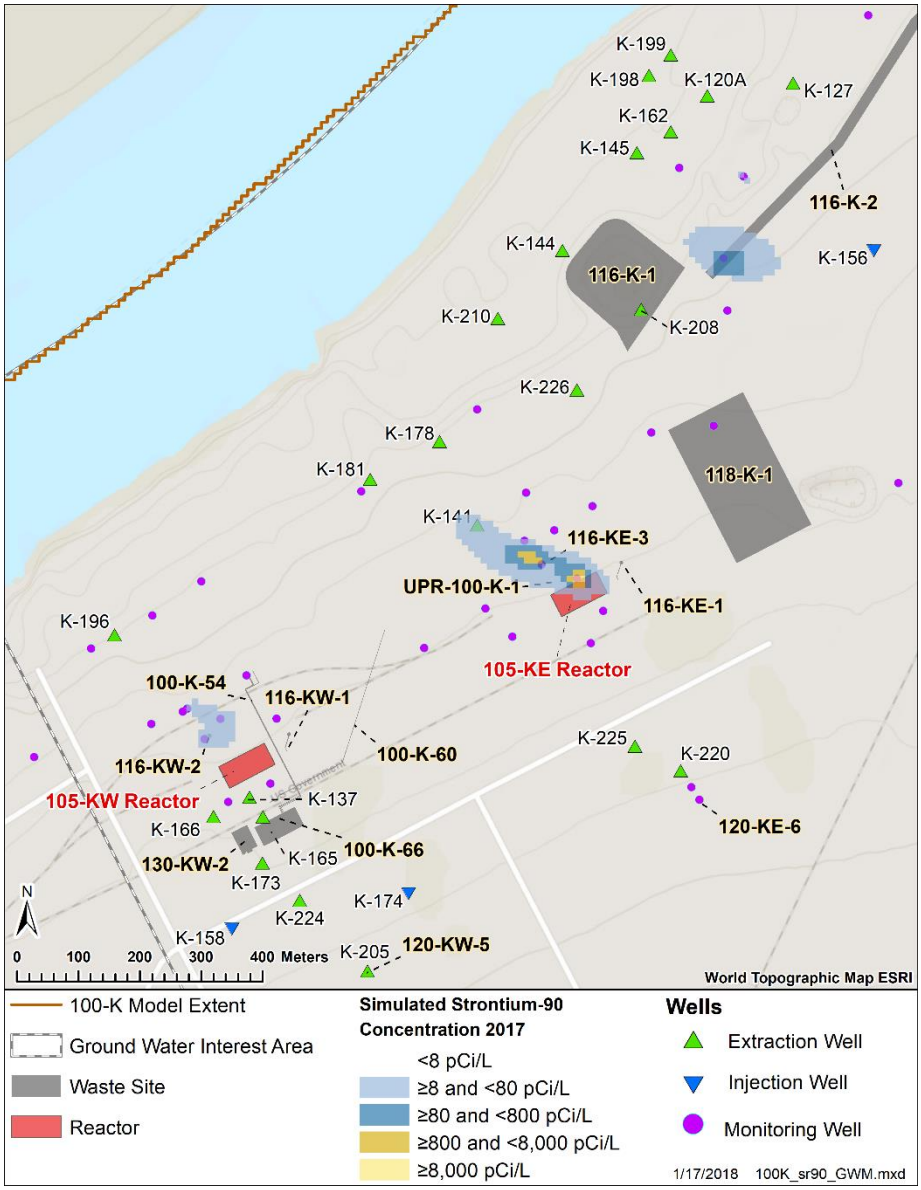


Figure 5-32. Simulated Strontium-90 Plume in 2017 at the Top of the Unconfined Aquifer

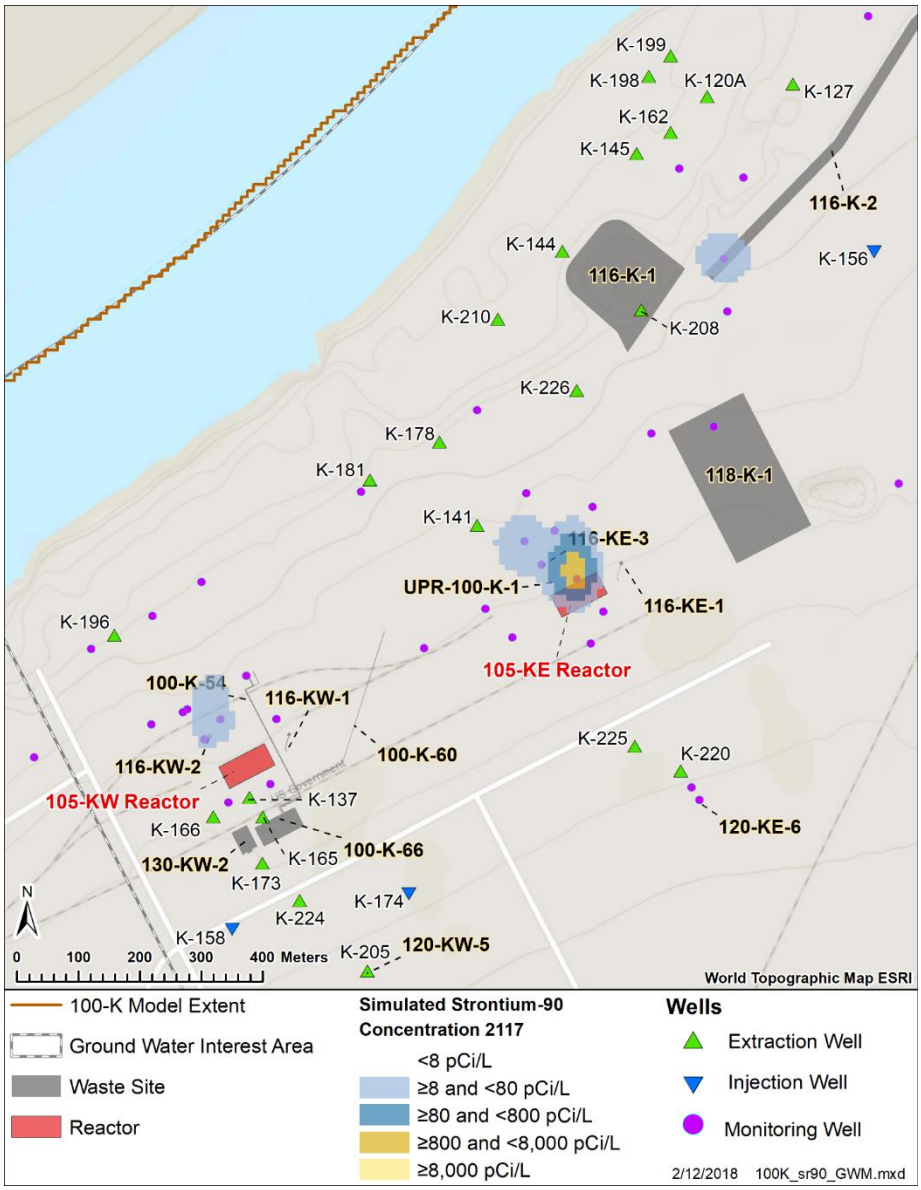


Figure 5-33. Simulated Strontium-90 Plume in 2117 at the Top of the Unconfined Aquifer

5.6.3 Carbon-14

The no further action case is assumed to begin in January 2020, with the P&T system continuing operation as described in SGW-58690 until then. Figure 5-34 shows the carbon-14 plumes in 2017, and Figure 5-35 shows the simulated plume remaining in 2027. The simulated plume extent is shrinking due to source depletion, as the carbon-14 half life is too long for radioactive decay to affect the results. Simulations indicate the carbon-14 plume in the KW area dissipates to <2,000 pCi/L by 2033.

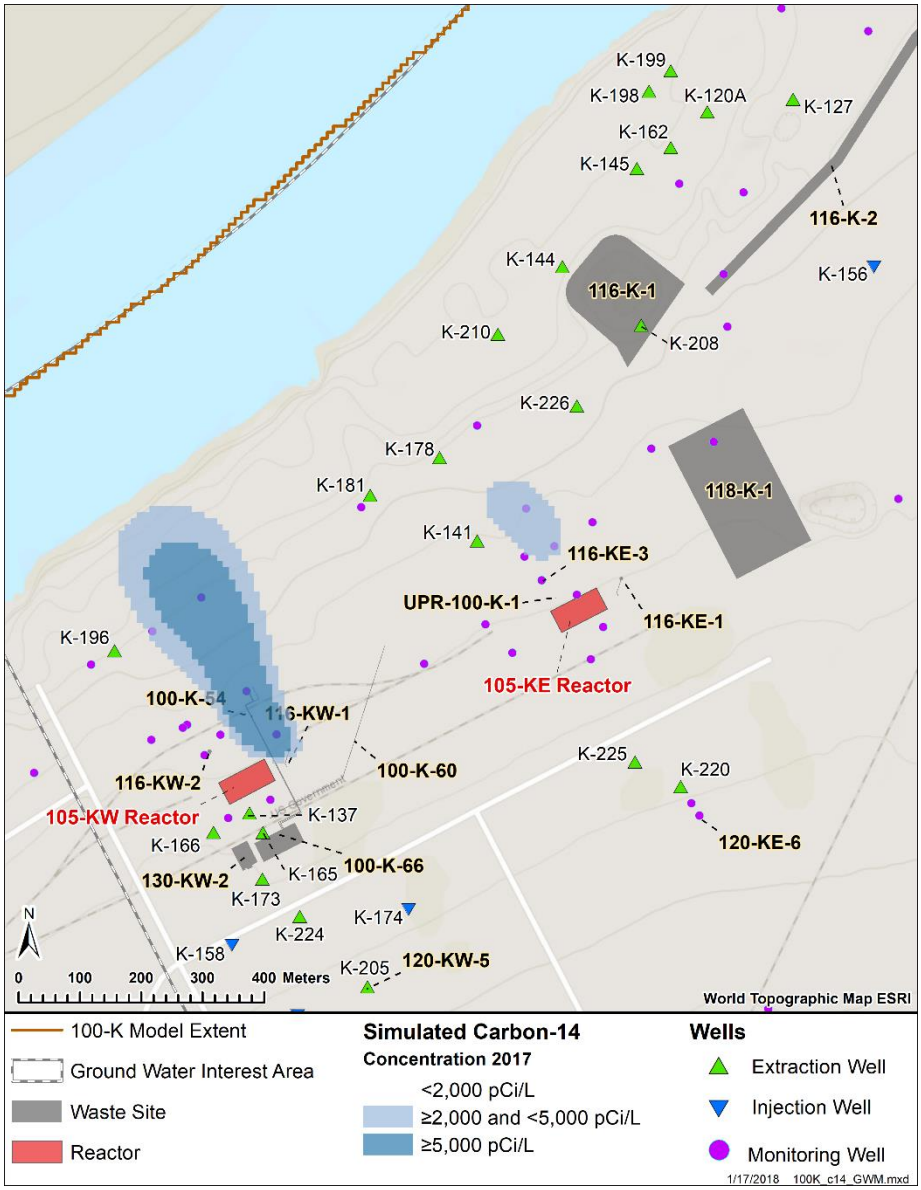


Figure 5-34. Simulated Carbon-14 Plume in 2017 at the Top of the Unconfined Aquifer

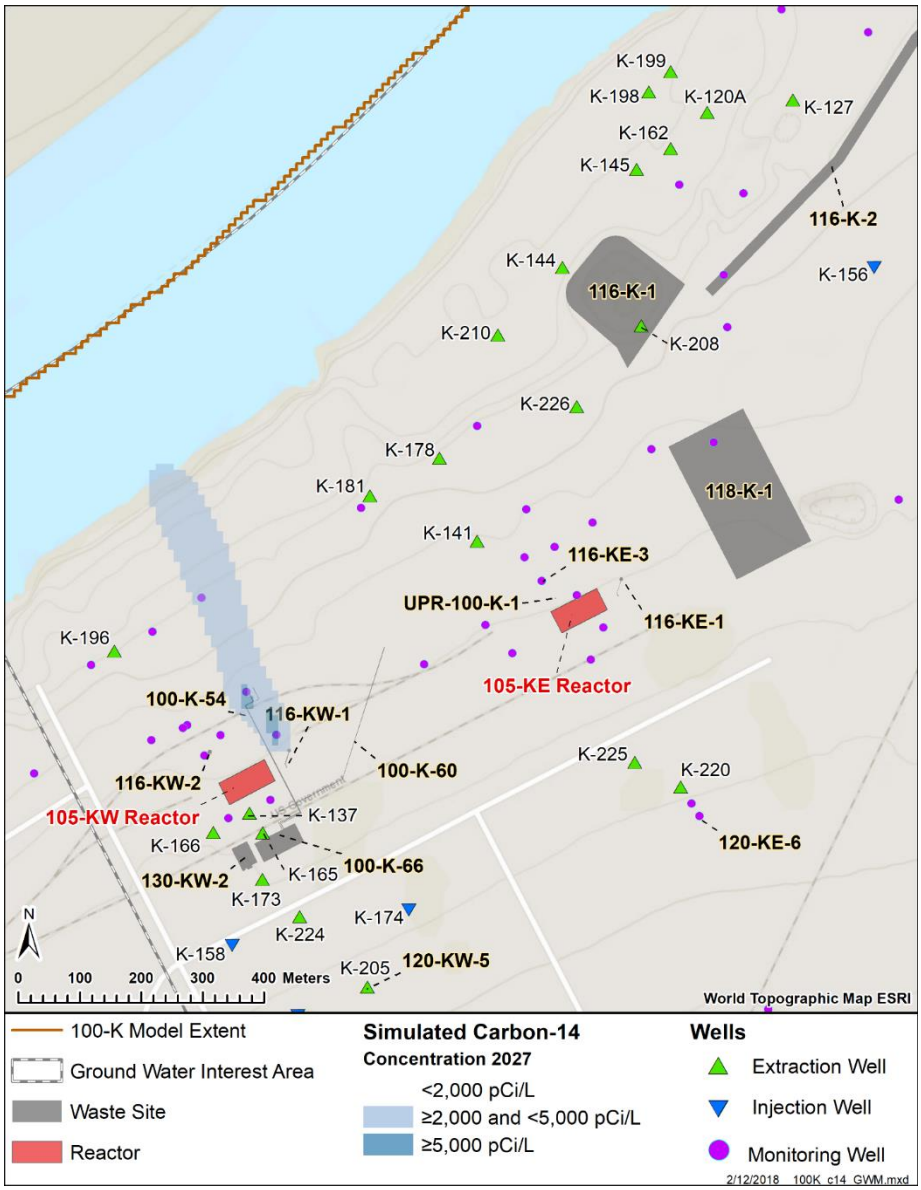


Figure 5-35. Simulated Carbon-14 Plume in 2027 at the Top of the Unconfined Aquifer

5.6.4 Nitrate

The no further action case is assumed to begin in January 2020, with the P&T system continuing operation as described in SGW-58690 until then. Figure 5-36 shows the nitrate plume in 2017, and Figure 5-37 shows the simulated plume in 2024. Source depletion at 116-KW-1 results in decreasing plume extent, and the simulated concentrations are <45 mg/L by 2027.

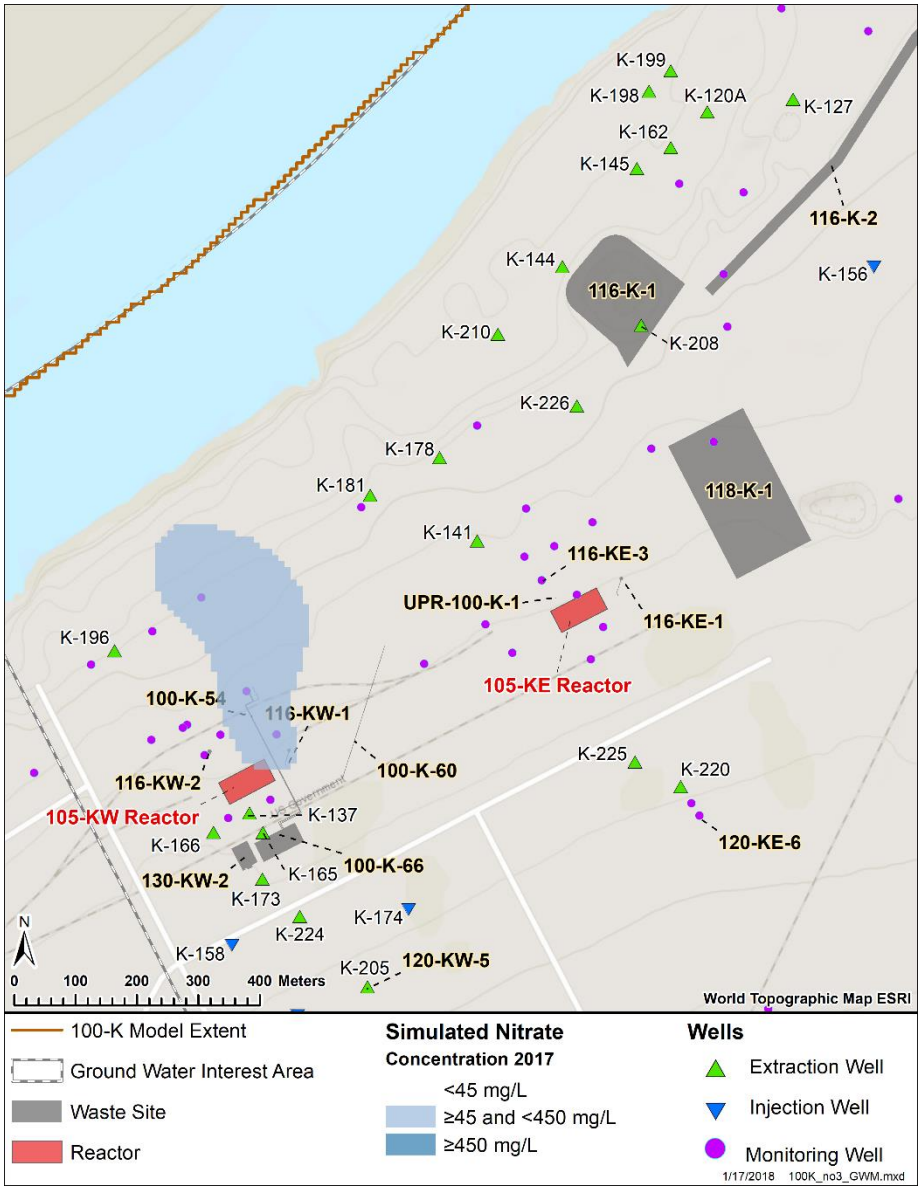


Figure 5-36. Simulated Nitrate Plume in 2017 at the Top of the Unconfined Aquifer

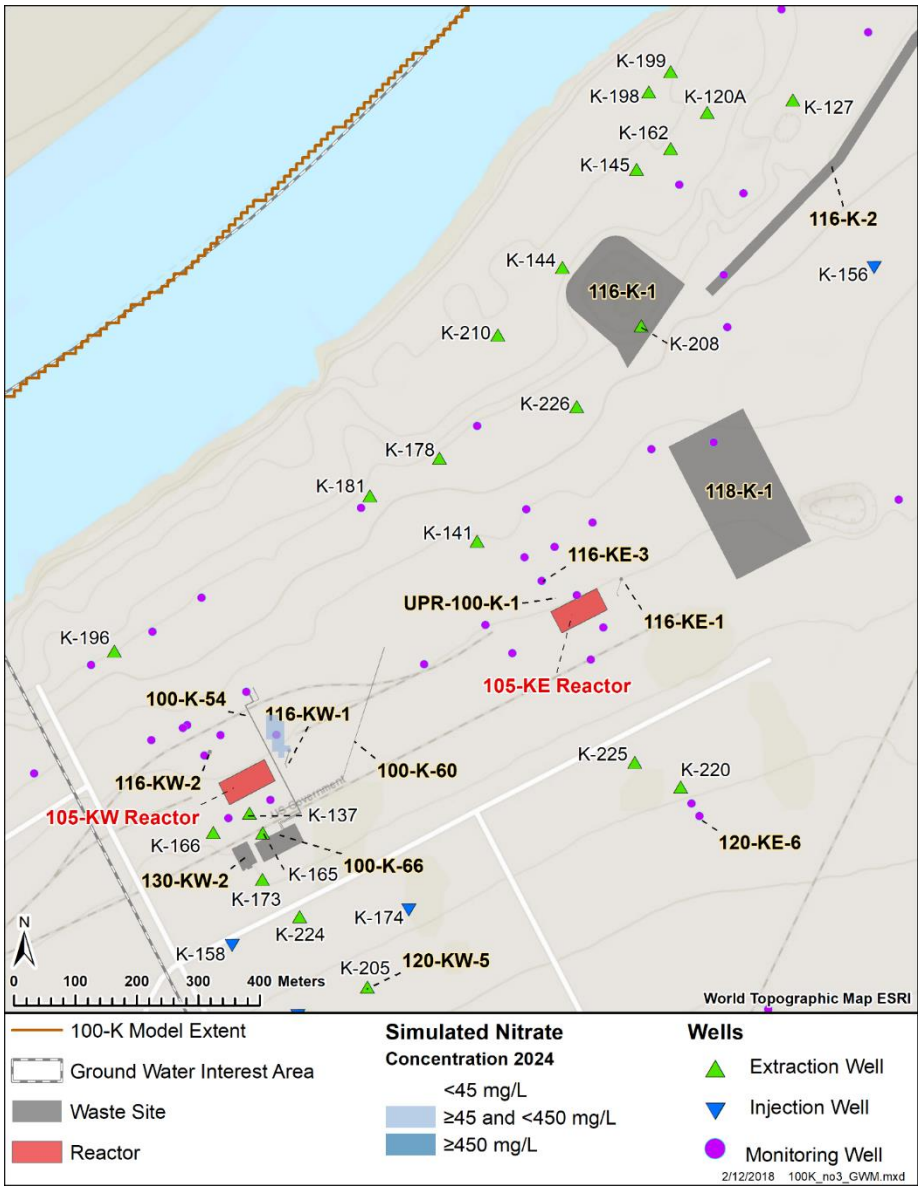


Figure 5-37. Simulated Nitrate Plume in 2024 at the Top of the Unconfined Aquifer

5.6.5 Tritium

The no further action case is assumed to begin in January 2020, with the P&T system continuing operation as described in SGW-58690 until then. Figure 5-38 shows the tritium plumes in 2017, and Figure 5-39 shows the simulated plume in 2027. Source depletion and radioactive decay act to reduce effects to groundwater, with no tritium concentrations >20,000 pCi/L simulated by 2027.

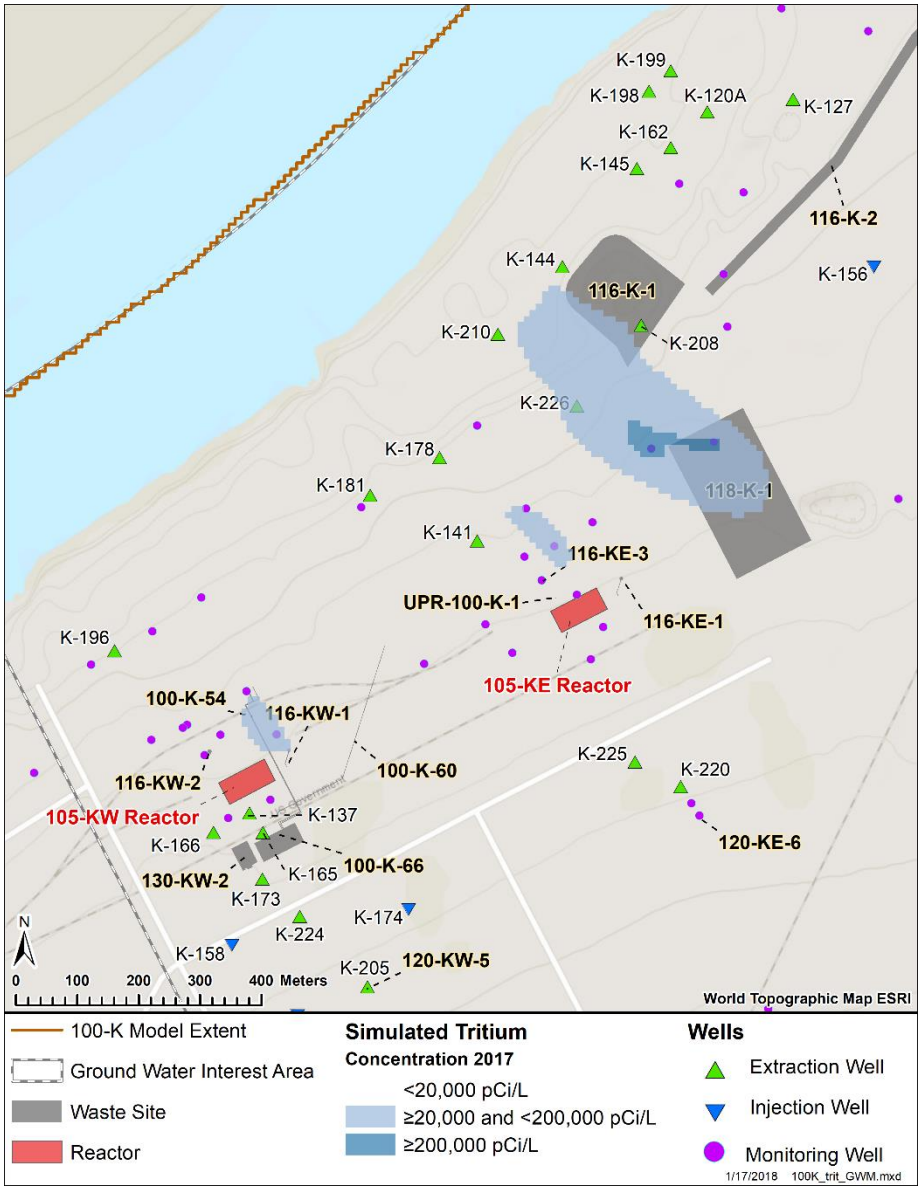


Figure 5-38. Simulated Tritium Plume in 2017 at the Top of the Unconfined Aquifer

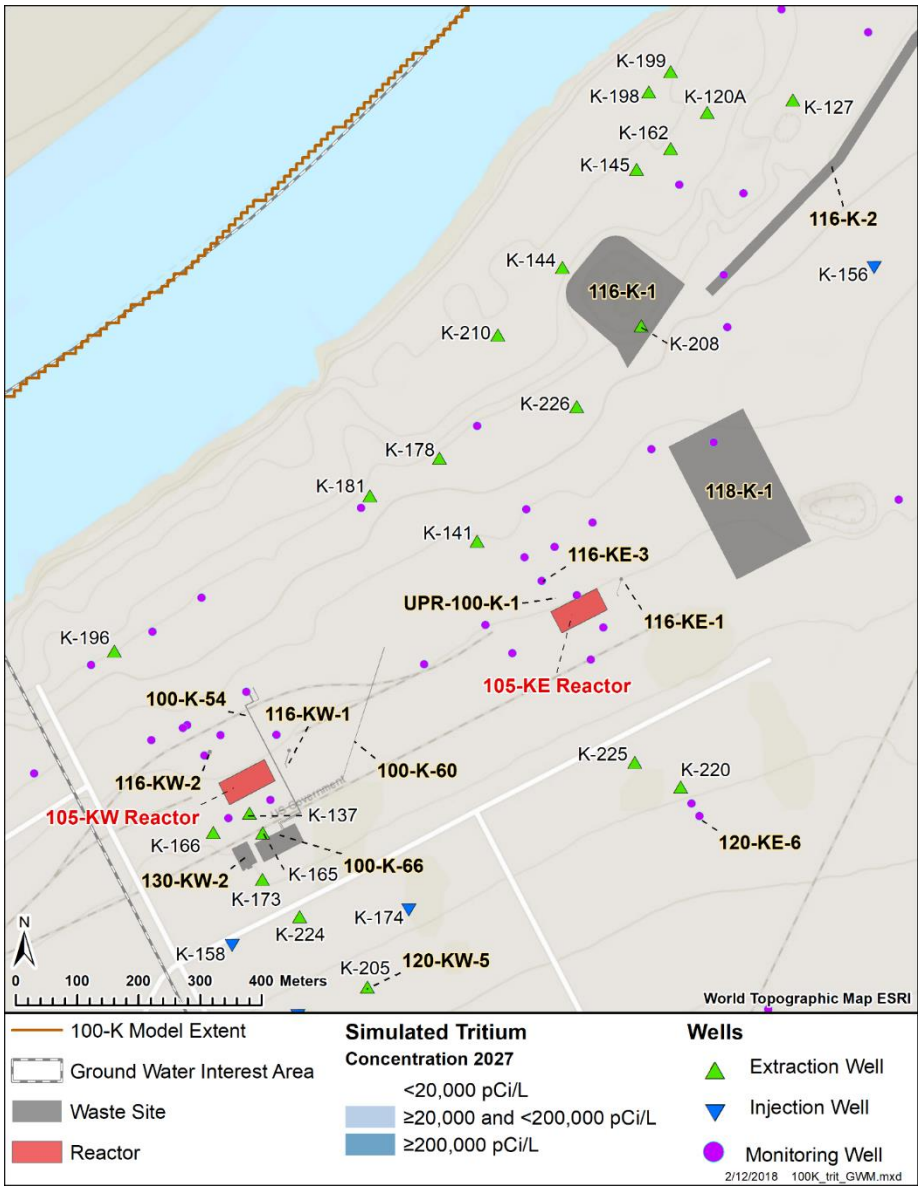


Figure 5-39. Simulated Tritium Plume in 2027 at the Top of the Unconfined Aquifer

5.6.6 Trichloroethene

The no further action case is assumed to begin in January 2020, with the P&T system continuing operation as described in SGW-58690 until then. Figure 5-40 shows the trichloroethene plume in 2017. Figure 5-41 shows the simulated plume extent in 2022, where the plume is only in the aquifer under the river. Simulations indicate the plume has dissipated to <5 µg/L by 2023.

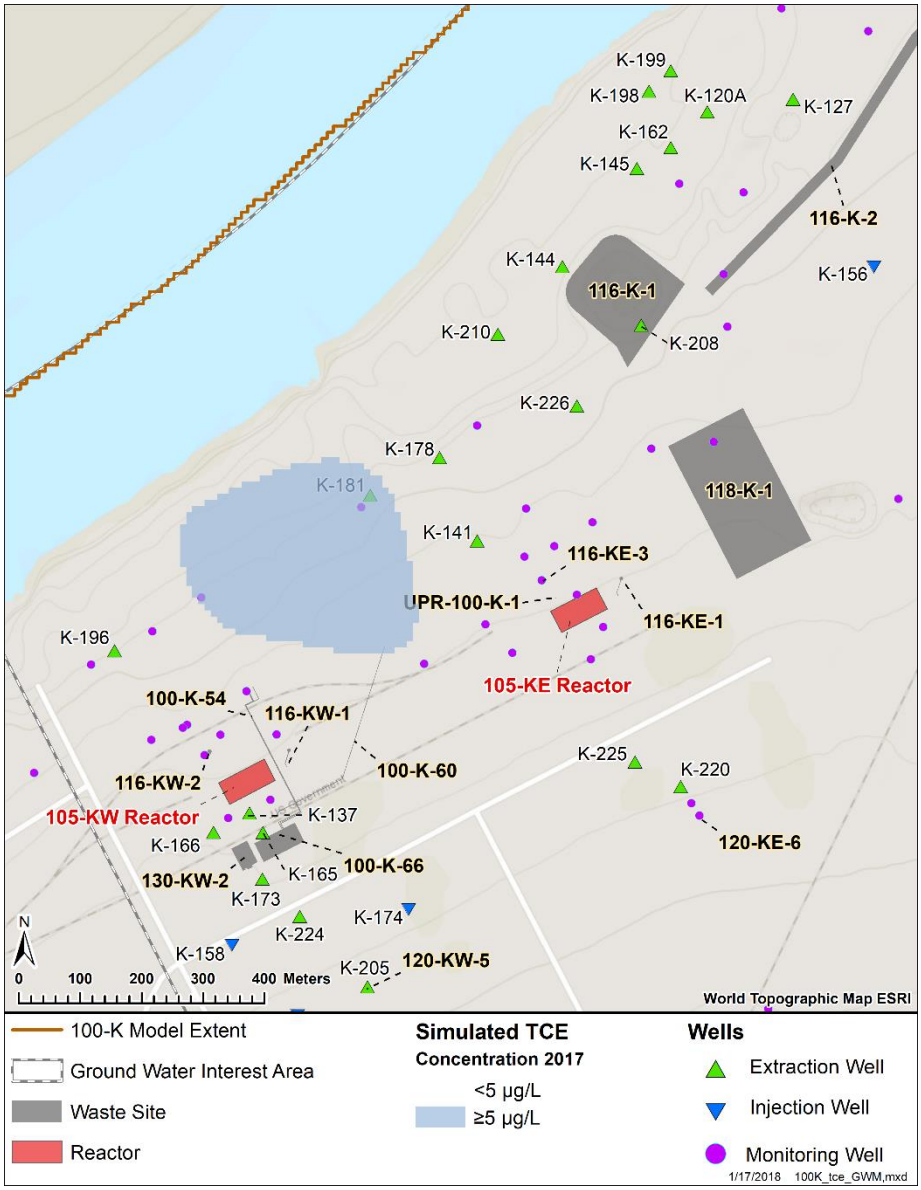


Figure 5-40. Simulated Trichloroethene Plume in 2017 at the Top of the Unconfined Aquifer

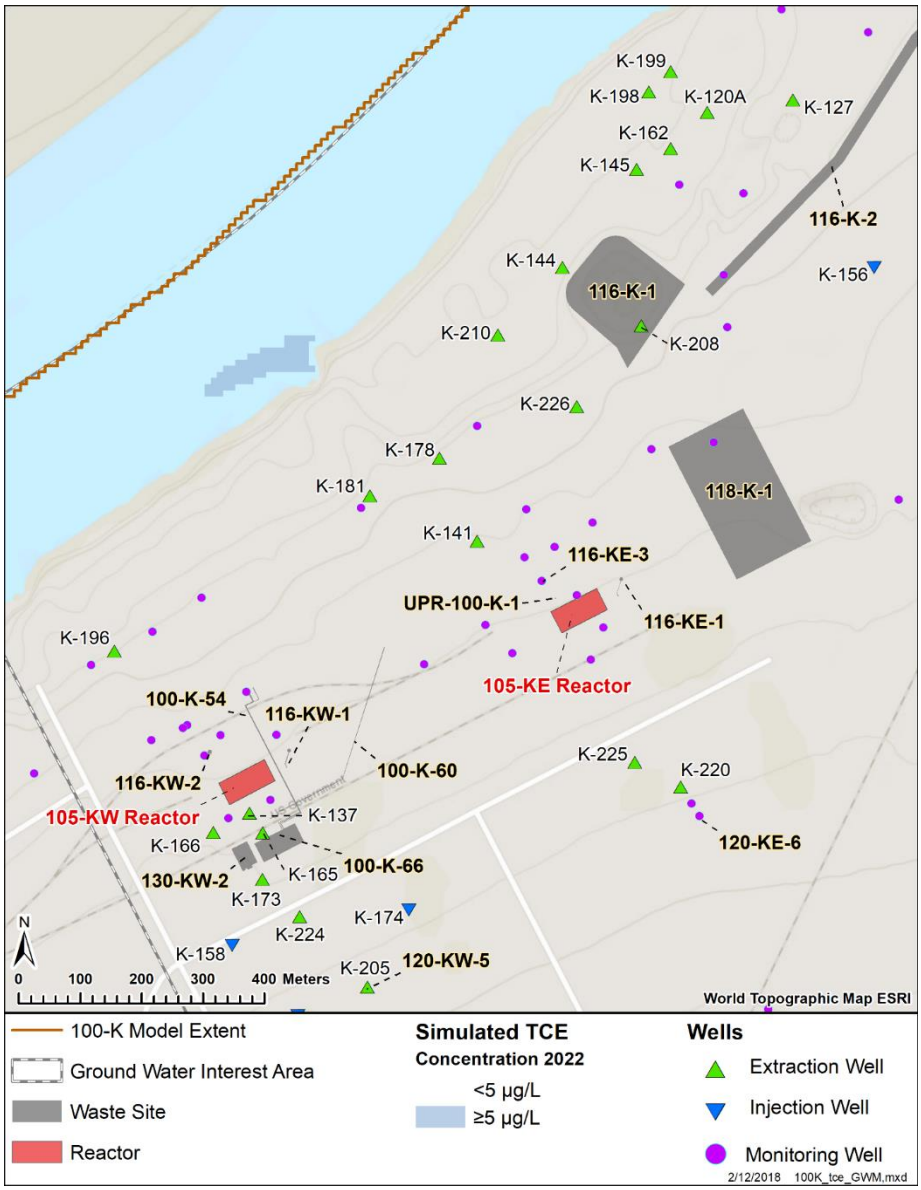


Figure 5-41. Simulated Trichloroethene Plume in 2022 at the Top of the Unconfined Aquifer

6 Human Health Risk Assessment

The following summarizes the results of the human health risk assessment (HHRA):

- A total of 64 remediated waste sites with closeout verification data were evaluated in the RI soil baseline risk assessment (BRA).
- Principal soil contaminants for direct contact exposure identified at one or more of the remediated waste sites include cesium-137, carbon-14, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90.
- A total of 82 monitoring wells were evaluated in the groundwater RI BRA.
- The groundwater BRA identified bromomethane, carbon-14, Cr(VI), total chromium, nitrate, 2-propanol, strontium-90, trichloroethene, and tritium as groundwater COPCs for potential remedial technologies evaluation in the FS.

The integration of past and current HHRAs supports the development of remedial alternatives for waste sites and contaminated groundwater in 100-K. The RI soil BRA was integrated with the cleanups performed under interim action RODs to identify the need for further remedial action and, if needed, to develop PRGs.

As described in the previous chapters, the remedial actions completed to date in the River Corridor were implemented primarily under interim action RODs. There is a requirement under CERCLA to perform a BRA to characterize current and potential threats to human health and the environment before final action RODs for final remedies can be issued. The HHRA presented in this chapter was prepared to address the regulatory requirement that a BRA be performed. This is a comprehensive HHRA for the 100-K OUs that considers relevant sources of contamination, exposure pathways, and contaminants to evaluate current and potential risks posed by contaminant concentrations that remain following interim remedial actions.

Per the risk assessment guide (EPA/540/1-89/002), a BRA is an “analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action).”

The BRA is part of the CERCLA RI/FS process. The BRA provides information to assist in the development, evaluation, and selection of appropriate response alternatives. The results of the BRA are used for the following:

- Determine whether additional response action is necessary at a site.
- Support development of PRGs.
- Document the magnitude of risk and primary contributors (e.g., contaminants and exposure pathways) to risk at a site.

Interim action RODs were written for River Corridor sites to allow cleanup activities to move forward as potential risks were identified. However, final remedy selection (development of final action RODs) must be completed in order for the NPL (40 CFR 300, Appendix B) CERCLA sites in the River Corridor to reach final closeout. One of the key evaluations needed to establish final action RODs for sites in the River Corridor was a BRA. The RCBRA HHRA and the companion ERA (DOE/RL-2007-21, Volumes I and II) provided an evaluation of ecological and human health risk from residual contamination at waste sites remediated under the interim action RODs and from potentially affected environmental media under various exposure scenarios. The primary purpose of the RCBRA was to provide the overall basis for

action to proceed with the regulatory requirement that a BRA be performed for each River Corridor OU to reach final closeout. A total of 64 waste sites in the 100-K Area identified in the interim action RODs have undergone remediation as of April 2017.

The RI soil risk assessment (Section 6.2) provides the data analysis (Section 6.2.1), estimated EPCs (Section 6.2.2), exposure assessment (Section 6.2.3), toxicity assessment (Section 6.2.4), risk characterization (Section 6.2.5), and the uncertainties assessment (Section 6.2.6).

The RI groundwater risk assessment (Section 6.3) discusses findings and uncertainties of the RCBRA (DOE/RL-2007-21) in Section 6.3.1. The Integrated Work Plan (DOE/RL-2008-46) added activities to help reduce uncertainties, verify conclusions, and ensure that no contaminants were inadvertently overlooked based on using the existing data set. The groundwater risk assessment involved the following: data analysis (Section 6.3.2), exposure assessment (Section 6.3.3), toxicity assessment (Section 6.3.4), risk characterization (Section 6.3.5), and an uncertainties assessment (Section 6.3.6). The results of Section 6.3 were used to identify COPCs, which represent contaminants that are evaluated in the FS to define the COCs and guide remedial alternatives selection.

Section 6.4 presents RCBRA conclusions for the riparian and nearshore environment (Section 6.4.1), and conclusions from the CRC (Section 6.4.2). Section 6.5 presents a summary and conclusions for the soil risk assessment (Section 6.5.1) and the groundwater risk assessment (Section 6.5.2).

6.1 Role of the RCBRA and the RI Risk Assessment

The RCBRA (DOE/RL-2007-21) provided the following range of analyses:

- Assessment of residual risks for 13 waste sites at 100-K remediated through December 2005 using the unrestricted land use exposure scenario that was the basis for remedial action goals (RAGs[1]) developed for the 100 Area interim action ROD cleanups
- Assessment of residual risks for remediated waste sites and broad areas[2] using a broad range of exposure scenarios
- Assessment of risks for several yet-to-be remediated waste sites using a broad range of exposure scenarios
- The overall basis for action to proceed with the BRA in support of final action RODs for the 100 Area decision areas

The residential scenario, the resident Monument worker scenario, and the casual recreational user scenario were evaluated in the RCBRA (DOE/RL-2007-21). The RI soil risk assessment calculated risk-based screening levels (RBSLs) for radionuclides for three scenarios, and RBSLs for chemicals using the casual recreational user scenario. The chemical RBSLs for the residential and the resident Monument worker scenarios were the 2007 MTCA (WAC 173-340) Method B direct contact soil cleanup levels. The RI RBSLs were used to evaluate total cancer risks and noncancer hazards for each remediated waste site evaluated in the soil risk assessment.

[1] RAGs were the cleanup levels used in the interim action ROD and published in DOE/RL-96-17.

[2] The term “broad area” is used in the RCBRA (DOE/RL-2007-21) to refer to an exposure area that could potentially be as large as an individual interim action ROD decision area or as large as the entire River Corridor.

The RCBRA also evaluated two Native American Resident scenarios that envision a complete subsistence lifestyle where all foods are grown at the home or (in the case of fish) caught in the Columbia River. PRGs were not calculated in the RCBRA for these scenarios.

The following sections provide additional background about the RCBRA (DOE/RL-2007-21), the methods used in the RI soil risk assessment, and how these differ from what was reported in the RCBRA:

- Section 6.1.1 summarizes the screening-level evaluation of residual risks performed in the RCBRA (DOE/RL-2007-21) for 13 waste sites remediated through December 2005 under the interim action ROD. Section 6.1.1.1 describes other unrestricted land use scenarios (subsistence farmer and Native American resident) that were evaluated in the RCBRA (DOE/RL-2007-21).
- Section 6.1.2 describes the residential scenario used in the RI soil risk assessment that reflects unrestricted land uses in the River Corridor. It also describes the differences between the residential scenario used in the RI soil risk assessment and the rural residential scenario that was used to develop the interim action RAGs and to conduct the screening-level evaluation presented in the RCBRA. The results of the RCBRA screening-level evaluation described in Section 6.1.1 are compared to the results of the RI soil risk assessment and presented in this section.
- Section 6.1.3 describes that the scenarios that reflect reasonably anticipated future land uses (i.e., the casual recreational user) originate in the RCBRA (DOE/RL-2007-21) and how they were updated to reflect current EPA guidance. This section also describes how both scenarios are used in the RI soil risk assessment.

6.1.1 Evaluation of Residual Risks for Interim Action ROD Cleanups from the RCBRA

This section discusses the results of the screening level evaluation presented in Chapter 2 of the RCBRA (DOE/RL-2007-21). It also compares the screening level evaluation results to the methodology used to develop the interim action RAGs and describes how analytical data from CVPs and RSVPs were used in the screening evaluation.

Chapter 2 of the RCBRA (DOE/RL-2007-21) presents a screening-level assessment of residual direct contact risks and noncancer hazards for the 13 waste sites remediated through December 2005 using the exposure scenarios that were the basis of the residential RAGs for the interim action ROD cleanups in the 100 Areas. The assessment described in Chapter 2 of the RCBRA was done to provide information about the cumulative residual direct contact cancer risks and noncancer hazards associated with post-interim action conditions at the remediated waste sites and help assess whether residual conditions protect human health.

Interim action ROD cleanups for the 100 Areas were based on an unrestricted scenario that was the basis for the RAGs. The interim action ROD residential scenario for radionuclides is a rural residential scenario that, in addition to direct contact, includes food chain exposure pathways (e.g., ingestion of homegrown produce, beef, and milk). The interim action ROD residential scenario for chemicals is based on the 1996 MTCA or the 2007 MTCA Method B direct contact Soil Cleanup Levels (WAC 173-340-740). The 1996 MTCA (WAC 173-340) Method B direct contact soil cleanup levels are based solely on incidental soil ingestion and do not address the inhalation or food exposure pathways that were included for the radionuclide rural residential scenario.[3] The RAG for arsenic was based on the 1996 MTCA Method A direct contact soil cleanup level (WAC 173-340-740). The RAG for lead was calculated using

[3] For beryllium, cadmium, and Cr(VI), the interim action RAG for direct contact is based on the inhalation pathway.

EPA/540/R-93/081, *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children*.

CVPs or RSVPs were prepared to document completion of interim action ROD cleanups per the applicable decision document and support waste site reclassification. The screening-level calculations presented in Chapter 2 of the RCBRA (DOE/RL-2007-21) use the interim action ROD risk assessment models, but differ from the calculations used in the CVPs and RSVPs to document the interim action ROD cleanup actions in four ways. These differences are summarized as follows:

- Analytes included in the screening-level calculations in the RCBRA were those COPCs identified for each ROD area described in Section 5.2 of the RCBRA, while CVPs and RSVPs focused on target analytes defined by Tri-Party concurrence based on process knowledge and analytical results from the LFIs and earlier interim actions.
- Residual soil concentrations calculated for the screening-level calculations in the RCBRA use cleanup verification sample data and RCBRA protocols for calculating representative concentrations described in Section 3.4, while CVPs and RSVPs used guidance on calculating the 95% UCL under MTCA. If 50% or more of a data set was nondetect, then the maximum chemical analytical results were used in lieu of a 95% UCL for a chemical. For radionuclides, a 95% UCL was always calculated using a nonparametric method based on the "z" statistic.
- Toxicity values used for the screening-level calculations in the RCBRA were current as of 2009, while CVPs and RSVPs were compared to RAGs based on toxicity criteria that were current as of 2006.
- Radionuclide risk-based screening levels were based on a cancer risk threshold value of 1×10^{-4} in the RCBRA, while the radionuclide RAGs used in the CVPs and RSVPs were calculated based on a radiation dose threshold of 15 mrem/yr.

Residual cumulative cancer risks for the direct contact pathway from chemicals evaluated in the RCBRA (DOE/RL-2007-21) are less than the cumulative target risk threshold of 1×10^{-5} using the interim action ROD residential scenario (i.e., MTCA [WAC 173-340] Method B direct contact soil cleanup levels for the Unrestricted Land Use scenario) (Table 6-1). Residual cumulative cancer risks from radionuclides evaluated in the RCBRA are $<1\times10^{-4}$ based on the interim action ROD rural residential scenario with the exception of 5 of the 13 remediated waste sites evaluated: 100-K-55:1, 100-K-56:1, 116-K-1, 116-K-2, and 116-KW-3 (Table 6-2).

The noncancer hazard indexes (HI) values for chemicals do not exceed a threshold of 1 at the 13 waste sites remediated through 2005 (Table 6-3).

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

Waste Site Name	Decision Unit	Chemical Carcinogens and Cancer Risk Drivers			
		RCBRA Chemical Risk	RCBRA Chemical Risk Driver	RI Chemical Risk	RI Chemical Risk Driver
100-K-29	Shallow Focused	--	--	3.7×10^{-6}	Arsenic (3.5×10^{-6})
100-K-30	Shallow Focused	4.0×10^{-6}	Arsenic (4.0×10^{-6})	3.9×10^{-6}	Arsenic (3.9×10^{-6})
100-K-31	Shallow Focused	4.0×10^{-6}	Arsenic (4.0×10^{-6})	4.2×10^{-6}	Arsenic (4.2×10^{-6})
100-K-32	Shallow Focused	4.0×10^{-6}	Arsenic (4.0×10^{-6})	4.5×10^{-6}	Arsenic (4.5×10^{-6})
100-K-33	Shallow Focused	4.0×10^{-6}	Arsenic (4.0×10^{-6})	1.0×10^{-5}	Arsenic (1.0×10^{-5})

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

Waste Site Name	Decision Unit	Chemical Carcinogens and Cancer Risk Drivers			
		RCBRA Chemical Risk	RCBRA Chemical Risk Driver	RI Chemical Risk	RI Chemical Risk Driver
100-K-55:1	Shallow	--	--	Not Analyzed	
	Shallow Focused	--	--	Not Analyzed	
100-K-56:1	Shallow	--	--	Not Analyzed	
	Shallow Focused	--	--	Not Analyzed	
116-K-1	Shallow	--	--	Not Analyzed	
116-K-2	Shallow_1	--	--	Not Analyzed	
	Shallow_2	--	--	Not Analyzed	
116-KE-4	Shallow	--	--	Not Analyzed	
116-KE-5	Shallow Focused	6.0×10^{-6}	Arsenic (6.0×10^{-6})	5.6×10^{-6}	Arsenic (5.6×10^{-6})
116-KW-3	Shallow	--	--	Not Analyzed	
116-KW-4	Shallow Focused	4.0×10^{-6}	Arsenic (4.0×10^{-6})	3.9×10^{-6}	Arsenic (3.9×10^{-6})

Reference: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, Part 2, Table 2-10.

Notes: RI data are in Table G-11 (Appendix G).

Chemical drivers shown have an associated risk $>1\times10^{-6}$.

The risk value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Risks are based on reasonable maximum EPCs.

-- = carcinogenic COPCs were not identified
COPC = contaminant of potential concern
EPC = exposure point concentration
Not Analyzed = soil samples collected from the waste site were not analyzed for nonradiological analytes
RCBRA = River Corridor Baseline Risk Assessment
RI = remedial investigation

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Radionuclides

Waste Site Name	Decision Unit	Radionuclides and Radiological Risk Drivers			
		RCBRA Radiological Risk	RCBRA Radiological Risk Driver	RI Radiological Risk	RI Radiological Risk Driver
100-K-29	Shallow Focused	--	--	Not Analyzed	
100-K-30	Shallow Focused	--	--	Not Analyzed	
100-K-31	Shallow Focused	--	--	Not Analyzed	
100-K-32	Shallow Focused	--	--	Not Analyzed	
100-K-33	Shallow Focused	--	--	Not Analyzed	
100-K-55:1	Shallow	1×10^{-4}	None	4.6×10^{-5}	None
	Shallow Focused	--	--	7.6×10^{-5}	None

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Radionuclides

Waste Site Name	Decision Unit	Radionuclides and Radiological Risk Drivers			
		RCBRA Radiological Risk	RCBRA Radiological Risk Driver	RI Radiological Risk	RI Radiological Risk Driver
100-K-56:1	Shallow	2.0×10^{-4}	Europium-152 (1.0×10^{-4})	1.2×10^{-4}	None
	Shallow Focused	--	--	1.3×10^{-4}	None
116-K-1	Shallow	2.0×10^{-4}	None	1.1×10^{-4}	None
116-K-2	Shallow_1	1.0×10^{-4}	None	3.9×10^{-5}	None
	Shallow_2	--	--	7.7×10^{-5}	None
116-KE-4	Shallow	8.0×10^{-5}	None	4.3×10^{-5}	None
116-KE-5	Shallow Focused	--	--	Not Analyzed	
116-KW-3	Shallow	1.0×10^{-4}	None	5.8×10^{-5}	None
116-KW-4	Shallow Focused	--	--	Not Analyzed	

Reference: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, Part 2, Table 2-10.

Notes: RI data are in Table G-11 (Appendix G).

Radionuclide drivers shown have an associated risk $>1\times 10^{-4}$.

The risk value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Risks are based on reasonable maximum EPCs.

-- = radionuclide COPCs were not identified
COPC = contaminant of potential concern
EPC = exposure point concentration
Not Analyzed = soil samples collected from the waste site were not analyzed for radiological analytes
RCBRA = River Corridor Baseline Risk Assessment
RI = remedial investigation

Table 6-3. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

Waste Site Name	Decision Unit	Noncancer Hazard Index and Noncancer Hazard Drivers			
		RCBRA Hazard Index	RCBRA Chemical Hazard Driver	RI Hazard Index	RI Chemical Hazard Driver
100-K-29	Shallow Focused	--	--	0.18	None
100-K-30	Shallow Focused	0.86	None	0.85	None
100-K-31	Shallow Focused	0.34	None	0.36	None
100-K-32	Shallow Focused	0.21	None	0.71	None
100-K-33	Shallow Focused	0.23	None	0.59	None
100-K-55:1	Shallow	0.01	None	Not Analyzed	
	Shallow Focused	--	--	<0.01	None
100-K-56:1	Shallow	0.01	None	Not Analyzed	
	Shallow Focused	--	--	<0.01	None
116-K-1	Shallow	<0.01	None	<0.01	None

Table 6-3. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

Waste Site Name	Decision Unit	Noncancer Hazard Index and Noncancer Hazard Drivers			
		RCBRA Hazard Index	RCBRA Chemical Hazard Driver	RI Hazard Index	RI Chemical Hazard Driver
116-K-2	Shallow_1	0.01	None	0.01	None
	Shallow_2	--	--	<0.01	None
116-KE-4	Shallow	0.01	None	0.01	None
116-KE-5	Shallow Focused	0.17	None	0.17	None
116-KW-3	Shallow	0.01	None	0.01	None
116-KW-4	Shallow Focused	0.11	None	0.11	None

Reference: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, Part 2, Table 2-10.
Notes: RI data are in Table G-11 (Appendix G).
Chemical drivers shown have an associated HQ >1.
The HQ value for the individual drivers is shown in parentheses after the name of the risk driver chemical.
Hazard indices are based on reasonable maximum EPCs.

-- = noncarcinogenic COPCs were not identified
COPC = contaminant of potential concern
EPC = exposure point concentration
HQ = hazard quotient
Not Analyzed = soil samples collected from the waste site were not analyzed for nonradiological analytes
RCBRA = River Corridor Baseline Risk Assessment
RI = remedial investigation

6.1.1.1 Other Residential Land Use Scenarios in RCBRA

The RCBRA (DOE/RL-2007-21) also evaluated three residential scenarios that describe exposures related to rural land-use patterns that involve home-produced foods. The subsistence farmer scenario envisions a substantial quantity of home-produced foods, but not a diet composed solely of such foods. The two Native American Resident scenarios, however, envision a complete subsistence lifestyle where all foods are grown at the home or (in the case of fish) caught in the Columbia River. In order to assign all soil-related exposures to a residence located on a remediated waste site, residential receptors are assumed to spend effectively all of their time in the area around that site.

PRGs were not calculated in the RCBRA (DOE/RL-2007-21) for these additional residential scenarios. Direct contact and food chain exposure associated with radiological contaminants for unrestricted land use are represented by the rural residential scenario described in Section 6.1.2.

DOE, through discussions with the Tribes, including the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), the Nez Perce Tribe, and the Confederated Tribes and Bands of the Yakama Nation (08-AMCP-0028, “Contract No. DE-AC06-96RL13200 – Native American Scenarios in Remedial Investigation and Feasibility Study Risk Assessments and Assuming Responsibility and Configuration Control of the Soil Inventory Model”), agreed to include quantitative analysis of Native American scenarios in risk assessments supporting RI and FS documents. The two scenarios considered are provided by the CTUIR and the Yakama Nation. The RCBRA (DOE/RL-2007-21) presents the risks and hazards calculated for both Native American exposure scenarios from direct contact, external gamma exposure, inhalation, and food chain pathways from remediated waste sites. The groundwater risk assessment in Section 6.3 presents results of both Native American scenarios for potentially complete

exposure pathways associated with groundwater. The groundwater risk assessment includes the cancer risks and noncancer hazards calculated for groundwater used as a source of drinking water and as a source of steam for sweat lodge use (Section 6.3.6.5.1). The results from the RCBRA for remediated waste sites and the results from the groundwater risk assessment can be summed to obtain a cumulative estimate of risk for all exposure pathways included in the CTUIR and Yakama Nation exposure scenarios. These Tribal scenarios have been evaluated and presented in Hanford Site risk assessments to assist interested parties in providing input on remedial alternatives, and have not been used for development of PRGs as part of alternatives analyses in FSs.

The results of the local area risk assessment for the other residential scenarios indicate that present-day reasonable maximum exposure (RME) cancer risk is frequently $>1\times10^{-4}$ (12 of 13 remediated sites for the Subsistence Farmer scenario) and that RME chemical HI frequently exceeds the threshold of 1.0 (6 of the 13 remediated sites for the Subsistence Farmer Scenario). Table 6-4 provides a summary of cancer risks and noncancer hazards associated with the Subsistence Farmer. Present-day RME cancer risks $>1\times10^{-4}$ for the Subsistence Farmer exposure scenario are almost entirely related to one of three factors:

- External irradiation from short-lived radionuclides including europium-152, cesium-137, and cobalt-60
- Exposure to arsenic from ingestion of garden produce
- Exposure to the short-lived radionuclide strontium-90 from ingestion of produce and livestock products

Table 6-4. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

Waste Site Name	Present-Day Total Risk	COPC	Pathway	Present-Day Hazard Index	COPC	Pathway
116-KE-5	6×10^{-4}	Arsenic	Produce Ingestion	7.5	Ethylene Glycol	Produce Ingestion
					Arsenic	Produce Ingestion
					Mercury	Beef Ingestion
100-K-56:1	5×10^{-4}	Europium-152	External Irradiation	0.17	None	--
		Cobalt-60	External Irradiation			
		Cesium-137	External Irradiation			
100-K-33	5×10^{-4}	Arsenic	Produce Ingestion	35	Mercury	Beef Ingestion
					Mercury	Produce Ingestion
100-K-31	4×10^{-4}	Arsenic	Produce Ingestion	68	Mercury	Beef Ingestion
					Mercury	Produce Ingestion
116-K-1	4×10^{-4}	Strontium-90	Milk Ingestion	0.0084	None	--
		Strontium-90	Produce Ingestion			
		Cesium-137	External Irradiation			
		Strontium-90	Beef Ingestion			
100-K-30	4×10^{-4}	Arsenic	Produce Ingestion	220	Mercury	Beef Ingestion
					Mercury	Produce Ingestion
100-K-29	--*	None	--	0.0018	None	--

Table 6-4. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

Waste Site Name	Present-Day Total Risk	COPC	Pathway	Present-Day Hazard Index	COPC	Pathway
100-K-32	4×10^{-4}	Arsenic	Produce Ingestion	32	Mercury	Beef Ingestion
					Mercury	Produce Ingestion
116-KW-4	4×10^{-4}	Arsenic	Produce Ingestion	2.2	Arsenic	Produce Ingestion
100-K-55:1	3×10^{-4}	Europium-152	External Irradiation	0.23	None	--
		Europium-154	External Irradiation			
		Cobalt-60	External Irradiation			
116-K-2	3×10^{-4}	Cesium-137	External Irradiation	0.19	None	--
		Europium-152	External Irradiation			
		Europium-154	External Irradiation			
116-KW-3	3×10^{-4}	Europium-152	External Irradiation	0.2	None	--
		Europium-154	External Irradiation			
		Cobalt-60	External Irradiation			
116-KE-4	2×10^{-4}	Europium-152	External Irradiation	0.18	None	--
		Europium-154	External Irradiation			
		Cobalt-60	External Irradiation			

Reference: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment, Part 2*, Tables 5-72 and 5-74.

Note: Risk drivers (COPCs) shown have an associated risk $>1\times10^{-4}$.

*No COPCs were identified for the health assessment.

COPC = contaminant of potential concern

RCBRA = River Corridor Baseline Risk Assessment

As evaluated and explained in the RCBRA (DOE/RL-2007-21), by the year 2075, Subsistence Farmer RME cancer risks above 1×10^{-4} are related overwhelmingly to arsenic exposure from produce ingestion. Because the CTUIR Resident and Yakama Resident scenarios use very high (subsistence level) site-raised food ingestion rates, strontium-90 still plays a significant role in food-related exposures at 2075 for these scenarios. By 2150, however, CTUIR Resident and Yakama Resident cancer risks above 1×10^{-4} are dominated by arsenic exposure from ingestion of garden produce.

The RCBRA Subsistence Farmer cancer risk and chemical HI results were frequently above threshold criteria. Two major differences were identified between the risk assessment methods used in the RCBRA (DOE/RL-2007-21) and the basis of the interim action RAGs. These differences largely explain why some waste sites remediated to meet the interim action RAGs still appear to present high levels of residual risk under the Subsistence Farmer scenario:

1. Residential interim action RAGs for chemicals are the 1996 MTCA (WAC 173-340) Method B direct contact soil cleanup levels (WAC 173-340-740]), which use an RME scenario based on incidental soil ingestion and does not address the food exposure pathways historically evaluated for radionuclides.

2. The interim action RAG for arsenic is 20 mg/kg, which is an "adjusted" value established by the State of Washington to address a range of natural background levels (WAC 173-340-900, "Tables").

One of the primary uncertainties for site-specific results relates to modeled exposure concentrations in foods, particularly garden produce. Further discussion of the potential biases in modeled food chain exposures is provided in the RCBRA (DOE/RL-2007-21). As discussed in Section 5.9.4.2 of the RCBRA, in the case of the noncancer HI results for produce ingestion of mercury, uranium, and copper, a large conservative bias is anticipated because a linear plant uptake model was applied to soil concentrations that are far above naturally occurring levels. In the case of arsenic, produce ingestion provides the largest contribution to total cancer risk, even though the range of site soil concentrations is relatively small. Uncertainty in produce concentrations is attributable to intrinsic variability related to soil conditions, plant species and tissue type, harvest time, and other variables. A review of recommended plant-soil ratios from a number of sources, as described in Section 5.9.2.4 of the RCBRA, shows that the range of soil to plant transfer ratios for arsenic (from 0.006 to 1.125) is approximately a factor of 200. The value of 0.53 used in the HHRA, from the RESRAD computer code that has been used to perform dose assessment at the Hanford Site and other DOE facilities, is near the upper end of this range. The high-end values for plant-soil concentrations, many of which were used in the RCBRA to assess exposure through food pathways, may result in a scenario that provides exposures to nonradionuclide contaminants higher than an RME. Therefore, these food chain pathways have not been incorporated into the development of PRGs for nonradiological constituents.

6.1.2 RI Soil Risk Assessment (Unrestricted Land Use)

This section describes the methodology used for the RI soil risk assessment and identifies the primary differences relative to the RCBRA screening-level evaluation. Differences in results are generally attributed to the COPC identification process, updates in exposure factors and toxicity values, inclusion of all decision units associated with a waste site, inclusion of analytical data from focused sampling designs, the method used to calculate EPCs, and the PRG value used for comparison. As a result of these differences, the evaluation provided in the RI soil risk assessment more directly supports the evaluation of remedial alternatives in the FS. Table 6-5 describes differences in methodologies used for assessing residual risks between the RCBRA (DOE/RL-2007-21) and the RI, and provides the methodologies used to develop the interim action RAGs and the methods used for preparing the closeout documentation.

For the 100-K Source OUs, the RI soil risk assessment results presented in this chapter are used to determine whether additional remedial action may be necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis. The risk-based screening evaluation that uses the RI residential scenario in this chapter provides information necessary to resolve the following questions and provides information needed to support final remedial decisions that will ensure protection of human health and the environment:

- Are residual conditions for cleanup actions completed under the interim action RODs protective of human health and the environment based on comparison to RBSLs calculated in accordance with current EPA guidance?
- Are there waste sites with an "interim no action" or "interim closed out" reclassification status that should be carried into the FS?
- What uncertainties are associated with the risk results that require a risk management decision?

Table 6-5. Comparison of Methods and Assumptions Used for the Residential Scenario

Parameter	Method Used in Closeout Documentation	Method Used in RCBRA	Method Used in RI	Overall Effect on RI
Basis of PRG Values for Radioisotopes and Chemicals				
Residential PRG value for radioisotopes	Radionuclide cancer risk is evaluated using the interim action ROD rural residential exposure scenario reported in DOE/RL-96-17, *Remedial Design Report/ Remedial Action Work Plan for the 100 Area*. Radionuclide RAGs were calculated based on a dose threshold of 15 mrem/yr.	Radionuclide cancer risk is evaluated using the interim action ROD rural residential exposure scenario reported in DOE/RL-96-17. Radionuclide RAGs were calculated based on a dose threshold of 15 mrem/yr. In the RCBRA (DOE/RL-2007-21), these RAGs were converted to RBSLs based on a risk threshold of 1×10^{-4} (RCBRA [DOE/RL-2007-21], pg. 2-41). The interim action ROD rural residential exposure scenario is considered a local area exposure scenario (located on a waste site).	Radionuclide cancer risk is evaluated using the residential exposure scenario. This exposure scenario is similar to the interim action ROD rural residential scenario but incorporates updates to reflect recent EPA guidance as identified in this table.	The residential scenario used in the RI reflects updates in methodology (risk-based versus dose-based threshold) and recent recommendations in exposure assumptions. RBSL/PRG values differ slightly between the RAGs reported in the closeout documentation, the RCBRA (DOE/RL-2007-21), and the RI for key COPCs (gamma emitters and strontium-90). Risk-based PRG values reported in the RI for gamma emitters and strontium-90 are slightly lower than the RAGs reported in closeout documents and in the RCBRA (DOE/RL-2007-21). Risk-based PRG values reported in the RI for some alpha emitters are greater than the RAGs reported in closeout documents and in the RCBRA (DOE/RL-2007-21).
Updates to EPA guidance for residential PRG	External gamma shielding factor is 0.8 (EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals) Interim*). Outdoor time fraction is 0.2 (5 hr/day over 350 days/yr) (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). Annual dose rate is 15 mrem/yr (40 CFR 196, "Radiation Site Cleanup Standards").	External gamma shielding factor is 0.7, which is based on the default value recommended in the RESRAD code. Outdoor time fraction is 0.2 (5 hr/day over 350 days/yr) (WDOH/320-015). Target cancer risk value is 1×10^{-4} (EPA/540/R/99/006, *Radiation Risk Assessment at CERCLA Sites: Q & A*).	External gamma shielding factor is 0.4 (EPA/540-R-00-007, *Soil Screening Guidance for Radionuclides: User's Guide*). Outdoor time fraction is 0.12 (3 hr/day over 350 days/yr) (EPA/600/P-95/002Fb, *Exposure Factors Handbook Volume II – Food Ingestion Factors*). Target cancer risk value is 1×10^{-4} (EPA/540/R/99/006).	Gamma shielding factor was revised from 0.7 to 0.4. The current assumption accounts for a 60% reduction in external exposure due to shielding from structures rather than a 30% reduction. Use of the updated assumption results in slightly less exposure and a less conservative PRG value (higher). Outdoor time fraction was revised from 0.2 to 0.12. The current assumption assumes the resident spends 3 hr/day outside rather than 5 hr/day. Use of the updated assumption results in less exposure and a less conservative PRG value (higher). The protective threshold value was updated from a dose-based value to a risk-based value. The overall outcome is that updated PRG values used in the RI are slightly lower for beta- and gamma-emitting radioisotopes and higher for alpha-emitting radioisotopes.
Updates to RESRAD for Windows	RESRAD Version 6.4 was used to calculate the interim action ROD remedial action goals. RESRAD version 6.4 incorporates dose coefficients from FGR No. 12 (EPA-402-R-93-081, *External Exposure to Radionuclides in Air, Water, and Soil*) and dose conversion factors from FGR No. 11 (EPA-520/1-88-020, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*).	RESRAD Version 6.4 was used to convert the interim action ROD RAGs based on a dose threshold of 15 mrem/yr to a cancer risk threshold of 1 ×10 4. RESRAD Version 6.4 incorporates cancer risk coefficients from FGR No. 13 (EPA 402-R-99-001, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*) Morbidity library.	RESRAD Version 7.0 was used to calculate the radionuclide residential RBSLs for the RI. RESRAD Version 7.0 incorporates the DCFPACK3.02 Morbidity library that includes the nuclear decay data from ICRP Publication 107, *Nuclear Decay Data for Dosimetric Calculations*.	RESRAD Version 7.0 incorporates the most recent radiological cancer risk coefficients. This version also includes the nuclear decay data that was not available in Version 6.4.
MTCA (WAC 173-340) Method B direct contact soil cleanup levels for unrestricted land use	Separate 1996 MTCA (WAC 173-340) Method B levels were calculated for incidental soil ingestion and inhalation.	2007 MTCA (WAC 173-340) Method B levels are based solely on incidental soil ingestion.	Separate 2013 MTCA (WAC 173-340) Method B direct contact soil cleanup levels were calculated for incidental soil ingestion and inhalation. The 2013 MTCA procedure updates the TEFs to reflect California EPA guidance.	Chemicals that only report toxicity values for the inhalation exposure route (beryllium, cadmium, cobalt, Cr(VI), and nickel) are not included in the RCBRA (DOE/RL-2007-21) evaluation. RAGs are reported for chemicals that only report toxicity values for the inhalation exposure route (beryllium, cadmium, cobalt, Cr(VI), and nickel). The RI separately reports cancer risks and noncancer hazard indices for both incidental soil ingestion and inhalation exposure routes. RAGs for PAHs and the RCBRA were calculated using the TEFs presented in the 2007 MTCA WAC 173-340-900, "Tables," Table 708-2. PAHs calculated using the 2013 MTCA procedure TEFs result in higher values for benzo(k)fluoranthene and chrysene and a lower value for dibenz(a,h)anthracene.

Table 6-5. Comparison of Methods and Assumptions Used for the Residential Scenario

Parameter	Method Used in Closeout Documentation	Method Used in RCBRA	Method Used in RI	Overall Effect on RI
MTCA (WAC 173-340) Method B inhalation cleanup levels for unrestricted land use	DOE/RL-96-17 reports RAGs for beryllium, cadmium, and Cr(VI) based on WAC 173-340-750(3), "Cleanup Standards to Protect Air Quality." A PEF value of 1.0×10^7 m^3/kg was used to convert air concentrations to soil concentrations. The PEF value of 1.0×10^7 m^3/kg is based on the default mass loading factor in RESRAD. This is roughly two orders of magnitude smaller than EPA's default PEF of 1.4×10^9 m^3/kg.	2007 MTCA (WAC 173-340) Method B inhalation cleanup levels were not evaluated in the RCBRA (DOE/RL-2007-21).	2013 MTCA (WAC 173-340) Method B inhalation cleanup levels were calculated for the inhalation exposure route. A PEF value of 7.3×10^{10} m^3/kg is used to convert air concentrations to soil concentrations. This PEF uses meteorological data from Boise, Idaho, and Hanford Site-specific annual wind speed. The PEF of 7.3×10^{10} m^3/kg is within a factor of two of EPA's default PEF of 1.4×10^9 m^3/kg published in OSWER Directive 9355.4-24, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*.	Inhalation pathway cleanup levels that use a PEF value based on the default mass loading factor in RESRAD are lower values (more conservative) that those RBSLs that use the PEF based on EPA methodology.
Data Analysis				
Waste site decision units and analysis time frame	The floor and sidewalls of an excavated waste site are divided into one or more decision units. A sample design is developed for the decision unit. Sampling requirements for each decision unit is described in DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*.	For local area exposure scenarios (including the interim action ROD rural residential scenario), the RCBRA (DOE/RL-2007-21) used only the CVP/RSVP data sets from shallow zone decision units. These data sets are from waste sites that were excavated /remediated through calendar year 2005. The shallow zone decision unit is typically represented by soil from the excavation floor if at or above 4.6 m (15 ft) and any sidewalls from grade level (0 m [0 ft]) to a depth of 4.6 m (15 ft).	The RI used CVP/RSVP data sets from all decision units associated with an excavated/remediated waste site through April 2017. In addition to the shallow zone decision unit, the RI evaluates the risk contribution from soil associated with the overburden, and the deep zone decision units.	The RI risk assessment results are used to identify waste sites that warrant evaluation of remedial alternatives in the FS. The RI risk assessment can also be used to disposition the waste site from an interim status to final closure status when risk thresholds are not exceeded.
Statistical and focused sample designs	The layout and orientation of sampling designs are based on the size, shape, and depth of the site. Data sets from the sample design are used to confirm attainment of remedial action objectives.	When both focused and statistical samples exist for an analyte at a waste site, only the statistical samples were used to calculate the representative concentrations. An uncertainty analysis was performed to evaluate the selection of focused and/or statistical samples has on the risk assessment results, representative concentrations for these waste sites are also calculated using the combined focused and statistical samples. The statistical representative concentrations were compared to the combined focused and statistical samples and shown in Table C3-11 in Appendix C, Section C-3, "Representative Concentrations."	The approach used to evaluate the data set for each sample design is the same as that used for the closeout documentation.	Evaluation of only the data from statistical sample designs when focused sample data are also collected has the potential to understate risk. Frequently focused sample results are collected in areas with the highest potential for contamination to be present. The RI risk assessment results are used to identify waste sites that warrant evaluation of remedial alternatives in the FS. The RI risk assessment can also be used to disposition the waste site from an interim status to final closure status when risk thresholds are not exceeded.
COPC Identification	Closeout documentation did not incorporate a COPC identification step. All detected analytes with RAGs reported in DOE/RL-96-17 were evaluated in the closeout documentation. It should be noted that the RAGs listed in DOE/RL-96-17 do not include analytes that meet exclusion criteria.	COPC refinement process includes a number of complementary steps and criteria, including a pre-selected list of contaminants that were excluded and a pre-selected list that were included, as determined and agreed upon among the Tri-Parties. Additional selection steps include evaluation of all data according to detection status, statistical comparisons of Hanford Site data to background and reference site data, and an analyte-specific evaluation. Each interim action ROD area has a separate list of COPCs.	COPC identification uses the exclusion criteria defined in Section 6.2.1.3 of this chapter. The inclusion list and other refinement steps used in the RCBRA (DOE/RL-2007-21) were not incorporated into the RI. When a COPC was detected at least once in a waste site decision unit (and it did not meet the exclusion criteria) it was carried into all risk calculations.	COPC refinement in the RCBRA (DOE/RL-2007-21) often included analytes that were not detected at the waste site. The inclusion of analytes that were not detected at a waste site decision unit results in an overstatement of risk. The method used to identify COPCs in the RI is similar to the method used in the closeout documentation. The RI and closeout documentation did not evaluate analytes that met exclusion criteria. Although two different COPC identification processes were used in the RCBRA (DOE/RL-2007-21) and the RI, similar risk drivers were identified in the risk characterization step of the analysis as shown in Tables 6-3 through 6-5.

Table 6-5. Comparison of Methods and Assumptions Used for the Residential Scenario

Parameter	Method Used in Closeout Documentation	Method Used in RCBRA	Method Used in RI	Overall Effect on RI
EPCs	The primary statistical calculation to support closeout documentation was the 95% UCL on the arithmetic mean of the data for waste sites closed using a statistical/random sampling design. Statistical calculations were performed in compliance with Ecology Publication 92-54, *Statistical Guidance for Ecology Site Managers*. This guidance addresses two kinds of data distributions: normal and lognormal. This guidance also implements the substitution method where a proxy value of one-half the detection limit is assigned to nondetected results. For small data sets (n<10), a nonparametric distribution was assumed. When a nonradionuclide was detected in fewer than 50% of the samples collected and for focused sampling designs, the maximum detected value was used for comparison purposes. For radionuclides, a 95 UCL was always calculated using a nonparametric method based on the "z" statistic.	Representative concentrations pertain to sampled medium, whereas EPCs also include modeled concentrations in other exposure media. In general, the process used in the RCBRA (DOE/RL-2007-21) follows EPA guidance as provided in EPA/600/R-07/038, *ProUCL Version 4.00.05 User Guide (Draft)*. The ProUCL software was not used to calculate representative concentrations.	OSWER Directive 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, is the EPA guidance for UCL calculation and ProUCL 5.1 serves as the companion software package for this guidance. ProUCL 5.1 contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods that can be used on full data sets without nondetects and on data sets with below detection or nondetect observations. Both ProUCL and OSWER Directive 9285.6-10 were used to recalculate the UCLs for the 100-K Source OUs.	EPA/600/R-07/038 draws from guidance documented in OSWER Directive 9285.6-10. Methodologies for calculating 95% UCLs are similar between the RCBRA (DOE/RL-2007-21) and RI. The methodology used in the closeout documentation addresses only two data distributions for the 95 UCL calculation and implemented the substitution of one-half the detection limit value for nondetected results.

COPC = contaminant of potential concern
Cr(VI) = hexavalent chromium
CVP = cleanup verification package
EPA = U.S. Environmental Protection Agency
FGR = Federal Guidance Report
FS = feasibility study
MTCA = "Model Toxics Control Act—Cleanup"
OU = operable unit
PAH = polycyclic aromatic hydrocarbons
PEF = particulate emission factor
PRG = preliminary remediation goal
RAG = remedial action goal
RBSL = risk based screening level
RCBRA = River Corridor Baseline Risk Assessment
RESRAD = Residual Radioactivity
RI = remedial investigation
ROD = record of decision
RSVP = remaining sites verification package
TEF = toxicity equivalent factor
UCL = upper confidence limit

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All waste sites evaluated in the RI soil BRA were interim closed using RAGs related to direct contact soil exposure by human receptors. These RAGs are reported in the 100 Area RDR/RAWP (DOE/RL-96-17). The RAGs for radionuclides under the interim action ROD have not been revised since originally published in 1996. Interim RAGs for direct contact in the 100 Area of the River Corridor were based on a rural residential exposure scenario. The interim action ROD residential scenario for radionuclides is a rural residential scenario that, in addition to direct contact, includes inhalation and food chain exposure pathways (e.g., ingestion of homegrown produce, beef, and milk). Since the 100 Area RDR/RAWP (DOE/RL-96-17) was originally published, EPA has published a change in policy associated with health protectiveness thresholds, updates in guidance associated with several exposure assumptions, and the RESRAD software code was updated to incorporate recent changes in radionuclide risk coefficients. The exposure scenario used to calculate the residential PRGs (or risk-based screening levels [RBSLs]) presented in this chapter is consistent with the scenario used for interim action RAGs; that is the same exposure pathways and exposure routes are incorporated. However, the PRG values are different from the interim action RAGs as a result of the described changes (Table 6-5).

The 2013 MTCA (WAC 173-340) Method B direct contact soil cleanup levels are based solely on incidental soil ingestion and do not address the inhalation or food exposure pathways that were included for the radionuclide residential scenario. The 2013 MTCA (WAC 173-340) Method B direct contact soil cleanup levels developed in this chapter are similar to those published in the most recent version of the 100 Area RDR/RAWP (DOE/RL-96-17), which implements the 2007 MTCA procedure. The revision to the 2013 MTCA rule adopts the California EPA potency equivalency factors for carcinogenic PAHs. As a result, the soil cleanup levels for benzo(k)fluoranthene, chrysene, and dibenz(a,h)anthracene were revised. Other changes were adopted by Ecology; however, they are associated with the calculation of cleanup levels for mixtures of dioxins, furans, and PCBs and do not affect the cleanup levels presented in this chapter. No changes were adopted for the exposure assumptions and equations used to calculate the 2013 MTCA (WAC 173-340) Method B direct contact soil cleanup levels.

The cancer risk and noncancer hazard results from the RI soil risk assessment are based on RBSLs that reflect changes in guidance, exposure assumptions, and toxicity values that have been updated since the interim action RAGs and the RCBRA were published. Tables 6-1 through 6-3 compare the screening-level risk results from the RCBRA (DOE/RL-2007-21) to the results of the RI soil risk assessment (Section 6.2.5.5.1).

6.1.3 RI Soil Risk Assessment (Reasonably Anticipated Future Land Use Scenario)

The RCBRA (DOE/RL-2007-21) evaluated risks for a range of exposure scenarios that represent a range of upper bound and reasonably anticipated receptors and activities. When River Corridor soil cleanup levels were initially established, the TPA (Ecology et al., 1989a) signatories agreed that it was appropriate to protect for a range of potential future exposures so that interim cleanup actions did not limit future use of the site. The casual recreational user scenario originated in the RCBRA (DOE/RL-2007-21). The RBSLs for the casual recreational user scenario in the RI were revised to reflect updates to exposure assumptions, chemical toxicity values, and radiological risk coefficients.

The casual recreational user scenario was evaluated in the RCBRA (DOE/RL-2007-21) as a recreational scenario and was applied on a broad-area scale. In the RCBRA, the casual user spent time enjoying recreational activities (broad area) in a region as large as an individual interim action ROD OU and potentially as large as the entire River Corridor. This exposure scenario was used in the RCBRA to calculate forward risk estimates. To incorporate the use of this exposure scenario in the RI, the scenario was modified to develop a PRG assuming that all of the casual recreational user time was spent on the waste site (local area). This assumption is the only modification made to this exposure scenario;

no changes were made to the exposure assumptions used to calculate PRG values. This modification develops a conservative numeric value to confirm that waste site cleanup actions protect casual users.

Some exposure assumptions for the casual recreational user scenario were updated based on recent EPA guidance or modified to conform to recommended EPA methodology for calculation of PRGs. Exposure assumptions that were updated based on recent guidance include the incidental soil ingestion rate, inhalation rate, particulate emission factor (PEF), time spent on the local area and broad area scale, external gamma shielding factor, and radiological decay. The exposure assumptions that were modified to correlate to standard PRGs equations include soil ingestion rates and use of decay factors. Table 6-6 summarizes the modifications made to the casual recreational user exposure scenario for use as a PRG.

CVP and RSVP data are compared to the residential and casual recreational user RBSLs in Sections 6.2.5.5.1 and 6.2.5.5.2, respectively. When the total risk for a remediated waste site is $<1\times10^{-4}$ for radionuclides based on the residential scenario or 1×10^{-5} for chemicals based on the 2013 MTCA Method B direct contact soil cleanup levels (WAC 173-340-740), then protection of the resident and casual recreational user is achieved.

Table 6-6. Summary of Differences in Exposure Assumptions for the Casual Recreational User between the RCBRA and RI Risk Assessment

Parameter	RCBRA Casual Recreational User	RI Casual Recreational User
Soil Ingestion Rate	A soil ingestion rate of 100 mg/day for an adult and 200 mg/day for a child were assumed for this receptor. Soil ingestion at the waste site was assumed proportional to the fraction of waking hours spent at the site.	A soil ingestion rate of 100 mg/day for an adult and 200 mg/day for a child were assumed for this receptor. All soil ingestion was assumed to occur at the waste site.
Inhalation Rate	The RCBRA assumed an inhalation rate of 1 m^3/hr for an adult and 1 m^3/hr for a child based on EPA recommended short-term exposure values for light activity.	The RI assumed an inhalation rate of 0.83 m^3/hr for an adult, based on an inhalation rate of 20 m^3/day, and 0.417 m^3/hr for a child, based on an inhalation rate of 10 m^3/day (EPA/540/R-92/003).
Particulate Emission Factor	The RCBRA used a PEF of 4.3×10^8 m^3/kg for the broad area.	The RI used the EPA default PEF of 7.3×10^{10} m^3/kg (OSWER Directive 9355.4-24).
Time Spent on the Local-Area and Broad-Area Scale	The RCBRA assumed an exposure time of 6 hr/day is spent onsite, all in the broad area.	The RI assumed an exposure time of 6 hr/day is spent onsite, all in the local area.
Exposure Frequency	The RCBRA and RI both assumed that the adult and child casual recreational user spent 30 days/year enjoying recreational activities.	
Gamma Shielding Factor	The RCBRA did not apply a gamma-shielding factor (all exposure is assumed to occur outdoors).	The RI did not apply a gamma-shielding factor (all exposure is assumed to occur outdoors).
Radiological Decay Factor	Decay of radioisotopes over the exposure duration was not accounted for.	Decay of radioisotopes over the exposure duration was incorporated.

References: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*.

EPA/540/R-92/003, Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk Based Preliminary Remediation Goals): Interim.

OSWER Directive 9355.4-24, Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.

EPA = U.S. Environmental Protection Agency
PEF = particulate emission factor
RCBRA = River Corridor Baseline Risk Assessment
RI = remedial investigation

6.2 Soil Risk Assessment

Section 6.1.1 summarizes the screening-level evaluation of residual risks performed in the RCBRA (DOE/RL-2007-21) for the 13 waste sites remediated through December 2005 under the interim action ROD. Section 6.1.2 describes the residential scenario used in the RI soil risk assessment and describes how the residential scenario was updated from what was used in the RCBRA (DOE/RL-2007-21). Section 6.2 provides the updated soil risk assessment which implements the updates described in Section 6.1.2.

The following describes the approach implemented for the 100-K Source OUs soil risk assessment:

- Identify all waste sites with "interim no action" or "interim closed out" reclassification status.
- Obtain verification sampling and analysis data for all "interim no action" and "interim closed out" waste sites that have been remediated through April 2017.[4]
- Compute EPCs for each detected analyte measured at a waste site using EPA's ProUCL version 5.1 software.
- Compare EPCs to direct contact RBSLs selected to represent baseline conditions and reasonably anticipated future land use.
- Calculate cancer risk and noncancer hazards for each detected analyte.
- Compare cancer risks and noncancer hazards to acceptable state and federal target risk and noncancer thresholds.
- Determine if the "interim no action" or "interim closed out" waste site should be carried forward into the FS to identify remedial alternatives.

This soil risk assessment follows the guidance in the risk assessment guide (EPA/540/1-89/002). The following subsections describe the four-step process.

6.2.1 Data Analysis

This section describes the data sources used in the risk assessment (Section 6.2.1.1), describes the DUA and data validation processes (Section 6.2.1.2), and identifies COPCs in vadose zone material that are accessible for human exposures (Section 6.2.1.3). During the course of this risk assessment, analytes are evaluated to identify COPCs, and analytes estimated to pose an unacceptable risk and warrant evaluation in the FS are prioritized.

6.2.1.1 Sources of Analytical Data Used in Risk Assessment

This evaluation includes vadose zone material samples for remediated waste sites with an "interim no action" or "interim closed out" reclassification status collected within the 100-KR-1 and 100-KR-2 Source OUs. Waste sites where remediation and verification sampling and analysis were assessed by the end of April 2017 are included in the soil risk assessment.

All samples were collected in accordance with requirements in DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, (hereinafter called the 100 Area SAP). Data collected under the 100 Area SAP (DOE/RL-96-22) are used to meet the purpose and objectives of the 100 Area

[4] These are waste sites for which interim action cleanups had been completed under interim action RODs and for which the CVPs, RSVPs, or waste reclassification forms were completed through April 2017.

RDR/RAWP (DOE/RL-96-17), which describes the remedial action design and implementation required by the following decision documents:

- EPA/AMD/R10-97/044, *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*
- EPA/ROD/R10-99/039, 100 Area Remaining Sites ROD
- EPA/ROD/R10-00/121, 100 Area Burial Grounds ROD

Remediation of waste sites in the 100-K Source OUs began in 2002. Waste site constituents were identified based on process knowledge, site history, and site-specific discussions with the lead regulatory agency. Constituents analyzed included the waste site COPCs; as a result, different constituents are analyzed at each waste site. Therefore, only constituents reported at each waste site are included in risk calculations. Analytical results for each waste site are included in the associated closeout documentation. A complete list of waste sites is provided in Appendix C, Table C-1, of the 100-K Work Plan (DOE/RL-2008-46-ADD2). Both the 100-K Work Plan and the 100 Area RDR/RAWP (DOE/RL-96-17) were reviewed and approved by the Tri-Parties.

A total of 64 waste sites in the 100-K Source OUs have verification sampling and analysis data and are included in this soil risk assessment. Of the 64 waste sites from the 100-K Source OUs, 13 were evaluated in the RCBRA (DOE/RL-2007-21). Table G-1 (Appendix G) provides a summary of the waste sites, associated decision unit(s), and reclassification status for 100-K Source OUs. Waste site decision units are defined in Section 6.2.2.2. The waste sites listed in Table G-1 are a subset of the waste sites that were listed in Appendix C, Table C-1, of the 100-K Work Plan (DOE/RL-2008-46-ADD2). Table 6-7 provides a summary of the remediated waste sites and consolidated waste sites for the 100-KR-1 and 100-KR-2 OUs.

The following analytical data sources were used in the soil risk assessment:

- All verification sampling and analysis data reside in the HEIS database.
- All closeout verification data used in this soil risk assessment are included in Appendix D of this report.

6.2.1.2 Assessment of Data Quality and Data Validation

An assessment of data quality is performed and reported in each closeout documentation report. The assessment compares the verification sampling approach and resulting analytical data with the sampling and data quality requirements specified by the project objectives and performance specifications. The assessment determines if the data are of the right type, quality, and quantity to support site cleanup verification decisions within specified error tolerances if the analytical data are found acceptable for decision-making purposes, and if the sample design was sufficient for the purpose of cleanup site verification. The cleanup verification sample analytical data and assessment are summarized in the appendices associated with the CVPs. Assessment results are incorporated by reference and no further assessments were performed as part of this risk assessment.

All analytical data were evaluated and a portion validated for compliance with QA project plan requirements as documented in the 100 Area RDR/RAWP (DOE/RL-96-17). Data evaluation was performed to determine if the laboratory carried out all steps required by the SAP and the laboratory contract governing the sample analysis and reporting of the data. This evaluation also examined the available laboratory data to determine if an analyte was present or absent in a sample and the degree of overall uncertainty associated with that determination. Data validation was done in accordance with validation procedures as part of data evaluation.

Table 6-7. Summary of Waste Sites with Verification Data in the 100-KR-1 and 100-KR-2 OUs

100-KR-1 Waste Sites			
100-K-63	100-K-78	116-K-1	116-K-2
116-KE-4	116-KW-3	--	--
100-KR-2 Waste Sites			
100-K-102 [a]	100-K-105	100-K-106	100-K-109
100-K-110	100-K-14 [a]	100-K-18 [a]	100-K-19 [a]
100-K-29	100-K-3 [a]	100-K-30	100-K-31
100-K-32	100-K-33	100-K-34 [a]	100-K-36 [a]
100-K-4	100-K-46 [a]	100-K-50 [a]	100-K-53
100-K-55:1	100-K-56:1	100-K-6 [a]	100-K-62 [a]
100-K-68 [a]	100-K-69 [a]	100-K-70 [a]	100-K-71 [a]
100-K-77	100-K-79:1 [a]	100-K-79:2 [a]	100-K-84
100-K-85	100-K-86	100-K-88	100-K-89 [a]
100-K-90	100-K-91	100-K-92	100-K-95
100-K-97 [a]	116-KE-5	116-KW-4	118-K-1
120-KW-1 [a]	120-KW-2 [a]	120-KW-3 [a]	120-KW-4 [a]
120-KW-5 [a]	120-KW-7 [a]	126-KE-2 [a]	128-K-1
128-K-2	130-KE-1	132-KE-1 [a]	1607-K2 [a]
1607-K3	600-29 [a]	--	--

a. Some of the sample results were evaluated according to the following 10 waste site groupings resulting in 54 waste site groups. Waste sites in bold font below were also sampled individually and have separate data in addition to waste site group data.

100-K-14; 126-KE-2

100-K-18; 100-K-19; 100-K-79:1; 100-K-79:2; 100-K-97; 120-KW-5; 120-KW-7

100-K-3; **100-K-36**; 100-K-79:7 [b]

100-K-3; 100-K-68; 100-K-69, 100-K-70; 100-K-71

1**00-K-34; 100-K-102**

100-K-47 [b]; 100-K-69; 100-K-70; 100-K-71

100-K-50; 1607-K2

100-K-6; **100-K-46; 100-K-62**; **132-KE-1**

100-K-89; **600-29**

120-KW-1; 120-KW-2; 120-KW-3; 120-KW-4

b. Although this site or subsite is listed, it has not undergone remediation and is not classified as interim closed out.

OU = operable unit

6.2.1.3 Identification of COPCs

For the purposes of this soil risk assessment, a "COPC" is defined as an analyte suspected of being associated with site-related activities, that represents a potential threat to human health and the environment, and whose data are of sufficient quality for use in a quantitative BRA.

All analytes detected at least once in a remediated waste site decision unit for the 54 waste site groups included in the risk assessment are identified as COPCs. As described in Section 6.2.2.2, the floor and sidewalls of an excavated waste site are divided into one or more decision units (e.g., shallow zone, deep zone, or overburden). Verification sampling and analysis data are collected according to sample design requirements for the type of decision unit. For the purpose of this risk assessment, an "exposure area" and a "decision unit" are operationally defined as being the same. Verification sampling and analysis data are subsequently grouped to calculate EPCs.

The contribution from naturally occurring metals and anthropogenic radioisotopes is discussed in the risk characterization section in accordance with EPA 540-R-01-003. The risk characterization discusses elevated background concentrations and their contribution to site risks, as well as naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants, but exceed the RBSLs.

The RCBRA (DOE/RL-2007-21) identified a subset of analytes that are excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. The following exclusion lists employed in the RCBRA were also applied to the waste site verification data during the data reduction steps described in Section 6.2.2.2 and also listed in Appendix G (Table G-4):

- **Radionuclides with a half-life of <3 years:** Radionuclides with half-lives <3 years, would not be present at the site as a result of historical Hanford Site operations due to radioactive decay that has occurred since operations ceased.
- **Essential nutrients:** Essential nutrients that are present at relatively low concentrations and are toxic only at high concentrations need not be considered in a quantitative risk assessment.
- **Water quality or soil physical property measurements:** These parameters were measured to obtain information on water quality or soil properties to understand potential confounding factors for bioassays conducted for soil, sediment, or water or to interpret their influence on the toxicity of COPCs (e.g., soil grain size, water hardness for metals effects).
- **Background radionuclides (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232):** These background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford Site operations or processes.

6.2.2 Exposure Point Concentrations

OSWER Directive 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, (hereinafter referred to as Calculating UCL for EPCs), states that, "an exposure point concentration (EPC) is a conservative estimate of the average chemical concentration in an exposure medium." OSWER Publication 9285.7-081, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, hereinafter called RAGS Supplemental Guidance, states that, "because of the uncertainty associated with estimating the true average concentration at a site, the 95% UCL of the arithmetic mean should be used for this variable." Use of the 95% UCL of the arithmetic mean yields risk estimates that correspond to an RME. Instances where a value different from a UCL is used as the EPC are clearly stated in this risk assessment. Reasons and/or justifications are also provided.

Calculating UCL for EPCs (OSWER Directive 9285.6-10) further states that, "The EPC is determined for each individual decision unit within a site. An exposure unit is the area throughout which a receptor moves and encounters an environmental medium for the duration of the exposure. Unless there is site-specific evidence to the contrary, an individual receptor is assumed to be equally exposed to media within all portions of the exposure unit over the time frame of the risk assessment." For this evaluation, the "exposure unit" and the "decision unit" are operationally defined as being the same. One or more decision units are included within a waste site including shallow vadose zone material (0 to 4.6 m [0 to 15 ft] bgs), deep vadose zone material (>4.6 m [15 ft] bgs), and overburden material.

Ecology Publication 92-54, *Statistical Guidance for Ecology Site Managers*, has been used to calculate EPCs for all closeout documentation to date. Ecology Publication 92-54 was published in 1992 and has been superseded by Calculating UCL for EPCs (OSWER Directive 9285.6-10), which was published in 2002. For this soil risk assessment, UCLs were recalculated for all waste sites and decision units to incorporate the updated guidance in Calculating UCL for EPCs. UCLs that incorporate updated guidance use more rigorous statistical methods to estimate exposure concentrations and eliminate the use of the simple substitution method for nondetects where a proxy value of one-half the detection limit is assigned to all nondetected results. Calculating UCL for EPCs notes that because of the complicated formulas used to compute UCLs, there is no general rule about which substitution rule will yield an appropriate UCL. The uncertainty associated with the substitution method increases and its appropriateness decreases as the detection limit becomes larger and as the number of nondetects in the data set increases.

The following sections describe the statistical methodology used for closeout documentation (Section 6.2.2.1) and the statistical methodology used for this soil risk assessment (Section 6.2.2.2). While both evaluations used the same dataset, the differences in statistical methodologies may result in differences in the EPC values between the closeout documentation and this risk assessment for the same COPCs in a waste site decision unit.

6.2.2.1 Statistical Evaluation Methodology Used for Closeout Documentation

For waste sites closed using a statistical/random sampling design, the primary statistical calculation to support cleanup verification was the 95% UCL on the arithmetic mean of the data. Statistical calculations were performed in compliance with Ecology Publication 92-54. This guidance addresses two kinds of data distributions: normal and lognormal. For normal data, the guidance recommends a UCL on the mean based on the Student's T-statistic. For lognormal data, the guidance recommends the Land method using the H-statistic. This guidance also implements the substitution method where a proxy value of one-half the detection limit is assigned to nondetected results.

Small data sets (n<10) were evaluated in accordance with Section 5.2.1.4 of Ecology Publication 92-54 and a nonparametric distribution was assumed. When a nonradionuclide was detected in fewer than 50% of the samples collected and for focused sampling designs, the maximum detected value was used for comparison purposes.

6.2.2.2 Statistical Evaluation Methodology Used for the Soil Risk Assessment

Calculating UCL for EPCs (OSWER Directive 9285.6-10) is the EPA guidance for UCL calculation and ProUCL 5.1 serves as the companion software package for this guidance. ProUCL 5.1 contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods that can be used on full data sets without nondetects and on data sets with nondetect observations. Both ProUCL and Calculating UCL for EPCs were used to recalculate the UCLs for the 100-K decision units.

To ensure that waste sites and decision units are grouped correctly and UCLs are accurately recalculated, all waste sites, decision unit groupings, and sample numbers were individually verified against the

original closeout documentation. ECF-100KR1-11-0007, *Waste Site Evaluation Process for the 100-KR-1 and 100-KR-2 Source Operable Units* (Appendix G), documents the process used to confirm a complete list of waste sites with a reclassification status of "interim closed out" or "interim no action" through April 2017. Verification of sample numbers associated with each waste site was confirmed along with the decision unit grouping with which the sample is associated. This list of samples was used to verify the sampling results are complete. The analytical data that have undergone this review process become the final data set used to calculate the UCLs and associated summary statistics used in this soil risk assessment. Appendix G (Table G-2) lists the sample numbers associated with each waste site decision unit, sample collection date, type of sample design used, and the sample location Washington state plane coordinates.

6.2.2.2.1 Waste Site Decision Units

Verification sampling and analysis data associated with the samples listed in Appendix G (Table G-2) are from several different decision units within a waste site, including shallow vadose zone material, deep vadose zone material, and overburden material. The following paragraphs describe the basis of each decision unit and briefly describe the sample designs used.

The floor and sidewalls of an excavated waste site are divided into one or more decision units, and a decision unit sample design is developed. Sample design requirements for each decision unit are described in the 100 Area SAP (DOE/RL-96-22). In practice, the shallow zone decision unit is typically represented by material from the excavation floor if at or above 4.6 m (15 ft) bgs and any sidewalls from grade level to a depth of 4.6 m [0 to 15 ft]). The deep zone decision unit is represented by material from the excavation floor (if >4.6 m [15 ft] bgs) and by any sidewall materials >4.6 m (15 ft) bgs. As needed, decision subunits and an associated sampling design are also established for suspect clean overburden stockpiles (i.e., to verify suitability for backfill material) and the footprint of the staging pile area. The layout and orientation of the sampling designs are based on the size, shape, and depth of the site. Sampling of a waste site decision unit to confirm attainment of RAOs was performed according to one of three types of sampling designs: focused sampling design, random or statistical sampling, or a combination of both.

The decision unit naming convention is summarized in Table 6-8.

Table 6-8. Summary and Definition of Decision Unit Types

Decision Unit Name	Depth	Sampling Design Description
Shallow	0 to 4.6 m (15 ft) bgs	Samples collected using a statistical sampling design
Deep	>4.6 m (15 ft) bgs	
Overburden	Not applicable	
Shallow_Focused	0 to 4.6 m (15 ft) bgs	Samples collected using a focused sampling design
Deep_Focused	>4.6 m (15 ft) bgs	
Overburden_Focused	Not applicable	

bgs = below ground surface

The process used to calculate EPCs for each waste site and decision unit is documented in ECF-100KR1-11-0008, *Computation of Exposure Point Concentrations for the 100-KR-1 and 100-KR-2 Source Operable Units* (Appendix G). The purpose of ECF-100KR1-11-0008 is to document the data

processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs.

6.2.2.2.2 Data Processing and Reduction

This section describes the data processing and reduction steps taken before the calculation of UCLs. Figure 6-1 shows each data processing and data reduction step and the number of records associated with each step for the 100-K Source OUs.

Redundant Analytes. When nitrate and nitrite are also reported as a concentration of nitrogen in nitrate or nitrogen in nitrite, then the nitrate and nitrite concentrations are used in the EPC computations and the redundant nitrogen in nitrate or nitrogen in nitrite are removed from the data set.

Laboratory and Data Validation Flags. Analytical data are received from the laboratory with data qualification flags; validation qualifiers are assigned during the data validation process. The following rules are applied to determine how the sample results are used for calculating UCLs.

- All sample results flagged with a "U" data qualifier or combination of qualifiers that include a "U," such as a "UJ," are considered nondetected concentrations.
- All sample results without a "U" data qualifier, including results with an "E" or a "J" qualifier, are considered detected concentrations.
- Sample results that are rejected and flagged with an "R" validation qualifier are not used for calculating UCLs.

where:

U = Analyzed for but not detected above limiting criteria

J = Estimated value

E = Reported value is estimated because of interference (inorganics)

R = Do not use. Further review indicates the result is not valid.

Identify Nondetected Analytes. Analytes that are measured at appropriate sampling locations have adequate detection limits, and that have not been detected in any of the samples are eliminated from further consideration. Any analyte detected at least once in the 100-K Source OU is carried forward to the next step of the process.

A total of 144 analytes were not detected in the 100-K Source OUs samples and are listed in Appendix G (Table G-3). The table also provides sampling dates, total number of samples, and minimum and maximum MDLs.

Analytes Reported by Multiple Analytical Methods. A sample may be analyzed for an analyte using more than one analytical method, resulting in multiple results for the analyte from the same location and sample date. When analytes are reported by more than one analytical method for a sample, the results are processed to select the method that provides the most reliable results. Considerations for determining data to be retained include method-associated sample size, detection frequency, method sensitivity, and detection limits. The most conservative (i.e., health protective) use of these types of data is the goal. Larger sample size, higher detection frequencies, and lower detection limits are given higher priority for method selection.

For example, lead may be analyzed using EPA Method 200.8 (EPA-600/R-94/111, *Methods for the Determination of Metals in Environmental Samples Supplement I*) with an estimated quantitation limit (EQL) of 0.5 mg/kg or EPA Method 6010 with an EQL of 5.0 mg/kg. For a sample with lead concentrations reported by both methods, the results reported by EPA Method 200.8 are chosen over EPA Method 6010 (SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B)* because of the more sensitive detection limit.

Field Duplicate Results. Field QC samples (field duplicates) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and field quality control samples are collected from the same location (i.e., sample node) and same date, resulting in more than one sample per location and date. Because multiple sets of analytical results cannot be used to quantify risk (i.e., this would result in multiple counting of a chemical), the results for the same location and date are reduced to a single result for each reported analyte. The following criteria are used to reduce multiple sample results for one location and date to a single result. The most conservative (i.e., health protective) result is the goal.

- If two or more detections are reported, the maximum concentration is used.
- If one detection and one or more nondetections are reported, the detected concentration is used.
- If two or more nondetections are reported, the lowest detection limit is used.

6.2.2.2.3 Identify Analytes for 95% and 97.5% UCL Calculation

After extracting and processing the data set, it is further reduced to identify a subset of analytes that require a UCL computation. Analytes that meet any of the exclusion criteria or were not detected in any of the samples analyzed with the 100-K Source OUs are not carried forward into the statistical calculations and EPC selection. The analyte identification steps and the number of records associated with each step are presented in Figure 6-1 for the 100-K Source OUs.

Apply Exclusion Criteria. The first step used to identify analytes that require a 95% UCL calculation is to apply exclusion criteria. Analytes that do not meet the exclusion criteria are carried forward into the next step of the process. Analytes that meet exclusion criteria are eliminated from further consideration. The following were excluded:

- Radionuclides that have half-lives of <3 years and daughter products are not significant risk contributors.
- Background radionuclides that are not directly related to Hanford Site operations or processes (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232).
- Essential nutrients (minerals) (calcium, magnesium, potassium, and sodium).
- Analytes without known toxicity information (e.g., delta-BHC, endrin ketone, and sulfate).

Twenty-one unique analytes for the 100-K Source OUs meet the exclusion criteria and are listed in Appendix G (Table G-4). Sampling dates, minimum and maximum detected concentrations, minimum and maximum MDLs, and the basis for their exclusion are provided in this table.

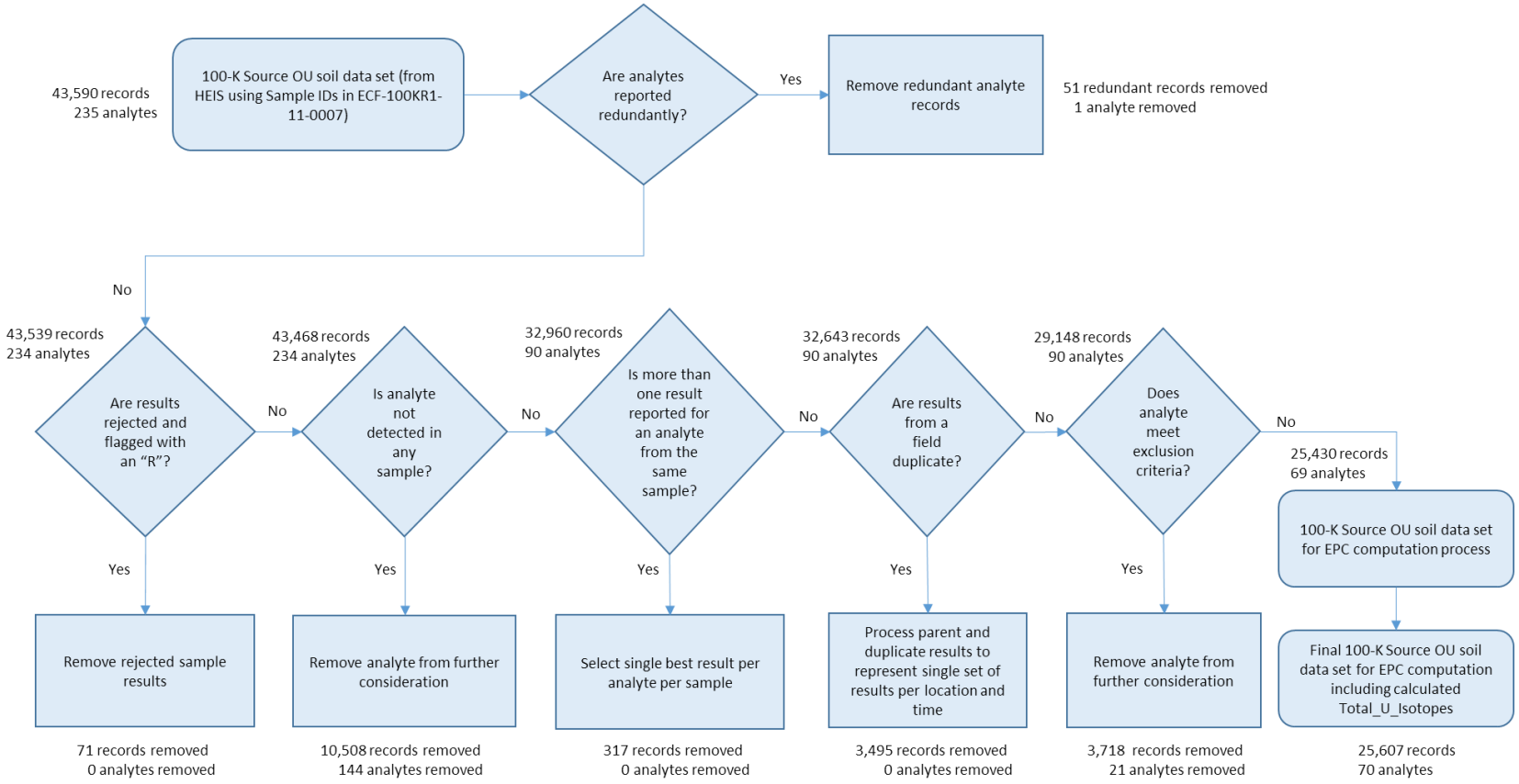

Figure 6-1. Analytical Data Processing and Reduction Steps for the 100-K Source OUs

6.2.2.2.4 Methodology for 95% and 97.5% UCL Calculation

A discussion of waste site decision units was provided earlier in this section. It should be noted that calculated UCLs and EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. As a result, risks are overstated because the UCL and the EPC do not take credit for the existing clean backfill that covers the remediated waste site.

Analytical data for all analytes that have been detected at least once in each waste site decision unit are extracted from the data set and subsequently formatted so they can be directly imported into ProUCL 5.1, where 95% UCL calculations and summary statistics are performed.

The following information is obtained from the UCL calculations and summary statistics generated for each waste site decision unit:

- Waste site decision unit name
- Analyte name and Chemical Abstract Service (CAS) registry number
- Total number of sample results, total number of detects, total number of nondetects, and frequency of detection
- Minimum and maximum detection limits for each detected analyte (when available)[5]
- Minimum and maximum detected concentrations for each analyte
- Coefficient of variation for each analyte
- The UCL value(s), the UCL basis(es), and comments and/or warning statements for each analyte

For most data sets, ProUCL 5.1 recommends a single UCL as the decision statistic. When a single decision statistic is recommended, this UCL is selected. However, ProUCL 5.1 will recommend more than one decision statistic for some data sets. The most conservative (i.e., health protective) result that is not greater than the maximum observed concentration is the goal when selecting the UCL to represent the EPC. When more than one decision statistic is given, the following logic is used to select the UCL:

- If a single UCL is recommended and is less than or equal to the maximum concentration, then select the single recommended UCL value as the decision statistic.
- If more than one UCL is recommended as a decision statistic and all UCLs are less than or equal to the maximum detected concentration, then the highest recommended UCL is selected as the decision statistic.
- If more than one UCL is recommended as a decision statistic and the highest UCL is greater than the maximum detected concentration, then the following decision logic is applied to the decision statistic:
  - When the 97.5% (Mean, Sd) UCL is greater than the maximum detected concentration or the 97.5% Chebyshev (Mean, Sd) UCL is not calculated, then the maximum detected concentration is selected as the decision statistic.

A discussion of the uncertainties associated with UCLs greater than the maximum detected concentration is provided in Section 6.2.6.2.

[5] Minimum and maximum detection limits are summarized in the ProUCL output only when a valid UCL can be calculated.

6.2.2.3 Selection of EPCs

The following logic was used to select the EPC for each detected analyte in a waste site decision unit:

- For samples collected in accordance with a focused sampling design, the maximum detected concentration is selected as the EPC for every detected analyte.
- For samples collected in accordance with a statistical sampling design, the following logic is applied.
  - If a single 95% UCL is recommended and it is less than or equal to the maximum concentration, then the recommended 95% UCL value is selected as the EPC.
  - If more than one 95% UCL is recommended and the highest recommended 95% UCL is less than or equal to the maximum concentration, then the highest recommended UCL value is selected as the EPC.
  - If a single 95% UCL is recommended and it is greater than the maximum concentration or if more than one 95% UCL is recommended and the highest recommended 95% UCL is greater than the maximum concentration, then the following decision logic is applied.
    - If a 97.5% Chebyshev (Mean, Sd) UCL was calculated and its value is less than or equal to the maximum detected concentration, select the 97.5% Chebyshev (Mean, Sd) UCL as the EPC.
    - If the 97.5% Chebyshev (Mean, Sd) UCL was calculated and its value is greater than the maximum detected concentration, select the maximum detected concentration as the EPC.
    - If a 97.5% Chebyshev (Mean, Sd) UCL was not calculated, select the maximum detected concentration as the EPC.

Selection of the EPC value using the above decision logic is presented in Figure 6-2. A summary of the EPCs for each detected analyte in a given waste site decision unit is provided in Appendix G (Table G-5).

6.2.2.3.1 Use of Maximum Detected Concentrations to Estimate the EPC

The EPC defaults to the maximum detected concentration when any of the following conditions are met:

- Samples were collected using a focused sampling design.
- A valid 95% UCL cannot be calculated because of a limited number of results (<3)
- A valid 95% UCL is greater than the maximum detected concentration and the 97.5% Chebyshev (Mean, Sd) UCL was either not calculated by ProUCL or its value was greater than the maximum concentration.

The sampling plan for a focused decision unit was designed to sample the areas of suspected contamination. The results from this type of sampling design can introduce bias into statistical analyses to estimate means, such as calculations of UCLs. RAGS Supplemental Guidance (OSWER Publication 9285.7-081) states “a value other than the 95% UCL can be used, provided the risk assessor can document that high coverage of the true population mean occurs (i.e., the value equals or exceeds the true population mean with high probability).” The closeout documentation for the focused decision units used the maximum detected concentration to determine if the remedial action goal has been attained (Section 3.6.3 of the 100 Area RDR/RAWP [DOE/RL-96-17]). Because of the potential for statistical bias and to maintain consistency with the 100 Area RDR/RAWP, the maximum detected concentration is selected as a conservative estimate of the EPC for the focused decision units.

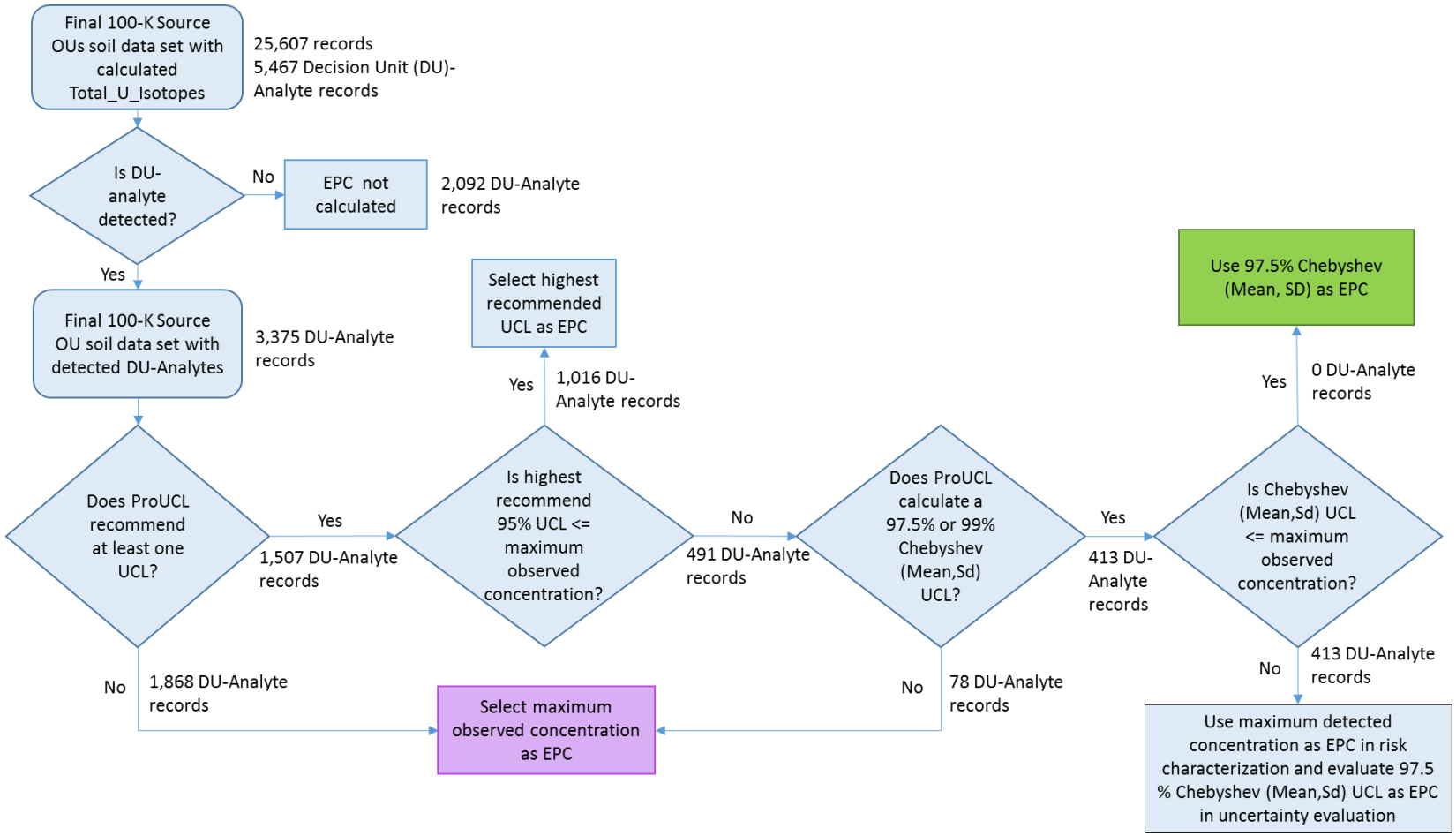

Figure 6-2. Decision Logic for Computing Soil EPCs for the 100-K Source OUs

Some decision statistics computed by ProUCL 5.1 require a minimum sample size. The following limitations of ProUCL apply to data sets with non-detected results (i.e., censored data sets):

- For data sets with less than three results, a 95% UCL is not calculated.
- For data sets of at least three results, a 95% UCL is not calculated when there is only one detected result in the data set.
- For data sets of at least four results, only Kaplan-Meier method-based UCLs are generated when there are only two detected results.
- For data sets of at least five results, most parametric and nonparametric (except for gamma distribution-based) 95% UCLs are generated when there are at least three detected values.
- For data sets of at least five results, all parametric and nonparametric 95% UCLs are generated when there are four or more detected values.

ProUCL generates warning messages for all small (sample size <8-10) data sets processed, informing the user about potential deficiencies in the data set.

Some of the distributional methods employed by ProUCL can produce very high estimates of the UCL (particularly the Land method). Calculating UCL for EPCs (OSWER Directive 9285.6-10) acknowledges that the Land method can produce extremely high values for the UCL when data exhibit high variance and the sample size is small. RAGS Supplemental Guidance (OSWER Publication 9285.7-081) recognizes the problem of extremely high UCLs, and recommends the maximum detected concentration become the default when the calculated UCL exceeds this value. When the recommended UCL exceeds the maximum detected concentration, ProUCL, however, advises that an alternative UCL (i.e., Chebyshev inequality) be selected instead of the maximum detected concentration for an EPC. When the recommended UCL is greater than the maximum detected result, the maximum detected value is selected as the EPC for the 100-K waste site decision units ProUCL displays a warning message when the recommended 95% UCL of the mean exceeds the observed maximum concentration.

6.2.2.4 Methodology Used to Calculate Total Uranium Concentrations from Isotopic Uranium Concentrations

Uranium analytical data are reported for all of the 100-K Area Source OUs waste site decision units as isotopic uranium (reported in units of pCi/g) and not as total uranium (reported in units of µg/kg). Because total uranium (µg/kg) is needed to support DOE/RL-2018-22, *Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, hereinafter called the 100-K Area Source OUs Feasibility Study, an additional step was performed to calculate a mass-based total uranium concentration (µg/kg) from the activity-based isotopic uranium concentrations (pCi/g) reported for each waste site decision unit. This step entails obtaining the uranium isotope analytical data for each sample, converting the data from activity- to mass-based concentrations, and then summing the converted values for detected concentrations to produce a mass-based total uranium value. For sample results where all uranium isotope results are reported as non-detects, the individual values are not summed, but the maximum non-detect value is retained and put in the ProUCL file, flagged as a nondetect.

The pCi/g to µg/kg conversions and subsequent summations are performed using specific activities for the uranium isotopes and appropriate conversion factors, as shown in the calculation example provided in Table 6-9. Only uranium isotopes that are detected at least once are included in the summations for calculation of the total uranium concentration. In the Table 6-9 example, uranium-235 is shown for demonstration purposes because it is not included in the summation. The calculated total uranium values are assigned an analyte name of Total_U_Isotopes in the data sets.

Table 6-9. Example Conversion from Activity- to Mass-Based Concentration (pCi/g to µg/kg) for Uranium Isotopes and Summation to Produce a Mass-Based Total Uranium Concentration (µg/kg)

Uranium Isotope	Measured Activity (pCi isotope/ g soil) [a] (ND or D)	Specific Activity (Bq isotope/ g isotope) [b]	Specific Activity (pCi isotope/ g isotope) [c]	Conversion Factor (µg isotope/ g isotope)	Conversion Factor (g soil/ kg soil)	Calculated Concentration (µg isotope/ kg soil) [d]
U-233/234 [e]	0.649 (D)	2.302E+08	6.222E+09	1,000,000	1,000	0.10
U-235	0.031 (ND)	7.995E+04	2.161E+06	1,000,000	1,000	14 (not summed)
U-238	0.338 (D)	1.243E+04	3.359E+05	1,000,000	1,000	1,006
Total Uranium Concentration (Total_U_Isotopes) (µg total uranium/kg soil) =						**1,006**

a. Example analytical data shown for illustration purposes only.

b. *Table of Isotopes* (Firestone and Shirley, 1998).

c. Formula = specific activity (Bq/g)/3.7E+10 Bq/Ci×1.0E+12 pCi/Ci.

d. Formula = measured activity (pCi/g)/specific activity (pCi/g)×conversion factor (µg/g)×conversion factor (g/kg).

e. Values presented are for uranium-234; uranium-234 is assumed to be the dominant isotope in undifferentiated uranium-233/234.

D = detect

ND = nondetect

6.2.3 Exposure Assessment

This section defines the exposure scenarios used for various land use and receptor activities, describes the potential exposure pathways resulting from site contaminants, and provides the methodology for calculating the RBSLs for direct contact, based on currently available Hanford Site information. The conceptual exposure model is formulated according to EPA guidance, taking into consideration information on contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups associated with the 100-K Source OUs. This results in a set of exposure pathways that reflect RME.

An exposure pathway can be described as the physical course that a COPC takes from the point of release to a receptor. The route of exposure is the means by which a COPC enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A contaminant source (or release point)
- A mechanism of chemical release
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete and, therefore, creates no risk or hazard[6]. Figure G-1 (Appendix G) schematically presents the exposure pathway analysis in the form of a human conceptual exposure model (CEM).

6.2.3.1 Contaminant Sources

The primary sources of contamination in the 100-K Source OUs were two water-cooled nuclear reactors (KE and KW) and the structures (e.g., FSBs) and processes (e.g., sodium dichromate process) associated with reactor operations. A discussion of primary and secondary contaminant sources is provided in Sections 4.2, 5.3, and 5.4 of this report.

6.2.3.2 Release Mechanisms and Environmental Transport Media

The primary COPC release mechanisms and transport pathways at 100-K illustrated in Appendix G, Figure G-1, include the following:

- Migration of contaminated liquids through the vadose zone column through infiltration, percolation, or leaching
- Direct contact and external radiation from vadose zone material containing COPCs (receptor contact with shallow vadose zone material replaces release and transport)
- Emission of dusts and vapors during former plant operations
- Generation of dust emanating from shallow vadose zone material to ambient air from wind, or during maintenance or excavation activities occurring at the 100-K Source OUs
- Volatilization of COPCs emanating from shallow vadose zone material to ambient air at the 100-K Source OUs

6.2.3.3 Potentially Complete Human Exposure Pathways and Receptors

Based on the current understanding of land use conditions near the 100-K Source OU, the most plausible exposure pathways for calculating PRGs and characterizing the human health risks have been identified (represented in Figures G-1 and G-2 in Appendix G). The groundwater risk assessment is provided in Section 6.3.

For this soil risk assessment, shallow vadose zone material is represented by samples collected from 0 to 4.6 m (0 to 15 ft) bgs and deep vadose zone material is represented by samples collected from depths >4.6 m (15 ft) bgs (Section 6.2.1.2, Table 6-8). Groundwater is represented by samples collected from the unconfined aquifer and discussed in Section 6.3.

6.2.3.3.1 Residential Scenario

PRGs (also used as RBSLs) developed for the residential scenario are the numeric values that represent the RAOs presented in the FS. The results of comparing EPCs to the RBSLs in this soil risk assessment are used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis.

The residential scenario for radiological and nonradiological analytes is based on two different conceptual exposure models. The exposure pathways for radionuclides include direct contact in addition to dust inhalation, consumption of homegrown foodstuffs (e.g., produce, beef, and milk), and the leaching

[6] With exception of external irradiation from radionuclides, environmental contaminants must cross a cellular barrier and enter the body of a receptor for exposure to occur.

pathway (includes drinking water ingestion and fish ingestion). The exposure pathways for nonradiological analytes in vadose zone material include direct contact from incidental ingestion and inhalation of vapors and dust in ambient air.

The residential scenario described below is used to calculate the residential RBSLs for this RI and is consistent with the exposure scenario used to develop the interim action RAGs for soil presented in the 100 Area RDR/RAWP (DOE/RL-96-17). That is, the residential scenario and the scenario used to calculate the interim action RAGs incorporate the same exposure pathways and exposure routes. However, the PRG values are different from the interim action RAGs as a result of the changes described in Table 6-5.

Radiological. Consistent with the 100 Area RDR/RAWP (DOE/RL-96-17), the RESRAD code is used to evaluate exposure to radiological contaminants in vadose zone material. Revisions to this exposure scenario reflect updates in guidance since the 100 Area RDR/RAWP (DOE/RL-96-17) was originally published in 1996. With the exception of changes resulting from updates in guidance, the residential scenario is the same as that published in the 100 Area RDR/RAWP. Exposure assumptions that were updated to reflect current EPA guidance include a decrease in the external gamma-shielding factor (increased shielding) and a decrease in the outdoor time fraction. Health protective levels were also updated from a target annual dose rate of 15 mrem/yr to a target risk of 1×10^{-4} to be consistent with guidance recommended in . A detailed description of this exposure scenario is provided in ECF-HANFORD-10-0429, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Report*.

For radiological PRG development, a subsistence farming setting is used. This assumes that each interim remediated waste site decision unit has the potential to be developed into a residence with a basement, vegetable and fruit crops grown in a backyard garden, and a pasture that is used to raise livestock sufficient for meat and milk production. A downgradient well is installed where exposure could potentially occur from contaminants leaching from the vadose zone material to groundwater beneath the residence (i.e., the leaching pathway). The resident could potentially come into direct contact with soil from the remediated waste site and potentially inhale dust in ambient air. The resident could potentially consume crops raised in a backyard garden and consume meat (beef and poultry) and milk from livestock raised on the pasture.

The residential scenario evaluates residential pathways that include exposure to shallow vadose zone material from residential yards or groundwater from domestic wells. Potential routes of exposure to shallow vadose zone material evaluated in the RESRAD code include direct external exposure, incidental material ingestion, and inhalation of dust generated from wind or from yard maintenance activities. This scenario also evaluates residential exposure to radiological contaminants through food chain pathways (uptake of contamination from vadose zone material to plants and animals). Food chain pathways include the consumption of fruits and vegetables grown in a backyard garden and consumption of meat and milk from livestock raised on the pasture. From the leaching pathway, this scenario evaluates residential consumption of drinking water from a downgradient well, use of the well for irrigation of crops and watering livestock, and residential consumption of fish raised in a pond supplemented with water from the downgradient well.

Nonradiological. The residential scenario for nonradiological analytes measured in soil is also consistent with the exposure scenario used for the interim action RAGs for soil in the 100 Area RDR/RAWP (DOE/RL-96-17). The exposure scenario for protection of human health is based on 2013 MTCA Method B direct contact soil cleanup levels (WAC 173-340-740(3) and WAC 173-340-750(3), "Cleanup Standards to Protect Air Quality," "Method B Air Cleanup Levels"). The 2013 MTCA Method B direct

contact soil cleanup levels (WAC 173-340) are based on exposure to a child receptor that includes incidental ingestion and use residential exposure frequency and duration assumptions. The 2013 MTCA (WAC 173-340) Method B inhalation cleanup levels are based on exposure to a child and adult receptor, includes inhalation of vapors and dust in ambient air, and assumes residential exposure frequency and duration assumptions. For arsenic and lead, 2013 MTCA (WAC 173-340-900, Table 740-1) Method A soil cleanup levels for unrestricted land use of 20 mg/kg and 250 mg/kg, respectively, were used. For TPH, Table 747-5 (WAC 173-340-900) residual saturation screening levels for TPH of 1,000 mg/kg for weathered gasoline and unknown composition or type and 2,000 mg/kg for middle distillates (e.g., diesel No. 2 fuel oil) were used.

Groundwater. Groundwater within the 100-KR-4 OU is currently contaminated, and withdrawal is prohibited as a result of ICs placed on it by DOE through the interim action ROD. ICs are also evaluated as part of the final remedy. Under current site use conditions, no complete human exposure pathways to groundwater are assumed to exist. In addition, groundwater currently discharges to the Columbia River through upwelling and seeps. Groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use. Groundwater in this risk analysis is evaluated for drinking water use, and undiluted groundwater concentrations are compared to DWSs and aquatic criteria to support the determination of the basis for action and to support the development of PRGs for evaluating remedial alternatives in the FS.

The residential scenario for radiological and nonradiological analytes measured in groundwater is also consistent with the RAGs documented in the interim action RODs and in the 100 Area RDR/RAWP (DOE/RL-96-17). Groundwater concentrations are compared to current MCLs for radionuclides, which are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including radium-226, but excluding uranium and radon), and 5 pCi/L combined for radium-226 and radium-228. A mass-based concentration MCL has been established for uranium as 30 μg/L. The exposure scenario for protection of human health is based on MTCA Method B (WAC 173-340-720 (4)(b)), "Groundwater Cleanup Standards," "Standard Method B Potable Groundwater Cleanup Levels". The MTCA (WAC 173-340) Method B groundwater cleanup levels are based on exposure to a child and adult receptor, include drinking water ingestion and inhalation of vapors, and assume residential exposure frequency and duration assumptions.

6.2.3.3.2 Casual Recreational User Scenario

The casual recreational user is selected as the receptor to represent potential exposures from recreational use along the River Corridor. This exposure scenario was included in the subset of recreational use scenarios presented in the RCBRA (DOE/RL-2007-21). The PRGs for this scenario were updated in the RI; exposure assumptions did not change. However, radionuclide risk coefficients and chemical toxicity values were updated in 2015 and 2017, respectively (see Section 6.1.3). The casual recreational user scenario is a site-specific scenario representing occasional recreational use that focuses on activities such as walking and picnicking in areas along the Columbia River where paths and benches may exist in the future. These receptors are assumed to be exposed entirely in an outdoor environment. This scenario also assumes that drinking water is obtained from an offsite source.

PRGs are presented in this section for the casual recreational user that represents reasonably anticipated future land use. Casual recreational user PRG values are developed for radiological and nonradiological contaminants. When the total risk for a waste site is $<1\times10^{-4}$ based on the residential scenario or 1×10^{-5} for chemicals based on the MTCA HHRA Procedures (WAC 173-340-708(5), "Human Health Risk Assessment Procedures") cumulative risk threshold, then protection of the casual recreational user is achieved. The results of these comparisons (presented in Section 6.2.5.5) can be used in risk management decisions.

The casual recreational user scenario for radiological and nonradiological analytes in vadose zone material is based on the same conceptual exposure model. The exposure pathways include direct contact and inhalation of vapors and dust in ambient air. Adults and children could potentially be exposed to site contaminants in shallow vadose zone material along the river through direct external exposure, incidental ingestion, dermal absorption, and inhalation of vapors and dust in ambient air.

6.2.3.4 Quantification of Potential Exposures

Quantification of potential exposures in this risk assessment is evaluated through the comparison of EPCs to PRGs (which are also used as RBSLs). EPA/540/R-92/003, *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim*, provides guidance on using EPA toxicity values and exposure information to calculate PRGs. Once the BRA has been performed, PRGs can be derived using site-specific risks; PRGs developed in the FS will usually be based on site-specific risks and promulgated standards and not on screening levels. PRGs are obtained from two general sources: concentrations based on promulgated standards (e.g., DWSs) and concentrations based on risk assessment. Exposure assumptions published by the state and EPA and toxicity values published by EPA are used to derive risk-based PRGs.

PRGs based on risk assessment equations include the resident and the casual recreational user scenarios and are summarized in Table 6-10. PRGs for these scenarios are calculated using methodologies published in EPA/540/R-92/003 and EPA, 2018, "Regional Screening Levels for Chemical Contaminants at Superfund Sites," hereinafter referred to as Regional Screening Levels. Toxicity values and exposure values published by EPA are used to derive risk-based PRGs.

6.2.3.4.1 Calculation of Residential PRGs Using RESRAD

The radionuclide PRGs for the residential scenario are calculated using the RESRAD (ANL, 2015, RESRAD, Version 7.0) model and code according to the guidance specified in ANL/EAD-4. The RESRAD model was used to calculate single radionuclide concentrations that correspond to a target cancer risk level of 1×10^{-4} for the residential scenario. For this risk assessment, the single radionuclide concentrations described in this section are used as PRGs for the residential scenario.

The RESRAD model allows for the use of site-specific chemical and physical parameters to estimate single radionuclide concentrations. The potentially complete exposure pathways considered are direct contact, inhalation pathway, the food chain pathway, and leaching of contaminants in the vadose zone through the vadose zone column to the groundwater table. Exposure routes associated with the direct contact and inhalation pathways include external gamma exposure, incidental ingestion, and inhalation of dust. Exposure routes associated with the food chain exposure pathway include consumption of homegrown produce, meat, and milk. Exposure routes associated with the leaching pathway include crop irrigation, aquatic food consumption, and drinking water ingestion. A detailed description of methodology, inputs, assumptions, and results of the calculations is presented in Appendix G (ECF-HANFORD-10-0429).

6.2.3.4.2 Calculation of Unrestricted Land Use PRGs using MTCA Equations

The direct contact nonradiological PRGs for unrestricted land use (i.e., the resident) are calculated using equations and input parameters described in MTCA (WAC 173-340-740(3)). The Method B direct contact soil cleanup levels for unrestricted land use are based on ingestion and were calculated for noncarcinogens and carcinogens using equation 740-1 and equation 740-2, respectively. The Method B direct contact soil cleanup levels for unrestricted land use are based on an acceptable cancer risk level of 1×10^{-6} for nonradiological carcinogens or a HQ of 1 for noncarcinogens.

Table 6-10. Summary of Human Health Direct Contact Preliminary Remediation Goals for the 100-K Source OUs

Analyte	90th Percentile Background	MTCA Method A Soil Cleanup Level	Residential RBSL	2013 MTCA Method B Direct Contact Soil Cleanup Level (Carcinogen)	2013 MTCA Method B Direct Contact Soil PRG (Noncarcinogen)	2013 MTCA Method B Inhalation Soil Cleanup Level (Carcinogen)	2013 MTCA Method B Inhalation Soil Cleanup Level (Noncarcinogen)	Casual Recreational User RBSL (Carcinogen)	Casual Recreational User RBSL (Noncarcinogen)
Radionuclides (pCi/g)									
Americium-241	--	--	153	--	--	--	--	2,770	--
Carbon-14	--	--	81	--	--	--	--	330,000	--
Cesium-137	1.1	--	4.4	--	--	--	--	98	--
Cobalt-60	0.0084	--	3.1	--	--	--	--	57	--
Europium-152	--	--	3.6	--	--	--	--	64	--
Europium-154	0.033	--	4.5	--	--	--	--	80	--
Europium-155	0.054	--	335	--	--	--	--	5,870	--
Nickel-63	--	--	594	--	--	--	--	600,000	--
Plutonium-238	0.0038	--	236	--	--	--	--	4,610	--
Plutonium-239/240	0.025	--	203	--	--	--	--	4,040	--
Total beta radiostrontium	0.18	--	2.3	--	--	--	--	5,280	--
Tritium	--		624	--	--	--	--	1,020	--
Uranium-233/234	1.1	--	133	--	--	--	--	6,200	--
Uranium-235	0.11	--	15	--	--	--	--	301	--
Uranium-238	1.1	--	52	--	--	--	--	1,070	--
Nonradionuclides (mg/kg)									
Metals (mg/kg)									
Aluminum	1.18E+04	--	--	--	8.00E+04	--	1.67E+08	--	9.12E+05
Antimony	0.130	--	--	--	32.0	--	--	--	365
Arsenic	20	20	--	0.667	24.0	4.24E+04	5.00E+05	4.99	256
Barium	132	--	--	--	1.60E+04	--	1.67E+07	--	1.82E+05
Beryllium	1.51	--	--	--	160	7.60E+04	6.67E+05	3.98E+06	1.82E+03
Boron	3.89	--	--	--	1.60E+04	--	6.67E+08	--	1.82E+05
Cadmium	0.563	--	--	--	80	6.38E+10	3.33E+05	5.31E+06	833
Chromium	18.5	--	--	--	1.20E+05	--	--	--	1.37E+06
Cobalt	15.7	--	--	--	24	2.03E+04	2.00E+05	1.06E+06	274
Copper	22	--	--	--	3.20E+03	--	--	--	3.65E+04
Hexavalent chromium	--	--	--	--	240	2.17E+03	3.33E+06	4.11E+04	2.74E+03
Iron	3.26E+04	--	--	--	5.60E+04	--	--	--	6.39E+05
Lead	10.2	250	--	--	--	--	--	--	--
Lithium	13.3	--	--	--	160	--	--	--	1.83E+03
Manganese	512	--	--	--	1.12E+04	--	1.67E+06	--	1.28E+05
Mercury	0.013	--	--	--	24	--	1.00E+07	--	274

Table 6-10. Summary of Human Health Direct Contact Preliminary Remediation Goals for the 100-K Source OUs

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Molybdenum	0.470	--	--	--	400	--	--	--	4.56E+03
Nickel	19.1	--	--	--	1.60E+03	7.01E+08	3.00E+06	3.68E+7	1.82E+04
Selenium	0.780	--	--	--	400	--	6.67E+08	--	4.56E+03
Silver	0.167	--	--	--	400	--	--	--	4.56E+03
Strontium	--	--	--	--	4.80E+04	--	--	--	5.48E+05
Thallium	0.185	--	--	--	0.800	--	--	--	9.130
Tin	--	--	--	--	4.80E+03	--	--	--	5.48E+05
Uranium	3.21	--	--	--	240	--	1.33E+06	--	2.74E+03
Vanadium	85.1	--	--	--	400	--	3.33E+06	--	4.56E+03
Zinc	67.8	--	--	--	2.40E+04	--	--	--	2.74E+05
Anions (mg/kg)									
Fluoride	2.81		--	--	4.80E+03	--	4.34E+08	--	5.47E+04
Nitrate	52		--	--	5.68E+05	--	--	--	6.48E+06
Nitrite	--		--	--	2.40E+04	--	--	--	2.74E+05
Polycyclic Aromatic Hydrocarbons (mg/kg)									
Acenaphthene	--	--	--	--	4.80E+03	--	--	--	4.18E+07
Anthracene	--	--	--	--	2.40E+04	--	--	--	2.09E+08
Benzo(a)anthracene	--	--	--	10	--	3.04E+09	--	13,400	--
Benzo(a)pyrene	--	--	--	1	24	3.04E+08	6.67E+07	1,340	209,000
Benzo(b)fluoranthene	--	--	--	10	--	3.04E+09	--	13,400	--
Benzo(k)fluoranthene	--	--	--	100	--	3.04E+10	--	134,000	--
Chrysene	--	--	--	1,000	--	3.04E+11	--	1.34E+06	--
Dibenz[a,h]anthracene	--	--	--	1	--	3.04E+08	--	1,340	--
Fluoranthene	--	--	--	--	3.20E+03	--	--	--	2.79E+07
Fluorene	--	--	--	--	3.20E+03	--	--	--	2.79E+07
Indeno(1,2,3-cd)pyrene	--	--	--	10	--	3.04E+09	--	13,400	--
Naphthalene	--	--	--	--	1.60E+03	1,358	25,320	71,100	2.26E+06
Pyrene	--	--	--	--	2.40E+03	--	--	--	2.09E+07
Polychlorinated Biphenyls (mg/kg)									
Aroclor-1016	--	--	--	14.3	5.6	9.12E+06	--	83.1	47.9
Aroclor-1254	--	--	--	0.500	1.6	3.20E+05	--	2,.91	13.7
Aroclor-1260	--	--	--	0.500	--	3.20E+05	--	2.91	--

Table 6-10. Summary of Human Health Direct Contact Preliminary Remediation Goals for the 100-K Source OUs

Analyte	90th Percentile Background	MTCA Method A Soil Cleanup Level	Residential RBSL	2013 MTCA Method B Direct Contact Soil Cleanup Level (Carcinogen)	2013 MTCA Method B Direct Contact Soil PRG (Noncarcinogen)	2013 MTCA Method B Inhalation Soil Cleanup Level (Carcinogen)	2013 MTCA Method B Inhalation Soil Cleanup Level (Noncarcinogen)	Casual Recreational User RBSL (Carcinogen)	Casual Recreational User RBSL (Noncarcinogen)
Total Petroleum Hydrocarbons (mg/kg)									
Total petroleum hydrocarbons	--	1.00E+03	--	--	--	--	--	--	--
Total petroleum hydrocarbons - diesel range	--	2.00E+03	--	--	--	--	--	--	--
Total petroleum hydrocarbons - diesel range extended to C36	--	2.00E+03	--	--	--	--	--	--	--
Total petroleum hydrocarbons - motor oil (high boiling)	--	2.00E+03	--	--	--	--	--	--	--
Volatile Organic Compounds (mg/kg)									
Acetone	--	--	--	--	7.20E+04	--	1.94E+05	--	7.90E+05
Ethylene glycol	--	--	--	--	1.60E+05	--	2.36E+04	--	9.30E+05
Methylene chloride	--	--	--	500	480	528	580	820	5.03E+03
Semivolatile Organic Compounds (mg/kg)									
Bis(2-ethylhexyl) phthalate	--	--	--	71.4	1.60E+03	7.60E+07	--	452	1.47E+04
Di-n-butylphthalate	--	--	--	--	8.00E+03	--	--	--	7.37E+04

Reference: WAC 173-340, "Model Toxics Control Act—Cleanup."

-- = not applicable
MTCA = "Model Toxics Control Act—Cleanup"
OU = operable unit
PRG = preliminary remediation goal
RBSL = risk based screening level

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Reference dose and carcinogenic potency factors are determined using the recommended reference hierarchy as described in Cook, 2003 "Human Health Toxicity Values in Superfund Risk Assessments" hereinafter called Superfund Human Health Toxicity (HHT) Risk Assessment Values. A detailed description of methodology, inputs, assumptions, and the results of the calculations are presented in ECF-HANFORD-10-0444, *Documentation of Standard Method B Soil Cleanup Levels for Unrestricted Land Use.*

The inhalation nonradiological PRGs for unrestricted land use (i.e., the resident) are calculated using equations and input parameters described in MTCA (WAC 173-340-750(3)). The Method B air PRGs are calculated for noncarcinogens and carcinogens using equations 750-1 and 750-2, respectively.

The Method B air PRGs are converted to soil concentrations using EPA published volatilization factors for analytes that meet the operational definition of a volatile and a PEF for analytes that are not volatile. Method B soil PRGs for the inhalation pathway are based on an acceptable cancer risk level of 1×10^{-6} for nonradiological carcinogens or an HQ of 1 for noncarcinogens. Inhalation reference dose (RfD) and inhalation carcinogenic potency factors are determined using the recommended reference hierarchy, as described in Superfund HHT Risk Assessment Values (Cook, 2003). A detailed description of methodology, inputs and assumptions, and the results of the calculations are presented in ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

6.2.3.4.3 Calculation of Casual Recreational User PRGs for Radiological Analytes using EPA Equations

The radiological PRGs for the casual recreational user are calculated using equations consistent with those published on the PRG website (EPA, 2015a). As described in Section 6.2.3.3.2, the casual recreational user is a site-specific exposure scenario.-Casual recreational user nonradiological PRGs are based on an acceptable cancer risk level of 1×10^{-4} for carcinogens. A detailed description of methodology, inputs, assumptions, and the results of the calculations are presented in Appendix G (ECF-HANFORD-10-0446, *Calculation of Radiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports)*.

6.2.3.4.4 Calculation of Casual Recreational User PRGs for Nonradiological Analytes using EPA Equations

The nonradiological PRGs for the casual recreational user are calculated using equations consistent with those published on EPA, 2018, "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (hereinafter called Regional Screening Levels). As described in Section 6.2.3.3.2, the casual recreational user is a site-specific exposure scenario. Casual recreational user nonradiological PRGs are based on an acceptable cancer risk level of 1×10^{-6} for carcinogens or an HQ of 1 for noncarcinogens. Reference dose and carcinogenic potency factors are determined using the recommended reference hierarchy as described in the Superfund HHT Risk Assessment values (Cook, 2003). A detailed description of methodology, inputs and assumptions, and the results of the calculations are presented in ECF-HANFORD-10-0445, *Calculation of Nonradiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

6.2.4 Toxicity Assessment

This toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant at the 100-K Source OUs and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse

effects associated with contaminant exposure. The toxicity assessment contains two steps: hazard characterization and dose-response evaluation, as discussed in the following subsections.

6.2.4.1 Hazard Characterization

Hazard characterization identifies the types of toxic effects that a chemical can exert. For the toxicity assessment, chemicals can be divided into two broad groups—noncarcinogens and carcinogens—based on their effects on human health.

Carcinogens are those contaminants that are known or suspected causes of cancer following exposure; noncarcinogenic compounds are associated with a wide variety of systemic effects, such as liver toxicity or developmental effects. Some contaminants are capable of eliciting both carcinogenic and noncarcinogenic responses; therefore, these contaminants are evaluated for both effects.

For cancer effects, EPA has developed a carcinogen classification system (EPA/630/P-03/001B, *Guidelines for Carcinogen Risk Assessment*) that uses a weight of evidence approach for classifying the likelihood that a chemical is a human carcinogen. Information considered in developing the classification includes human studies of the association between cancer incidence and exposure, as well as long-term animal studies under controlled laboratory conditions. Other supporting evidence considered includes short-term tests for genotoxicity, metabolic and pharmacokinetic properties, toxicological effects other than cancer, structure-activity relationships, and physical and chemical properties of the chemical.

For noncancer effects, toxicity values are derived based on the critical toxic endpoint (i.e., the most sensitive adverse effect following exposure). Table G-6 (Appendix G) lists the COPCs detected at the 100-K Source OUs that have been identified as having documented systemic effects.

6.2.4.1.1 Dose Response Evaluation

The magnitude of toxicity of a contaminant depends on the dose to a receptor. Dose refers to exposure to a contaminant concentration over a specified period of time. Human exposures are generally classified as acute (typically <2 weeks), subchronic (about 2 weeks to 7 years), or chronic (7 years to a lifetime). This HHRA specifically addresses chronic exposure. Acute exposures and risks are evaluated only when chronic exposure estimates pose a high risk. A dose-response curve describes the relationship between the degree of exposure (i.e., dose) and the incidence of the adverse effects (i.e., response) in the exposed population. EPA uses this dose-response information to establish toxicity values for particular chemicals, as described in the following sections.

Reference Doses for Noncancer Effects. The toxicity value describing the dose-response relationship for noncancer effects is the RfD value. For noncarcinogenic effects, the body's protective mechanisms must be overcome before an adverse effect is manifested. If exposure is high enough and these protective mechanisms (or thresholds) are exceeded, adverse health effects can occur. EPA attempts to identify the upper bound of this tolerance range in the development of noncancer toxicity values. EPA uses the apparent toxic threshold value, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD value. EPA defines an RfD value as follows:

> *In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of mg/kg-day.*

Available chronic RfD values for the oral and inhalation exposure routes are used to calculate PRGs. Because EPA has not derived toxicity values specific to skin contact, dermal slope factors and RfD values

were derived from oral toxicity factors in accordance with EPA guidance. The RfD values for the contaminants evaluated in the 100-K Source OUs are summarized in Table G-6 (Appendix G).

6.2.4.1.2 Cancer Slope Factors for Cancer Effects

The dose-response relationship for cancer effects is expressed as a cancer slope factor that converts estimated intake directly to excess lifetime cancer risk (ELCR). Slope factors are expressed in units of risk per level of exposure (or intake). The data used for estimating the dose-response relationship are taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, because risk at low intake levels cannot be directly measured in animal or human epidemiological studies, a number of mathematical models and procedures have been developed to extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty associated with the carcinogenic response at very low levels of exposure. EPA assumes linearity at low doses when uncertainty exists about the mechanism of action of a carcinogen and when information suggesting nonlinearity is absent.

It is assumed, therefore, that if a cancer response occurs at the dose levels used in the study, there is some probability that a response will occur at all lower exposure levels (i.e., a dose-response relationship with no threshold is assumed). Moreover, the dose-response slope chosen is usually the 95% UCL on the mean on the actual dose-response curve observed in the laboratory studies. As a result, uncertainty and conservatism are built into the EPA risk extrapolation approach. EPA has stated that cancer risks estimated by this method produce estimates that "provide a rough but plausible upper limit of risk." The cancer slope factors used in this assessment are summarized in Appendix G (Table G-6).

6.2.4.2 Toxicity Values

The analyte-specific toxicity values presented Appendix G (Table G-6) are determined using the recommended reference hierarchy as described in Superfund HHT Risk Assessment values (Cook, 2003). The hierarchy is summarized as follows:

- Tier 1—The EPA Integrated Risk Information System (IRIS) database
- Tier 2—The EPA Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3—Other Toxicity Values

6.2.4.2.1 Tier 1—IRIS

The preferred source of toxicity data is the EPA IRIS database. Expert toxicologists at EPA have derived the values in this database and the values have undergone a thorough review and validation both within and outside EPA. If a toxicity value is available in IRIS, that value is used in preference to any other value.

6.2.4.2.2 Tier 2—PPRTVs

If a toxicity value is not available in IRIS, the next source is EPA's PPRTVs. This source includes toxicity values that have been developed by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center. These values are also published at the EPA's "Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV)" website at https://hhpprtv.ornl.gov/.

6.2.4.2.3 Tier 3—Other Toxicity Values

Tier 3 includes additional EPA and non-EPA sources of toxicity information, including the following:

- The California EPA's Toxicity Criteria Database contains toxicity values that are peer reviewed and address both cancer and non-cancer effects.

- The Agency for Toxic Substances and Disease Registry (ATSDR)'s Minimal Risk Levels for Hazardous Substances are peer-reviewed estimates of the daily human exposure to hazardous substances that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure.

- Toxicity values in EPA 540-R-97-036, Health Effects Assessment Summary Tables: FY 1997 Update (HEAST). The HEAST values for chemical contaminants are not currently available on an EPA internet site. Note that toxicity values are archived (removed) when an IRIS profile or a PPRTV assessment is released for a specific chemical. The toxicity value is removed from HEAST even if the PPRTV assessment indicates a toxicity value could not be derived.

- The Human Health Benchmarks for Pesticides (HHBPs) derived by EPA's Office of Pesticide Programs. IRIS has archived 51 chemical assessments for pesticides and has recommended the use of the toxicity values presented in the HHBP table. The Office of Pesticide Programs lists 363 pesticides in the HHBP table. Only the 51 archived by IRIS are used in the RSL calculations. The food quality protection factors are applied to the RfDs, if available. Derivation of the RfDs, for use in RSL calculations, is done by dividing the given RfD by the food quality protection factors to derive a value that is more protective.

A derived RfD for nitrate was calculated from the RfD reported in IRIS (1.6 mg/kg-day) for nitrate as nitrogen (NO_3--N) using the mass fraction of nitrogen in nitrate. The mass fraction of nitrogen in nitrate = mol wt N/mol wt NO_3^- = (14 g/mol)/(62 g/mol) = 0.226. The derived RfD for nitrate = (1.6 mg NO_3-N/kg-day)×(1 mg NO_3^-/0.226 mg NO_3--N) = 7.1 mg NO_3-/kg-day.

A derived RfD for nitrite was calculated from the RfD reported in IRIS (0.1 mg/kg-day) for nitrite as nitrogen (NO_2--N) using the mass fraction of nitrogen in nitrite. The mass fraction of nitrogen in nitrite = mol wt N/mol wt NO_2- = (14 g/mol)/(46 g/mol) = 0.304. The derived RfD for nitrite = (0.1 mg NO_2-N/kg-day)×(1 mg NO_2-/0.304 mg NO_2--N) = 0.3 mg NO_2-/kg-day.

Toxic equivalence factors (TEFs) were used to calculate toxicity values for dioxins, furans, and carcinogenic PAHs as described in 2013 MTCA HHRA Procedures (WAC 173-340-708(8)(D)(iii)(A)).

For Cr(VI), the current assessment considers cancer effects only for inhalation exposures. Note that an oral reference dose and a reference concentration is available for assessment of noncancer effects. An oral cancer slope factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral cancer slope factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$, as presented in NJDEP, 2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for Cr^{+6} Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*. If the NJDEP value were used to calculate the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) soil cleanup level, the soil concentration would decrease from 240 to 2.0 mg/kg. Assessing only inhalation cancer effects from Cr(VI) has the potential to under-estimate cancer risk.

The EPA recently updated (January 2017) the recommended oral RfD for uranium (soluble salts) published in the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" website. The website has published the oral RfD of 0.0002 mg/kg-day based on the intermediate-duration oral minimal risk levels resulting in renal effects in rats exposed to drinking water containing uranium for 91 days (ATSDR 2013). Previously this website published the oral RfD derived by EPA (and listed in the IRIS database) health assessment of 0.003 mg/kg-day based on initial weight loss and moderate nephrotoxicity in rabbits exposed to uranium in the diet for 30 days. ATSDR 2013 states the EPA oral RfD of 0.003 mg/kg-day is currently under review by EPA. However, the IRIS database has not withdrawn the oral RfD and indicates the uranium soluble salts is not being reassessed by IRIS at this

time. Use of the EPA oral RfD has the potential to under-estimate noncancer effects from uranium (soluble salts). If the ATSDR oral RfD was used to calculate the MTCA (WAC 173-340) Standard Method B soil cleanup level would decrease from 240 mg/kg to 16 mg/kg.

The radionuclide-specific cancer slope factors, decay constants, and half-lives presented in Appendix G (Table G-6) are obtained from "*Preliminary Remediation Goals for Radionuclides (PRG)", PRG Download, "Summary Tables"* (November 24, 2014).

6.2.5 Risk Characterization

Risk characterization is completed through the comparison of the EPC to RBSLs and the comparison of total site cancer risk and site noncancer HI to their respective thresholds. ECF-100KR1-11-0009, *Human Health Risk Evaluation for the 100-KR-1 and 100-KR-2 Source Operable Units*, which is provided in Appendix G, documents the process used to develop the human health risk and hazard estimates for each decision unit within the 100-K Source OUs. The comparisons are used to determine whether post-remediation soil concentrations protect human health. They are also used to determine if current material concentrations have the potential to exceed an HI >1 or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

Although this risk assessment produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision-making. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

For this risk characterization step, the potential for unacceptable human health risk is identified using the following risk thresholds:

- ELCR values are compared to the target range of 10^{-4} to 10^{-6} that is generally used by regulatory agencies. The MTCA (WAC 173-340) states that cancer risks resulting from multiple hazardous substances should not exceed 1×10^{-5} for unrestricted land use. ELCR values within or exceeding this target range require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.
- An HI (the sum of the ratios of the chemical intake to the RfDs for all COPCs) >1 indicates that some potential exists for adverse noncancer health effects associated with exposure to the COPCs.

6.2.5.1 Cancer Risk Estimation Method

To estimate the cancer risks from exposure to an individual carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{soil}}{RBSL_{carcinogen}} \times TR$$

where:

$Risk_I$	=	ELCR for individual chemical or radioisotope (unitless)
EPC_{soil}	=	EPC in soil (µg/kg or pCi/g)
$RBSL_{carcinogen}$	=	Soil RBSL based on 10^{-6} carcinogenic effect for chemical (µg/kg) or 10^{-4} carcinogenic effect for radioisotope (pCi/g)

TR = Target ELCR of 10^{-6} for individual hazardous substance or 10^{-4} for individual radioisotope

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used. The equation presented below is consistent with that published in EPA, 2018.

$$Risk_T = \sum_i \frac{EPC_{soil}}{RBSL_{carcinogen}} \times TR$$

where:

$Risk_T$ = Total ELCR for all chemicals and radioisotopes

EPC_{soil} = EPC in soil (µg/kg or pCi/g)

$RBSL_{carcinogen}$ = RBSL based on 10^{-6} carcinogenic effect for chemical (µg/kg) or 10^{-4} carcinogenic effect for radioisotope (pCi/g)

TR = Target ELCR of 10^{-6} for individual hazardous substance or 10^{-4} for individual radioisotope

i = The sum of the ratios for the ith chemical or radioisotope.

6.2.5.2 Noncancer Hazard Estimation Method

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (i.e., its RfD). The ratio of the chronic daily intake divided by RfD is termed the HQ.

To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{soil}}{RBSL_{noncarcinogen}}$$

where:

HQ = HQ for individual chemical

EPC_{soil} = EPC in soil (µg/kg)

$RBSL_{noncarcinogen}$ = RBSL based on HQ=1 noncarcinogenic effects (µg/kg).

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used. The equation presented below is consistent with that published in EPA, 2018.

$$HI_T = \sum_i \frac{EPC_{soil}}{RBSL_{noncarcinogen}}$$

where:

HI_T = Total HI for all chemicals

EPC_{soil} = EPC in soil (µg/kg)

$RBSL_{noncarcinogen}$ = RBSL based on HQ=1 noncarcinogenic effects (μg/kg)

T = The sum of the ratios for the ith chemical.

6.2.5.3 Comparisons of Lead and Arsenic to MTCA Method A Soil Cleanup Levels and Residual Saturation Screening Levels for TPH

Potential risks from lead concentrations were evaluated using a different method than what is conventionally used for other carcinogens and noncarcinogens. For direct contact pathways, the EPCs for lead were compared to the MTCA (WAC 173-340-900, Table 740-1) Method A, soil cleanup level for unrestricted land use of 250 mg/kg.

The Method A cleanup level, which is based on the EPA Integrated Exposure Uptake Biokinetic model, is designed to calculate the probability of blood-lead concentrations for children between 6 and 84 months (i.e., up to 7 years) of age who have been exposed to lead through various sources (e.g., air, water, soil, dust, and in utero contributions from the mother) to exceed a specific blood lead concentration.

Arsenic EPCs were compared to the MTCA (WAC 173-340-900, Table 740-1) Method A soil cleanup level for unrestricted land use of 20 mg/kg.

TPH EPCs were compared to the MTCA (WAC 173-340-900, Table 747-5) residual saturation screening levels for TPH of 1,000 mg/kg for weathered gasoline and unknown composition or type and 2,000 mg/kg for middle distillates (e.g., Diesel No. 2 fuel oil) or heavy fuel oils (e.g., No. 6 fuel oil).

6.2.5.4 Consideration of Background in Risk Assessment

EPA 540-R-01-003 provides national policy considerations for application of background data in risk assessment and remedy selection. This policy recommends an approach that addresses site-specific background issues in the risk characterization. EPA 540-R-01-003 indicates the following:

> *COPCs that have both release-related and background-related sources should be included in the risk assessment. When concentrations of naturally occurring elements at a site exceed risk-based screening levels, that information should be discussed qualitatively in the risk characterization.*

EPA 540-R-01-003 defines background constituents as the following: anthropogenic—natural and artificial substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question), and naturally occurring—substances present in the environment in forms that have not been influenced by human activity.

6.2.5.4.1 Sources of Background Concentrations

The 90th percentile and maximum background concentrations for the Hanford Site have been developed for both inorganic chemicals and radionuclides and are considered representative of both naturally occurring and anthropogenic substances. The maximum inorganic background concentrations used in this evaluation are identified as the "overall maximum concentrations" in the Non-Rad Soil Background document (DOE/RL-92-24), Summary Table 1, and the 90th percentile inorganic background concentrations are identified as the "lognormal distribution 90th percentiles" in the Non-Rad Soil Background document, (DOE/RL-92-24), Summary Table 2. The exceptions to this are described in the following paragraph. Two types of sampling were conducted to determine the inorganic background values: systematic random sampling and judgment sampling. The overall maximum concentrations were determined by considering the analytical results from both systematic random samples and judgmental samples. The 90th percentile values were calculated using the analytical results from the systematic random samples only.

The Hanford Site cleanup value for arsenic is 20 mg/kg based on a letter (Ecology, 2013) indicating that the Method A soil cleanup level of 20 mg/kg can be used to define natural background levels when developing Method B soil cleanup levels for the Hanford Site. While the measured 90th percentile background concentration of arsenic in Hanford soil is about 6.47 mg/kg, the 20 mg/kg value is used as the applicable cleanup level.

The Hanford Site background values for antimony, boron, cadmium, lithium, mercury, molybdenum, selenium, silver, and thallium, are documented in ECF-HANFORD-11-0038 in Appendix G. Boron was not analyzed for in the Non-Rad Soil Background document (DOE/RL-92-24) and the analytical data associated with the remaining analytes in the Non-Rad Soil Background document are considered unusable for statistical analyses because of elevated MDLs. The background concentration values documented in ECF-HANFORD-11-0038, reference PNNL-18577, *A Review of Metal Concentrations Measured in Surface Soil Samples Collected on and Around the Hanford Site*, (hereinafter called Review of Metal Concentrations). The ECF documents a review of the data sets from the Non-Rad Soil Background document and Review of Metal Concentrations (PNNL-18577), which indicate the data are comparable and issues associated with elevated detection limits were eliminated as a result of improvements in analytical methods used for Review of Metal Concentrations (PNNL-18577). It is noted that ECF-HANFORD-11-0038, in Appendix G, recalculates the percentile values based on using a nonparametric (Kaplan-Meier) method, consistent with the methodology used in the Non-Rad Soil Background document. Review of Metal Concentrations (PNNL-18577) calculated the 90th percentile values based on an assumption of normally distributed data.

The background concentration values documented in ECF-HANFORD-11-0038, for selenium reference Ecology Publication 94-115, *Natural Background Soil Metals Concentrations in Washington State* because neither the Non-Rad Soil Background document (DOE/RL-92-24) nor Review of Metal Concentrations (PNNL-18577) provided adequate analytical results.

Radionuclide background values (lognormal 90th percentile and maximum) are identified in the Rad Soil Background document (DOE/RL-96-12), Table 5-1. The background values for naturally occurring radionuclides were determined primarily by analyzing a subset of the inorganic systematic random samples from the vadose zone (upper 30 cm [76 in.] of the soil column). The background values for the anthropogenic radionuclides were determined from analytical results from surface sampling (upper 2.5 cm [1 in.] of the soil column).

The composition of background samples described in the Non-Rad Soil Background document (DOE/RL-92-24), the Rad Soil Background document (DOE/RL-96-12), and Review of Metal Concentrations (PNNL-18577) is representative of the sedimentary facies in the vadose zone at the 100-K Source OUs. These background data are recommended for use in environmental-restoration activities on the Hanford Site to maintain consistency between projects, and they have been peer reviewed for technical credibility. Appendix G (Table G-7) lists the maximum and 90th percentile background concentration values for inorganic chemicals and radionuclides.

6.2.5.4.2 Comparison of Site and Background Risk Contributions

Understanding the contribution to risk from naturally occurring elements is important because cleanup levels are not set at concentrations below natural background levels under CERCLA. Similarly, MTCA WAC 173-340-700(6)(d), "Overview of Cleanup Standards," "Natural Background and Analytical Considerations" states the following:

> *In some cases, cleanup levels calculated using the methods specified in this chapter are less than natural background levels or levels that can be reliably measured. In those*

> *situations, the cleanup level shall be established at a concentration equal to the practical quantitation limit or natural background concentration, whichever is higher.*

EPA 540-R-01-003 states that:

> *When background concentrations are high relative to the concentrations of released hazardous substances, pollutants, and contaminants, a comparison of site and background concentrations may help risk managers make decisions concerning appropriate remedial actions. The contribution of background concentrations to risks associated with CERCLA releases may be important for refining specific RAGs for contaminants of concern that warrant remedial action.*

The 90th percentile value is used as a fixed benchmark concentration for the purpose of determining which contaminants should be evaluated for purposes of background risk. To assist in risk management decisions concerning appropriate remedial actions, a comparison of background risks to risks from CERCLA releases is provided approach described in the following text.

EPCs from each decision unit are compared to the background value for metals and radionuclides listed in Appendix G (Table G-7). Appendix G, Table G-8, provides a comparison of EPCs to the lognormal 90th percentile value for each decision unit for the 100-K Source OUs. Risk estimates are calculated as follows:

- If the EPC is less than or equal to the background value, then a risk estimate or an HQ is not calculated.
- If the EPC is greater than the background value, then a risk estimate or an HQ is calculated.
- If a background value is not available for an analyte, then a risk estimate or an HQ is calculated.
- The total ELCR is summed for all analytes with EPCs greater than their respective background value.
- The HI is summed for all analytes with EPCs greater than their respective background value.

6.2.5.5 Summary of Risk Estimates by Exposure Scenario

This section summarizes the risk estimates for each of the exposure scenarios considered for the 100-K Source OUs.

6.2.5.5.1 Residential Scenario

PRGs developed for the residential scenario are the numeric values that represent the RAOs presented in the FS. PRGs are established to help determine the need for remedial action at unremediated waste sites. The PRGs are also used to compare EPCs to the RBSLs in this soil risk assessment and are used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis. A complete description of the residential exposure pathways is provided in Section 6.2.3.3.1.

For completeness in analysis, all risk estimates for each remediated waste site decision unit are provided in Appendix G. The risk estimates for 100-K, which include all COPCs regardless of their EPCs relative to the background value, are presented in Appendix G (Tables G-9 through G-15).

Appendix G also presents risk estimates for each remediated waste site decision unit, which includes only those COPCs with EPCs greater than background values or do not have a background value. Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone

material, deep vadose zone material, and overburden material. The results for the residential scenario are summarized in Appendix G (Tables G-16 through G-23) for the 100-K Source OUs. Only the risk estimates without background contributions are discussed in the risk characterization because this information is used for decisions concerning appropriate remedial actions.

An overall summary of the cumulative risk estimates for each of the remediated waste sites evaluated is provided in Tables 6-11 and 6-12 for the shallow zone material, Tables 6-13 and 6-14 for the overburden material, and Table 6-15 for the deep zone material. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the decision unit with the highest estimated risks and hazards, the total ELCR, risk driver and percent contribution (if applicable), and the HI and the noncancer hazard driver and percent contribution (if applicable).

Shallow Zone. A total of 52 of the 54 remediated waste site groups are reported with CVP/RSVP data associated with shallow zone material in the 100-K Source OUs. The following sample designs were applied to the 52 remediated waste sites evaluated:

- Fifteen waste sites were sampled using a focused sampling design.
- Twenty-two waste sites were sampled using a statistical sampling design.
- Fifteen waste sites were sampled using both a statistical and a focused sampling design.

Radiological Results. As presented in Table 6-11, the potential cumulative ELCR is greater than the upper risk threshold of 1×10^{-4} at four remediated waste sites, and is within the regulatory target risk range of 1×10^{-4} to 1×10^{-6} at 13 remediated waste sites. Risks were not reported at six remediated waste sites because there were no COPCs reported above background concentrations and risks were not reported for 29 remediated waste sites because radiological COPCs were not reported.

Four remediated waste sites report concentrations of site-related COPCs that exceed the upper range of the target threshold for the residential scenario. The cancer risk levels for the residential scenario are as follows:

- The 116-K-1 remediated waste site (shallow decision unit) reports a total ELCR of 1.1×10^{-4}. Primary contributors to risk include cesium-137 (2.8×10^{-5}; 25% contribution) and strontium-90 (7.7×10^{-5}; 68% contribution). The EPC of cesium-137 is 1.2 pCi/g, which is less than the residential RBSL of 4.4 pCi/g and is also less than the direct exposure RAG of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 1.7 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and is also less than the direct exposure RAG of 4.5 pCi/G published in the 100 Area RDR/RAWP (DOE/RL-96-17).

- The 100-K-56:1 remediated waste site (shallow focused decision unit) reports a total ELCR of 1.2×10^{-4}. The primary contributors to risk include europium-152 (8.6×10^{-5}, 72% contribution) and strontium-90 (2.2×10^{-5}, 18% contribution). The EPC of europium-152 is 3.1 pCi/g, which is less than the residential RBSL of 3.6 pCi/g and is also less than the direct exposure RAG of 3.3 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 0.5 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and is also less than the direct exposure RAG of 4.5 pCi/G published in the 100 Area RDR/RAWP (DOE/RL-96-17).

Table 6-11. Summary of Total Risks from Direct Contact with Radionuclides in Shallow Vadose Zone Material from the100-K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution
100-KR-1 Source OU				
Interim Closed Out	116-K-1	Shallow	1.1×10^{-4}	Cesium-137 (2.8×10^{-5} – 25%) Strontium-90 (7.7×10^{-5} – 68%)
	100-K-63	None	1×10^{-4} to 1×10^{-6}	None
	116-K-2			
	116-KE-4			
	116-KW-3			
Interim No Action	100-K-78	None	1×10^{-4} to 1×10^{-6}	None
100-KR-2 Source OU				
Interim Closed Out	100-K-56:1	Shallow Focused	1.2×10^{-4}	Europium-152 (8.6×10^{-5}– 72%) Strontium-90 (2.2×10^{-5}– 18%)
	100-K-6, 100-K-46, 100-K-62, 132-KE-1	Shallow 2 [b]	1.0×10^{-3}	Carbon-14 (1.7×10^{-4}– 17%) Cesium-137 (3.5×10^{-4}– 35%) Strontium-90 (4.8×10^{-4}– 48%)
	118-K-1	P1 Shallow 4	2.5×10^{-4}	Strontium-90 (2.4×10^{-4}– 99%)
	100-K-3	None	1×10^{-4} to 1×10^{-6}	None
	100-K-3; 100-K-36; 100-K-79:7 [c]			
	100-K-3; 100-K-68; 100-K-69, 100-K-70; 100-K-71			
	100-K-53			
	100-K-55:1			
	100-K-6			
	100-K-62			
	132-KE-1			

Table 6-11. Summary of Total Risks from Direct Contact with Radionuclides in Shallow Vadose Zone Material from the100-K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution
	100-K-109		Radiological COPCs less than background	None
	100-K-36			
	100-K-4			
	100-K-77			
Interim Closed Out	100-K-102	None	Radiological COPCs not reported	None
	100-K-106			
	100-K-14, 126-KE-2			
	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7			
	100-K-29			
	100-K-30			
	100-K-31			
	100-K-32			
	100-K-33			
	100-K-34			
	100-K-34, 100-K-102, 1607-K3			
	100-K-50, 1607-K2			
	100-K-84			
	100-K-86			
	100-K-89, 600-29			
	100-K-91			
	100-K-92			
	100-K-95			

Table 6-11. Summary of Total Risks from Direct Contact with Radionuclides in Shallow Vadose Zone Material from the100-K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution
	116-KE-5			
	116-KW-4			
	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4			
	128-K-1			
	130-KE-1			
	128-K-2			
	1607-K3			
	600-29			
Interim No Action	100-K-105	None	Radiological COPCs less than background	None
	100-K-110			
	100-K-85	None	Radiological COPCs not reported	None
	100-K-88E			
	100-K-90			

Note: Results summarized from Table G-19, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-K Source OUs Waste Site Decision Units Without Background Contribution.

a. Total ELCR represents risk contributions from radiological COPCs only.

b. The samples associated with a total cancer risk $>1\times10^{-4}$ are located in the deep zone (i.e., >15 ft bgs).

c. Although this site or subsite is listed, it has not undergone remediation and is not classified as interim closed out

bgs = below ground surface

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

Table 6-12. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact with Shallow Vadose Zone Material from the 100-KR Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution	HI	Hazard Driver and % Contribution
100-KR-1 Source OU						
Interim Closed Out	100-K-63	None	Carcinogenic COPCs less than background	None	<1	None
	116-K-1	None	Carcinogenic COPCs not reported	None	<1	None
	116-K-2					
	116-KE-4					
	116-KW-3					
Interim No Action	100-K-78	None	Carcinogenic COPCs less than background	None	<1	None
100-KR-2 Source OU						
Interim Closed Out	128-K-1	Shallow Focused	5.8×10^{-6}	Benzo(a)pyrene (2.9×10^{-6} – 50%) Dibenz(a,h)anthracene ($1.\times10^{6}$ – 21%)	<1	None
	100-K-29	None	$<1\times10^{-6}$	None	<1	None
	100-K-3, 100-K-36, 100-K-79:7 [b]					
	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71					
	100-K-50, 1607-K2					
	100-K-77					
	100-K-86					
	100-K-89, 600-29					
	100-K-92					
	100-K-95					

Table 6-12. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact with Shallow Vadose Zone Material from the 100-KR Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution	HI	Hazard Driver and % Contribution
Interim Closed Out	118-K-1	None	$<1\times10^{-6}$	None	<1	None
	128-K-2					
	1607-K3					
	600-29					
Interim Closed Out	100-K-102	None	Carcinogenic COPCs less than background	None	<1	None
	100-K-106					
	100-K-109					
	100-K-14, 126-KE-2					
	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7					
	100-K-3					
	100-K-30					
	100-K-31					
	100-K-32					
	100-K-33					
	100-K-34, 100-K-102, 1607-K3					
	100-K-34					
	100-K-36					
	100-K-4					
	100-K-53					
	100-K-6, 100-K-46, 100-K-62, 132-KE-1					
	100-K-6					

Table 6-12. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact with Shallow Vadose Zone Material from the 100-KR Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution	HI	Hazard Driver and % Contribution
Interim Closed Out	100-K-62	None	Carcinogenic COPCs less than background	None	<1	None
	100-K-84					
	100-K-91					
	116-KE-5					
	116-KW-4					
	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4					
	132-KE-1					
	130-KE-1 [c]		Carcinogenic COPCs not reported		Noncarcinogenic COPCs not reported	
	100-K-55:1				Noncarcinogenic COPCs less than background	
	100-K-56:1				<1	
Interim No Action	100-K-85	None	Carcinogenic COPCs less than background	None	Noncarcinogenic COPCs less than background	None
	100-K-88				<1	None
	100-K-105					
	100-K-110					
	100-K-90		Carcinogenic COPCs not reported		<1	None

Note: Results summarized from Table G-19, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-K Source OUs Waste Site Decision Units Without Background Contribution.

a. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

b. Although this site or subsite is listed, it has not undergone remediation and is not classified as interim closed out.

c. Samples from 130-KE-1 were only analyzed for TPH; it is listed here for accounting purposes.

COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HI = hazard index
OU = operable unit
TPH = total petroleum hydrocarbon

Table 6-13. Summary of Total Risks from Direct Contact with Radionuclides in Overburden Material from the 100 K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR*	Risk Driver and % Contribution
100-KR-1				
Interim Closed Out	116-K-1	None	1×10^{-4} to 1×10^{-6}	None
	116-K-2			
100-KR-2				
Interim Closed Out	100-K-106	None	Radiological COPCs not reported	None
	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7			
	100-K-34, 100-K-102, 1607-K3			
	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4			
	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71		1×10^{-4} to 1×10^{-6}	
	100-K-55:1			
	100-K-6, 100-K-46, 100-K-62, 132-KE-1			
	118-K-1		Radiological COPCs less than background	

Note: Results summarized from Table G-21, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-K Source OUs Waste Site Decision Units Without Background Contribution.

*Total ELCR represents risk contributions from radiological COPCs only.

COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
OU = operable unit

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact in Overburden Material from the 100 K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR*	Risk Driver and % Contribution	HI	Hazard Driver and % Contribution
100-KR-1 Source OU						
Interim Closed Out	116-K-1	None	Carcinogenic COPCs not reported	None	Noncarcinogenic COPCs less than background	None
	116-K-2				<1	None
100-KR-2 Source OU						
Interim Closed Out	100-K-106	None	Carcinogenic COPCs less than background	None	<1	None
	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7					
	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71					
	100-K-34, 100-K-102, 1607-K3					
	100-K-6, 100-K-46, 100-K-62, 132-KE-1					
	100-K-55:1		Carcinogenic COPCs not reported		Noncarcinogenic COPCs not reported	
	118-K-1		Carcinogenic COPCs less than background		Noncarcinogenic COPCs less than background	
	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4				<1	

Note: Results summarized from Table G-21, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-K Source OUs Waste Site Decision Units Without Background Contribution.

*Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HI = hazard index
OU = operable unit

Table 6-15. Summary of Total Risks from Direct Contact with Radionuclides for the Deep Vadose Zone from the 100 K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution
100-KR-1				
Interim Closed Out	116-K-1	Deep	9.7×10^{-4}	Cesium-137 (3.4×10^{-4} – 35%) Cobalt-60 (8.1×10^{-5} – 8.3%) Europium-152 (1.5×10^{-4} – 16%) Strontium-90 (3.8×10^{-4} – 39%)
	116-K-2	Deep 2	6.4×10^{-3}	Cesium-137 (3.3×10^{-3} – 51%) Cobalt-60 (1.4×10^{-4} – 2.2%) Europium-152 (2.3×10^{-3} – 36%) Europium-154 (2.7×10^{-4} – 4.2%) Nickel-63 (1.1×10^{-4} – 1.7%) Strontium-90 (2.9×10^{-4} – 4.6%)
100-KR-2				
Interim Closed Out	100-K-3, 100-K-36, 100-K-79:7 [b]	Deep Focused 1	2.7×10^{-4}	Strontium-90 (2.7×10^{-4}– 100%)
	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71	Deep Focused 1	1.8×10^{-3}	Cesium-137 (1.1×10^{-3}– 61%) Strontium-90 (7.0×10^{-4}– 39%)
	100-K-36	None	Radiological COPCs less than background	None
	100-K-4			
	100-K-46	Deep	1.9×10^{-4}	Cesium-137 (1.4×10^{-4}– 73%) Strontium-90 (4.3×10^{-5}– 22%)
	100-K-47 [b], 100-K-69, 100-K-70, 100-K-71	Deep	1.4×10^{-4}	Strontium-90 (1.2×10^{-4}– 86%) Europium-152 (1.9×10^{-5}– 13%)
	100-K-55:1	Deep	1.4×10^{-4}	Cesium-137 (8.8×10^{-5}– 65%) Cobalt-60 (1.9×10^{-5}– 14%) Europium-152 (2.2×10^{-5}– 16%)
	100-K-56:1	Deep	1.5×10^{-3}	Cesium-137 (5.9×10^{-4}– 38%) Cobalt-60 (3.5×10^{-5}– 2%) Europium-152 (8.7×10^{-4}– 57%) Europium-154 (4.4×10^{-5}– 3%)

Table 6-15. Summary of Total Risks from Direct Contact with Radionuclides for the Deep Vadose Zone from the 100 K Source OUs – Residential Scenario

Classification Status	Remediated Waste Site	Decision Unit with Exceedance	Total ELCR [a]	Risk Driver and % Contribution
	118-K-1	P2 Deep Focused 2	1.9×10^{-3}	Cesium-137 (1.0×10^{-4}– 5.4%) Europium-152 (1.0×10^{-3}– 55%) Strontium-90 (6.6×10^{-4}– 35%)

Note: Results summarized from Table G-23, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-K Source OUs Waste Site Decision Units Without Background Contribution.

a. Total ELCR represents risk contributions from radiological COPCs only.

b. Although this site or subsite is listed, it has not undergone remediation and is not classified as interim closed out.

COPC = contaminant of potential concern

ELCR = excess lifetime cancer risk

OU = operable unit

- The 100-K-6, 100-K-46, 100-K-62, 132-KE-1 remediated waste site (shallow 1 decision unit) report a total ELCR of 1.7×10^{-4}. Primary contributors to risk include carbon-14 (8.1×10^{-5}; 49% contribution), cesium-137 (3.8×10^{-5}; 23% contribution), and strontium-90 (3.5×10^{-5}, 21% contribution). The EPC of carbon-14 is 66 pCi/g, which is less than the residential RBSL of 81 pCi/g and is greater than the direct exposure RAG of 8.69 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of cesium-137 is 1.7 pCi/g, which is less than the residential RBSL of 4.4 pCi/g and is also less than the direct exposure RAG of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 0.79 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and also less than the direct exposure RAG of 4.5 pCi/G published in the 100 Area RDR/RAWP (DOE/RL-96-17).

- The 100-K-6, 100-K-46, 100-K-62, 132-KE-1 remediated waste site (shallow 2 decision unit) report a total ELCR of 1.0×10^{-3}. Primary contributors to risk include carbon-14 (1.7×10^{-4}; 17% contribution), cesium-137 (3.5×10^{-4}; 35% contribution), and strontium-90 (4.8×10^{-4}, 48% contribution). The EPC of carbon-14 is 139 pCi/g, which is greater than the residential RBSL of 81 pCi/g and is greater than the direct exposure RAG of 8.69 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of cesium-137 is 15 pCi/g, which is greater than the residential RBSL of 4.4 pCi/g and is also greater than the direct exposure RAG of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 11 pCi/g, which is greater than the residential RBSL of 2.3 pCi/g and also greater than the direct exposure RAG of 4.5 pCi/G published in the 100 Area RDR/RAWP (DOE/RL-96-17). Although the samples from this decision unit were assigned to the shallow zone, soil samples were collected from both the shallow and deep zones. Vadose zone material collected from the deep zone reported concentrations greater than the RBSLs as reported in DOE/RL-2012-38, *Remaining Sites Verification Package for the 100-KR-2 Operable Unit Waste Sites: 100-K-6, 100-K-46, 100-K-62 and 132-KE-1*.

- The 118-K-1 remediated waste site (P1 shallow 4 decision unit) reports a total ELCR of 2.5×10^{-4}. The primary contributor to risk is strontium-90 (2.4×10^{-4}; 99% contribution). The EPC of strontium-90 is 5.6 pCi/g, which is greater than the residential RBSL of 2.3 pCi/g, and also greater than the direct exposure RAG of 4.5 pCi/G published in the 100 Area RDR/RAWP (DOE/RL-96-17).

- The 118-K-1 remediated waste site (P1 shallow focused 1 decision unit) reports a total ELCR of 1.7×10^{-4}. Primary contributors to risk include strontium-90 (8.7×10^{-5}; 51% contribution) and cesium-137 (8.4×10^{-5}; 49% contribution). The EPC of strontium-90 is 2.0 pCi/g, which is less than the residential RBSL of 2.3 pCi/g, and also less than the direct exposure RAG of 4.5 pCi/G published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of cesium-137 is 3.7 pCi/g, which is less than the residential RBSL of 4.4 pCi/g and is also less than the direct exposure RAG of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17).

Nonradiological Results (Direct Contact). As presented in Table 6-12, the total ELCR is $>1\times10^{-6}$ for one remediated waste site and is $<1\times10^{-6}$ for 13 remediated waste sites. Risks were not reported at 30 remediated waste sites because nonradiological carcinogenic COPCs were less than background. Risks were not reported at eight remediated waste sites because nonradiological carcinogenic COPCs were not reported.

One remediated waste site reports individual carcinogens that exceed the MTCA (WAC 173-340-740) acceptable cancer risk level of 1×10^{-6}; however, this remediated waste site is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

As presented in Table 6-12, the noncancer HI from direct contact for noncancer effects is <1 at 49 remediated waste sites. HIs were not reported at two remediated waste sites because nonradiological noncarcinogenic COPCs were less than background and HIs were not reported at one remediated waste sites because nonradiological noncarcinogenic COPCs were not reported.

Nonradiological Results (Inhalation). As presented in Table G-20 (Appendix G), the potential total ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from 2.1×10^{-7} to 1.5×10^{-17}. The potential cumulative ELCR is less than the lower risk threshold of 1×10^{-6} for individual carcinogens for 35 remediated waste sites. Risks were not reported at 15 remediated waste sites because carcinogenic COPC concentrations were less than background and risks were not reported at two remediated waste sites because nonradiological carcinogenic COPCs were not reported.

A presented in Table G-20 (Appendix G), the potential HI is less than the MTCA (WAC 173-340-750) target HI of 1 at 43 remediated waste sites. Noncancer hazards were not reported at 8 remediated waste sites because noncarcinogenic COPC concentrations were less than background, and noncancer hazards were not reported at one remediated waste site because nonradiological COPCs were not reported.

MTCA Method A Comparisons. As shown in Table G-18 (Appendix G), all lead, arsenic, and TPH concentrations for the shallow zone decision units are less than their respective Method A soil cleanup levels.

Overburden. Ten remediated waste sites were reported with CVP/RSVP data associated with overburden material in the 100-K Source OUs. Overburden material from one waste site was sampled using a focused and statistical sampling design and overburden material from nine waste sites was sampled using a statistical sampling design.

Radionuclide Results. As presented in Table 6-13, the total ELCR is within the target risk range of 1×10^{-4} to 1×10^{-6} for overburden material associated with five remediated waste sites. Risks were not reported for overburden material associated with one remediated waste site because radiological COPC concentrations were less than background and risks were not reported for overburden material associated with four remediated waste sites because radiological COPCs were not reported.

Nonradiological Results (Direct Contact). As presented in Table 6-14, risks were not reported for overburden material from seven remediated waste sites because nonradiological carcinogenic COPCs were less than background. Risks were not reported for overburden material from three remediated waste sites because nonradiological carcinogenic COPCs were not reported.

As presented in Table 6-14, the noncancer HI from direct contact is <1 for overburden material from seven remediated waste sites. HIs were not reported in overburden material from two remediated waste sites because noncarcinogenic COPCs were less than background and were not reported in overburden material from one remediated waste site because noncarcinogenic COPCs were not reported.

Nonradiological Results (Inhalation). As presented in Table G-22 (Appendix G), the potential total ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contributions ranges from 3.3×10^{-11} to 1.3×10^{-10}. The potential total ELCR is less than the MTCA (WAC 173-340-750) risk value of 1×10^{-6} for individual carcinogens from overburden material associated with three remediated waste sites. Risks were not reported at five remediated waste sites because carcinogenic COPC concentrations were less than background and risk were not reported in overburden material from two remediated waste sites because carcinogenic COPCs were not reported.

As presented in Table G-22 (Appendix G), the potential HI is less than the MTCA (WAC 173-340-750) target HI of 1 in overburden material associated with six remediated waste sites. Noncancer hazards were not reported in overburden material from two remediated waste sites because noncarcinogenic COPC concentrations were less than background and were not reported in overburden material from two remediated waste sites because noncarcinogenic COPCs were not reported.

MTCA Method A Comparisons. As shown in Table G-18 (Appendix G), all lead, arsenic, and TPH concentrations for the overburden decision units are less than their respective MTCA Method A soil cleanup levels.

Deep Zone. Deep vadose zone soil samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. Although there is no current exposure pathway for deep contamination, the RBSLs developed for the residential exposure scenario were used as a screening value to identify such sites in order to allow ICs to be established to control access to deep contamination.

A total of 11 remediated waste sites were reported with CVP/RSVP data from deep zone decision units in the 100-K Source OUs. The following sample designs were applied to the 11 waste sites evaluated:

- Two waste sites were sampled using a focused sampling design.
- Seven waste sites were sampled using a statistical sampling design.
- Two waste sites were sampled using both a statistical and a focused sampling design.

Waste sites that were not evaluated for depths >4.6 m (15 ft) bgs are not discussed in this section.

Radiological Results. As presented in Table 6-15, the total ELCR is greater than the upper risk threshold of 1×10^{-4} for deep zone material associated with nine remediated waste sites. Risks were not reported for deep zone material for two remediated waste sites because concentrations of radiological COPCs were less than background.

6.2.5.5.2 Casual Recreational User Scenario

PRGs developed for the casual recreational user scenario represent reasonably anticipated future land use. The results of this comparison are used to confirm that cleanup actions protect the reasonably anticipated future land uses that DOE and USFWS anticipate for the River Corridor. The casual recreational user scenario is described in Section 6.2.3.3.2.

For completeness in analysis, risk estimates for each remediated waste site decision unit are provided in Appendix G, which includes all COPCs regardless of their EPC relative to the background values. The risk estimates are provided in Table G-24 through Table G-26 (Appendix G).

Appendix G also provides risk estimates for each remediated waste site decision unit, which include only those COPCs with EPCs greater than background values or that do not have a background value, in Tables G-27 through G-29 (Appendix G). Only these results are discussed in the risk characterization because this information is used for decisions concerning appropriate remedial actions.

Risk estimates were calculated for the shallow vadose zone material and overburden material decision units within a remediated waste site. Risk estimates were not calculated for the deep zone decision units because the direct contact exposure pathway is incomplete (i.e., samples are collected from depths >4.6 m [15 ft] bgs). The results for the casual recreation user scenario are presented in Table G-27 (Appendix G).

Shallow Zone. A total of 52 of the 54 remediated waste site groups are reported with CVP/RSVP data associated with the shallow zone in the 100-K Source OUs. The following sample designs were applied to the 52 remediated waste sites evaluated:

- Fifteen waste sites were sampled using a focused sampling design.
- Twenty-two waste sites were sampled using a statistical sampling design.
- Fifteen waste sites were sampled using both a statistical and a focused sampling design.

Radiological Results. As presented in Table G-28, the potential cumulative ELCR is within the target risk range of 1×10^{-4} to 1×10^{-6} for shallow zone material at 10 remediated waste sites and is less than the lower risk threshold value of 1×10^{-6} from shallow zone material at seven remediated waste sites. Risks were not reported at six remediated waste sites because radiological COPC concentrations were less than background and risks were not reported for 29 remediated waste sites because radiological COPCs were not reported. The following compares the results of the casual recreational user scenario to the residential scenario.

Four remediated waste sites report concentrations of Hanford Site-related COPCs that exceed the upper range of the target risk threshold for the residential scenario (Table 6-11). In comparison, there are no remediated waste sites that report concentrations of Hanford Site-related COPCs greater than the upper range of the target threshold for the casual recreational user scenario.

Nonradiological Results (Direct Contact and Inhalation). As presented in Table G-28 (Appendix G), the total ELCR is $>1\times10^{-6}$ for one shallow zone remediated waste site and is $<1\times10^{-6}$ for shallow zone material from 34 remediated waste sites. Risks were not reported at 15 remediated waste sites because nonradiological carcinogenic COPCs were less than background. Risks were not reported at two remediated waste sites because nonradiological carcinogenic COPCs were not reported.

One remediated waste site reports individual carcinogens greater than the MTCA (WAC 173-340-740) acceptable cancer risk level of 1×10^{-6} (Table 6-12) for unrestricted land use (Resident) and for the casual recreational user-scenario. For both the resident and the casual recreational user scenarios, all of the remediated waste sites are less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-28, the noncancer HI from direct contact and inhalation pathways is <1 at the shallow zone material associated with 48 remediated waste sites. HIs were not reported at three remediated waste sites because nonradiological noncarcinogenic COPCs were less than background and HI was not reported at one remediated waste site because nonradiological noncarcinogenic COPCs were not reported.

Overburden. Ten remediated waste sites are reported with CVP/RSVP data associated with overburden material in the 100-K Source OUs. Overburden material from one waste site was sampled using a focused sampling design and nine were sampled using a statistical sampling design.

Radiological Results. As presented in Table G-29, the potential total ELCR for radiological analytes is less than the lower risk threshold of 1×10^{-6} for overburden material from five remediated waste sites. Risks were not reported for overburden material associated with one remediated waste site because radiological COPC concentrations were less than background and risks were not reported for overburden material associated with four remediated waste sites because radiological COPCs were not reported.

For both the residential and casual recreational user scenarios, there is no overburden material associated with remediated waste sites that report concentrations of Hanford Site-related COPCs that exceed the upper range of the target risk threshold.

Nonradiological Results (Direct Contact and Inhalation). As presented in Table G-29 (Appendix G), the total ELCR is $<1\times10^{-6}$ for overburden material from three remediated waste sites. Risks were not reported for overburden material from five remediated waste sites because nonradiological carcinogenic COPCs were less than background. Risks were not reported for overburden material from two remediated waste sites because nonradiological carcinogenic COPCs were not reported.

For both the residential and casual recreational user scenarios, there is no overburden material associated with remediated waste sites that report individual carcinogens greater than the MTCA (WAC 173-340-740) acceptable cancer risk level of 1×10^{-6} or the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-29, the noncancer HI from direct contact and inhalation pathways is <1 for overburden material associated with seven remediated waste sites. Noncancer hazards were not reported in overburden material from two remediated waste sites because COPC concentrations were less than background. Noncancer hazards were not reported in overburden from one remediated waste site because nonradiological COPCs were not reported.

For both the residential and casual recreational user scenarios, the potential HIs in overburden material associated with remediated waste sites were less than the MTCA HHRA Procedures WAC 173-340-708(5)) target HI of 1.

6.2.6 Uncertainties in the Soil Risk Assessment

The purpose of this soil risk assessment is to determine whether further remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties are associated with sampling and analysis data, sampling design, the EPCs, radiological decay, exposure, toxicity assumptions, and risk characterization.

6.2.6.1 Uncertainties Associated with Sampling and Analysis Data

Sampling and analysis data used in this soil risk assessment represent post-remediation conditions of waste sites with an “interim no action” or an “interim closed out” remediation status. All soil samples were collected in accordance with the requirements stated in the 100 Area SAP (DOE/RL-96-22). These data were collected specifically to determine if the remedial action processes implemented met the remedial action objectives and remedial action goals stated in the interim action RODs listed in Section 6.2.1.1.

Some uncertainties may be associated with the changing requirements associated with the analysis of COCs identified in each record of decision. When remediation initially began in 1996 in the 100 Area, only those analytes identified as COCs were analyzed for and reported by the laboratory. However, as remediation continued, analytical methods improved, guidance was superseded, and reporting requirements changed. Currently, analytes identified as COCs are analyzed using a method-based approach, which requires each laboratory to report the concentration of the COC and all associated target analytes included in the analytical method.

Waste sites associated with the earliest interim action RODs are generally the radioactive high volume liquid effluent sites. In general, verification samples collected to determine if RAGs had been met report fewer analytes than those that have been remediated more recently. The majority of waste sites typically include verification samples analyzed using a method-based approach. These generally include burial grounds and waste sites identified during discovery process. If a method-based approach was used, risks

may be slightly higher but would remain protective of human health. This conclusion is supported by results of the method-based approach used for RI samples collected for this report.

6.2.6.2 Uncertainties Associated with Sampling Design and Exposure Point Concentrations

Calculating UCL for EPCs (OSWER Directive 9285.6-10) recommends using a 95% UCL on the mean for estimating EPCs. Section 6.2.2.2 describes the methodology for calculating the EPCs for detected analytes.

When any of the following conditions were met, the maximum concentration rather than the 95% UCL was selected as the EPC:

- When samples are collected using a focused sampling design
- When a valid 95% UCL cannot be calculated because of a limited number of detections (<3)
- When a valid 95% UCL is greater than the maximum detected concentration and the 97.5% Chebyshev (Mean, Sd) UCL either was not calculated by ProUCL or its value was also greater than the maximum detected concentration or is not calculated

When any of these conditions are met, statistical bias is introduced, resulting in the potential to underestimate or overestimate risk.

There were 491 instances when ProUCL calculated at least one 95% UCL that was greater than the maximum detected concentration. Of these 491 analytes, the following logic was used to select EPCs:

- For 47 analytes, a single UCL was recommended, which was greater than the maximum observed concentration. A Chebyshev (Mean, Sd) UCL was not calculated; therefore, the maximum observed concentration was selected as the EPC.
- For 31 analytes, two recommended UCLs were calculated. One recommended UCL was greater than the maximum observation and the second recommended UCL was less than the maximum observed concentration. A 97.5 Chebyshev (Mean, Sd) UCL was not calculated; therefore, the maximum observed concentration was selected as the EPC.
- For 5 analytes, two recommended UCLs were calculated. One recommended UCL was greater than the maximum observation and the second recommended UCL was based on the 97.5% Chebyshev (Mean, Sd), which was greater than the maximum concentration. Therefore, the maximum observed concentration was selected as the EPC.
- For 408 analytes, a single UCL was recommended, which was greater than the maximum observation. A Chebyshev (Mean, Sd) UCL was also calculated, which was greater than the maximum observed concentration. Therefore, the maximum concentration was selected as the EPC.

Additional information describing instances when ProUCL calculated at least one 95% UCL greater than the maximum detected concentration is in ECF-100KR1-11-0008, which is provided in Appendix G.

In addition, EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. As a result, risks are likely overstated because the EPC does not take credit for the existing clean backfill that covers the remediated waste site.

6.2.6.3 Uncertainties Associated with Sample Design and Depth of Collection

Remediated waste sites 100-K-6, 100-K-46, 100-K-62, 132-KE-1 (shallow 2 decision unit) include soil samples collected from both the shallow zone and the deep zone decision units but all samples were assigned to the shallow zone decision unit for interim closure purposes. The MTCA (WAC 173-340-740(6)(d)) indicates that the point of compliance for human exposure via direct contact be established in the soil throughout the site from the ground surface to 4.6 m (15 ft) bgs. The closeout documentation for these waste sites identified two sample locations (sample numbers B2L2P3/ B2L2P4, and B2L2P6/B2L2P7) in the shallow zone and three sample locations (sample numbers B2L2N4/B2L2N5, B2L2N7/B2L2N8, and B2L2P0/B2L2P1) in the deep zone. Concentrations of carbon-14, cesium-137, and strontium-90 were reported above their residential RBSLs in all three deep zone sample locations; all shallow zone sample results were less than the residential RBSLs for these radioisotopes. As a result, remedial alternatives should be evaluated for these waste sites based on soil samples collected at depths >4.6 m (15 ft) bgs.

6.2.6.4 Adjustments in EPCs Associated with Decay of Radioisotopes

Section 6.2.5.2 provides a summary of the risk estimates by exposure scenario evaluated. The results of the soil risk assessment for the residential scenario identify a group of waste sites, with concentrations of site-related COPCs that result in individual risks greater than the upper regulatory risk threshold value of 1×10^{-4}. Table 6-16 lists the 100-K remediated waste sites, the applicable decision unit, each radioisotope reported for the remediated waste site decision unit, the year the samples were collected, the EPCs, the half-life for each radioisotope, and the year that each radioisotope decays to an activity level less than the residential RBSL (as applicable) (also provided in Appendix G, Table G-30). The table also presents the number of years required for radioisotopic decay to reach a total cumulative ELCR less than the upper risk threshold value of 1×10^{-4}; based on all radionuclides that contribute to the cumulative risk. Deep vadose zone soil samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. Although there is no current exposure pathway for deep contamination, the RBSLs developed for the residential exposure scenario were used as a screening value to identify such sites where ICs may be established to control access to deep contamination.

The elapsed time at which the activity level would decay below the residential RBSL is based on the radioactive decay law using the following equation:

$$\tau = \frac{log\ \frac{A_E}{A_O}}{log\ 0.5} \times \tau_{\frac{1}{2}}$$

where:

A_E = the remaining amount of substance (the PRG) (pCi/g)

A_O = the original amount of substance (the EPC) (pCi/g)

$\tau½$ = the half-life of the substance (years)

τ = the elapsed amount of time (years).

The number of years required for total risk to be $<1\times10^{-4}$ (represented by "t") was back-calculated using the following inequality for a waste site with "n" radionuclides reported:

$$\left(\frac{EPC_1 \times 10^{\left[\frac{t}{t_{\frac{1}{2}}}\times log\left(\frac{1}{2}\right)\right]}}{PRG_1}\right) + \cdots + \left(\frac{EPC_n \times 10^{\left[\frac{t}{t_{\frac{1}{2}}}\times log\left(\frac{1}{2}\right)\right]}}{PRG_n}\right) < 1 \times 10^{-4}$$

The following bullets list the year that radioisotope concentrations in shallow decision units decay to a total cumulative ELCR $<1\times10^{-4}$.

- Carbon-14, cesium-137, and strontium-90 concentrations at 100-K-6, 100-K-46, 100-K-62, 132-KE-1 (shallow 1 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2066.
- Strontium-90 concentrations at 118-K-1 (P1 shallow 4 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2045.
- Cesium-137 and strontium-90 concentrations at 118-K-1 (P1 shallow focused 1 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2032.
- Europium-152 and strontium-90 concentrations at 100-K-56:1 (shallow focused decision unit) decayed to a total cumulative ELCR of $<1.0\times10^{-4}$ in 2007.
- Cesium-137 and strontium-90 concentrations at 116-K-1 (shallow decision unit) decayed to a total cumulative ELCR of $<1.0\times10^{-4}$ in 2007.

The following bullets list the year that radioisotope concentrations in deep zone decision units decay to a total cumulative ELCR is $<1\times10^{-4}$:

- Carbon-14, cesium-137, and strontium-90 concentrations at 100-K-6, 100-K-46, 100-K-62, 132-KE-1 (shallow 2 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 6357. As described in Section 6.2.6.3, six of the ten samples from this decision unit are located in the deep zone (i.e., > 15 ft bgs).
- Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 concentrations at 116-K-2 (deep 1 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2185.
- Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 concentrations at 116-K-2 (deep 2 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2176.
- Cesium-137 and strontium-90 concentrations at 100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71 (deep focused 1 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2135.
- Cesium-137 and strontium-90 concentrations at 118-K-1 (P2 deep focused 1 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2126.
- Cesium-137 and strontium-90 concentrations at 118-K-1 (P2 deep focused 7 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2123.
- Cesium-137, europium-152, and strontium-90 concentrations at 118-K-1 (P2 deep focused 2 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2102.

Table 6-16. Year When 100-K Source OUs Soil Concentrations Decay to Total Risk Less than 1×10^{-4}

Waste Site/ Decision Unit	Collection Date	Analyte Name	Half-Life (Year)	EPC (pCi/g)	Residential Cancer Effects PRG (pCi/g)	Number of Years When EPC = Resident PRG	Maximum Number of Years When EPC = Resident PRG	Number of Years When Total Risk Estimate $<1\times10^{-4}$	Year When Total Risk Estimate $< 1\times10^{-4}$	EPC Year -- Total Risk $<1\times10^{-4}$	Cancer Risk Estimate Year-- Total Risk $<1\times10^{-4}$	% Contribution
100-K-3, 100-K-36, 100-K-79:7_Deep_Focused_1	7/11/2012	Strontium-90	29	6.2	2.3	42	42	42	2054	2.3	1.00E-04	100
Total Radiological Risk Estimate											**1.00E-04**	
100-K-3, 100-K-36, 100-K-79:7_Deep_P4P5	7/11/2012	Strontium-90	29	5.4	2.3	36	36	36	2048	2.3	1.00E-04	100
Total Radiological Risk Estimate											**1.00E-04**	
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Deep_Focused_1	7/19/2012	Cesium-137	30	48	4.4	103	103	123	2135	2.8	6.36E-05	62.93
		Strontium-90	29	16	2.3	82				0.85	3.75E-05	37.0
Total Radiological Risk Estimate											**1.01E-04**	**100**
100-K-46_Deep	4/1/2012	Cesium-137	30	6.2	4.4	15	15	26	2038	3.4	7.73E-05	76.78
		Strontium-90	29	1.0	2.3	-35				0.53	2.34E-05	23.22
Total Radiological Risk Estimate											**1.01E-04**	**100**
100-K-47, 100-K-69, 100-K-70, 100-K-71_Deep	7/19/2012	Europium-152	13	0.68	3.6	-32	9	13	2025	0.3	9.59E-06	9.62
		Strontium-90	29	2.8	2.3	8.6				2.05	9.01E-05	90.38
Total Radiological Risk Estimate											**9.97E-05**	**100**
100-K-55:1_Deep	2/15/2005	Cesium-137	30	3.9	4.4	-6	-6	6	2011	3.4	7.62E-05	76
		Cobalt-60	5.3	0.59	3.1	-13				0.3	8.69E-06	9
		Europium-152	13	0.78	3.6	-29				0.6	1.59E-05	16
Total Radiological Risk Estimate											**1.01E-04**	**100**
100-K-56:1_Deep	6/16/2005	Cesium-137	30	26	4.4	77	77	82	2087	3.9	8.92E-05	88
		Cobalt-60	5.3	1.1	3.1	-8				0.0	7.15E-10	0
		Europium-152	13	31	3.6	42				0.4	1.22E-05	12
		Europium-154	8.8	2.0	4.5	-10				0.0	6.93E-08	0
Total Radiological Risk Estimate											**1.01E-04**	**100**
100-K-56:1_Shallow_Focused	4/6/2005	Europium-152	13	3.1	3.6	-3	-3	2	2007	2.8	7.78E-05	79
		Strontium-90	29	0.50	2.3	-64				0.5	2.07E-05	21
Total Radiological Risk Estimate											**9.86E-05**	**100**
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	4/1/2012	Carbon-14	5730	66	81	-1756	-42	54	2066	65.1	8.03E-05	80
		Cesium-137	30	1.7	4.4	-42				0.5	1.10E-05	11
		Strontium-90	29	0.79	2.3	-44				0.2	9.57E-06	9
Total Radiological Risk Estimate											**1.01E-04**	**100**

Table 6-16. Year When 100-K Source OUs Soil Concentrations Decay to Total Risk Less than 1×10^{-4}

Waste Site/ Decision Unit	Collection Date	Analyte Name	Half-Life (Year)	EPC (pCi/g)	Residential Cancer Effects PRG (pCi/g)	Number of Years When EPC = Resident PRG	Maximum Number of Years When EPC = Resident PRG	Number of Years When Total Risk Estimate $<1\times10^{-4}$	Year When Total Risk Estimate $< 1\times10^{-4}$	EPC Year -- Total Risk $<1\times10^{-4}$	Cancer Risk Estimate Year-- Total Risk $<1\times10^{-4}$	% Contribution
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_2	4/1/2012	Carbon-14	5730	139	81	4464	4464	4345	6357	82.2	1.01E-04	100
		Cesium-137	30	16	4.4	55				0.0	8.87E-48	0
		Strontium-90	29	11	2.3	66				0.0	5.44E-49	0
Total Radiological Risk Estimate											**1.01E-04**	**100**
100-K-63_Shallow_1	9/15/2011	Cobalt-60	5.3	0.023	3.1	-37	-3	2	2013	0.0	5.70E-07	1
		Europium-152	13	0.19	3.6	-56				0.2	4.86E-06	5
		Europium-154	8.8	0.16	4.5	-42				0.1	3.04E-06	3
		Europium-155	5.0	0.20	3.4	-20				0.2	4.45E-06	
		Strontium-90	29	2.1	2.3	-3				2.0	8.78E-05	87%
Total Radiological Risk Estimate											**1.01E-04**	**100**
116-K-1_Deep	11/26/2003	Cesium-137	30	15	4.4	53	56	85	2088	2.1	4.78E-05	48
		Cobalt-60	5.3	2.50	3.1	-2				0.0	1.13E-09	0.001
		Europium-152	13.3	5.5	3.6	8				0.1	1.82E-06	2
		Europium-154	8.8	1.01	4.5	-19						
		Strontium-90	29.1	8.6	2.3	56				1.1	4.98E-05	50
Total Radiological Risk Estimate											**9.95E-05**	**100**
116-K-1_Shallow	11/24/2003	Cesium-137	30	1.2	4.4	-55	-11	4	2007	1.1	2.57E-05	26
		Europium-152	13	0.23	3.6	-53				0.2	5.07E-06	5
		Strontium-90	29	1.7	2.3	-11				1.6	6.94E-05	69
Total Radiological Risk Estimate											**1.00E-04**	**100**
116-K-2_Deep_1	7/26/2005	Cesium-137	30	140	4.4	150	150	180	2185	2.2	4.97E-05	50
		Cobalt-60	5.3	2.79	3.1	-1						
		Europium-152	13	68.6	3.6	57				0.0	1.61E-07	0
		Europium-154	8.8	6.24	4.5	4				0.0	9.65E-11	0
		Strontium-90	29	7.72	2.3	51				0.1	4.65E-06	5
		Nickel-63	96	995	594	71				271	4.57E-05	46
Total Radiological Risk Estimate											**1.00E-04**	**100**
116-K-2_Deep_2	10/24/2005	Cesium-137	30	144	4.4	151	151	171	2176	2.8	6.30E-05	63
		Cobalt-60	5	4.4	3.1	3				0.0	2.44E-14	0
		Europium-152	13	82	3.6	60				0.0	3.08E-07	0
		Europium-154	8.8	12	4.5	13				0.0	3.80E-10	0
		Nickel-63	96	659	594	14				192	3.23E-05	32
		Strontium-90	29	6.7	2.3	45				0.1	5.00E-06	5
Total Radiological Risk Estimate											**1.01E-04**	**100**

Table 6-16. Year When 100-K Source OUs Soil Concentrations Decay to Total Risk Less than 1×10^{-4}

Waste Site/ Decision Unit	Collection Date	Analyte Name	Half-Life (Year)	EPC (pCi/g)	Residential Cancer Effects PRG (pCi/g)	Number of Years When EPC = Resident PRG	Maximum Number of Years When EPC = Resident PRG	Number of Years When Total Risk Estimate $<1\times10^{-4}$	Year When Total Risk Estimate $< 1\times10^{-4}$	EPC Year -- Total Risk $<1\times10^{-4}$	Cancer Risk Estimate Year-- Total Risk $<1\times10^{-4}$	% Contribution
118-K-1_P1_Shallow_4	11/19/2008	Strontium-90	29	5.6	2.3	37	37	37	2045	2.3	1.01E-04	100
Total Radiological Risk Estimate											**1.01E-04**	**100**
118-K-1_P1_Shallow_Focused_1	4/16/2009	Cesium-137	30	3.7	4.4	-7	-6	23	2032	2.2	4.94E-05	49
		Strontium-90	29	2.0	2.3	-6				1.2	5.05E-05	51
Total Radiological Risk Estimate											**9.99E-05**	**100**
118-K-1_P2_Deep_7	11/15/2012	Cesium-137	30	10	4.4	36	49	72	2084	1.9	4.35E-05	42.88
		Strontium-90	29	7.3	2.3	49				1.32	5.79E-05	57.12
Total Radiological Risk Estimate											**1.01E-04**	**100**
118-K-1_P2_Deep_Focused_1	6/11/2012	Cesium-137	30	11	4.4	38	106	114	2126	0.8	1.75E-05	17
		Strontium-90	29	29	2.3	106				1.9	8.27E-05	83
Total Radiological Risk Estimate											**1.00E-04**	**100**
118-K-1_P2_Deep_Focused_2	6/12/2012	Cesium-137	30	4.4	4.4	0	79	90	2102	0.6	1.26E-05	13
		Europium-152	13	37	3.6	44				0.3	9.34E-06	9
		Strontium-90	29	15	2.3	79				1.8	7.71E-05	78
Total Radiological Risk Estimate											**9.90E-05**	**100**
118-K-1_P2_Deep_Focused_7	6/14/2012	Cesium-137	30	36	4.4	91	91	111	2123	2.8	6.35E-05	63
		Strontium-90	29	12	2.3	69				0.8	3.71E-05	37
Total Radiological Risk Estimate											**1.01E-04**	**100**
100-K-201 (19.3-21.8 ft bgs)	9/1/2010	Cesium-137	30	177	4.4	160	160	161	2171	4.3	9.75E-05	95
		Europium-152	13	34	3.6	43				0.0	2.15E-07	0
		Strontium-90	29	5	2.3	37				0.1	5.16E-06	5
Total Radiological Risk Estimate											**1.03E-04**	**100**
100-K-201 (21-23.5 ft bgs)	9/2/2010	Cesium-137	30	105	4.4	137	137	139	2149	4.2	9.62E-05	93
		Europium-152	13	57	3.6	53				0.0	1.13E-06	1
		Europium-154	8.8	5	4.5	1				0.0	1.87E-09	0
		Strontium-90	29	4	2.3	25				0.2	6.62E-06	6
Total Radiological Risk Estimate											**1.04E-04**	**100**
100-K-201 (23.2-25.7 ft bgs)	9/2/2010	Cesium-137	30	131	4.4	147	147	148	2158	4.3	9.74E-05	95
		Europium-152	13	58	3.6	53				0.0	7.14E-07	1
		Europium-154	8.8	5	4.5	1				0.0	9.06E-10	0
		Strontium-90	29	3	2.3	17				0.1	4.36E-06	4
Total Radiological Risk Estimate											**1.03E-04**	**100**

Table 6-16. Year When 100-K Source OUs Soil Concentrations Decay to Total Risk Less than 1×10^{-4}

Waste Site/ Decision Unit	Collection Date	Analyte Name	Half-Life (Year)	EPC (pCi/g)	Residential Cancer Effects PRG (pCi/g)	Number of Years When EPC = Resident PRG	Maximum Number of Years When EPC = Resident PRG	Number of Years When Total Risk Estimate $<1\times10^{-4}$	Year When Total Risk Estimate $< 1\times10^{-4}$	EPC Year -- Total Risk $<1\times10^{-4}$	Cancer Risk Estimate Year-- Total Risk $<1\times10^{-4}$	% Contribution
100-K-222 (24.1-26.5 ft bgs)	8/17/2015	Americium-241	432	3,220	153	1899	98598	98598	100613	0.0	4.14E-72	0
		Plutonium-239/240	24100	3,460	203	98598				203	1.00E-04	100
		Strontium-90	29	36,400	2.3	406				0.0	0.00E+00	0
Total Radiological Risk Estimate											**1.00E-04**	**100**
100-K-222 (26.7-27.7 ft bgs)	8/17/2015	Americium-241	432	550	153	797	34907	34907	36922	0.0	1.70E-28	0
		Plutonium-239/240	24100	554	203	34907				203	1.00E-04	100
		Strontium-90	29	7,140	2.3	338				0.0	0.00E+00	0
Total Radiological Risk Estimate											**1.00E-04**	**100**

bgs = below ground surface
EPC = exposure point concentration
OU = operable unit
PRG = preliminary remediation goal

- Cesium-137, cobalt-60, europium-152 and strontium-90 concentrations at 116-K-1 (deep decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2088.
- Cesium-137, cobalt-60, europium-152, and europium-154 concentrations at 100-K-56:1 (deep decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2087.
- Cesium-137 and strontium-90 concentrations at 118-K-1 (P2 deep 7 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2084.
- Strontium-90 concentrations at 100-K-3, 100-K-36, 100-K-79:7 (deep focused 1 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2054.
- Strontium-90 concentrations at 100-K-3, 100-K-36, 100-K-79:7 (deep P4P5 decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2048.
- Cesium-137 and strontium-90 concentrations at 100-K-46 (deep decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2038.
- Europium-152 and strontium-90 concentrations at 100-K-47, 100-K-69, 100-K-70, 100-K-71 (deep decision unit) decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2025.
- Cesium-137, cobalt-60, and europium-152 concentrations at 100-K-55:1 (deep decision unit) decayed to a total cumulative ELCR of $<1.0\times10^{-4}$ in 2011.

6.2.6.5 Uncertainties Associated with Exposure Assumptions

The exposure assumptions used to develop the RBSLs for each exposure scenario represent an RME. For estimating the RME, 95 percentile values (or upper-bound estimates of national averages) are generally used for exposure assumptions, and exposed populations and exposure scenarios are also selected to represent upper-bound exposures. The intent of the RME, as discussed by the EPA Deputy Administrator and the Risk Assessment Council (Habicht, 1992, "Guidance on Risk Characterization for Risk Managers and Risk Assessors"), is to present risks as a range from central tendency to high-end risk (above the 90th percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable "high-end" segments of the subject population (Habicht, 1992). EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an upper bound of the true risk or hazard.

6.2.6.6 Uncertainties Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty as defined in the risk assessment guide (EPA/540/1-89/002) and in Superfund HHT Risk Assessment Values (Cook, 2003). These sources may include or result from the extrapolation from high to low doses and from animals to humans. This is contingent on the species, gender, age, and strain differences in the uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The human population's variability with respect to diet, environment, activity patterns, and cultural factors are also sources of uncertainty.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are nonthreshold contaminants. However, EPA has recently published revised cancer guidelines EPA/630/P-03/001B, where they have modified their former position of assuming nonthreshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States will be

developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or where the mode of action is not known. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a nonthreshold model.

In most of the world, nonthreshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (TERA, 2011, International Toxicity Estimates for Risk database). Specifically, for genotoxic contaminants, the cancer dose-response model is based on high to low-dose extrapolation and assumes there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses are found in laboratory animals or are extrapolated from occupational or epidemiological studies. Cancer effects observed at low doses are commonly found in environmental exposures. These models are essentially linear at low doses, so no dose is without some risk of cancer. Although this assumes there is no dose without some risk of cancer, there may be a threshold level at low doses.

6.2.6.6.1 Slope Factors for Hexavalent Chromium

The oral reference dose of 0.003 mg/kg day published by IRIS is used to develop the MTCA (WAC 173-340-740) direct contact soil cleanup level for Cr(VI). NJDEP has recently published an oral carcinogenic potency factor of 0.5 $(mg/kg\text{-}day)^{-1}$ (NJDEP, 2009). If the NJDEP value was used to calculate the MTCA (WAC 173-340-740) direct contact soil cleanup level, the cleanup level would decrease from 240 mg/kg to 2.0 mg/kg. The use of the oral reference dose published by IRIS may result in underestimating risk.

6.2.6.6.2 Oral Reference Dose for Total Uranium (Soluble Salts)

The RfD for uranium that is published in IRIS (0.003 mg/kg-day) was used for hazard calculations in this risk assessment. The reference dose value (0.0002 mg/kg-day) published in EPA, 2016, “Considering a Noncancer Oral Reference Dose for Uranium for Superfund Human Health Risk Assessments,” and EPA, 2018, is not published in IRIS and an MCL using this value has not been promulgated. As such, the RfD value of 0.0002 mg/kg-day for total uranium was not used in this risk assessment. Using the IRIS value has the potential to underestimate the noncancer hazard. If the ATSDR oral RfD was used to calculate the WAC 173-340-740 Method B cleanup level for unrestricted land use, the soil cleanup level would decrease from 240 mg/kg to 16 mg/kg. All uranium concentrations at the 100-K Source OUs are <16 mg/kg.

6.2.6.7 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically, resulting in an overestimation or underestimation of risk.

6.2.6.7.1 Uncertainties in Risk Estimates Associated with Remedial Investigation and Limited Field Investigation Soil Data

In addition to the waste site remediation data (CVP/RSVP), three additional sources of data were considered for use in the risk assessment: vadose zone data collected during well installations, vadose zone data collected for the RI to fill data gaps associated with the nature and extent of contamination or associated with understanding the fate and transport of contaminants, and LFI data collected in 1991 and 1992 from the 100-K Source OUs. These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used to calculate EPCs or evaluate risks quantitatively.

However, these data were evaluated qualitatively by comparing concentrations of analytes at each screen interval to RBSLs to determine if the results could be useful for risk management decisions.

Soil data identified as useful for informing risk management decisions include those collected to fill data gaps 2, 3, and 4. Chapter 2, Table 2-1, lists the data gaps and the work conducted per the RI/FS Work Plan (DOE/RL-2008-46-ADD2) for 100-K. In general, the comparison of soil concentrations from RI data to RBSLs are consistent with closeout documentation data (CVP/RSVP) for borehole data collected at previously remediated waste sites. However, use of the LFI data overstates risks because these waste sites have been subsequently remediated under the interim action ROD. A more detailed discussion of the results is provided in Appendix G, and comparison results are shown in Tables G-31 through G-35.

6.3 Groundwater Risk Assessment

EPA guidance provided in Woolford and Reeder, 2009, "Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration," clarifies EPA's policies for determining whether a groundwater remedial action is warranted under CERCLA. In discussing the role of the BRA, Woolford and Reeder, 2009, quotes the preamble to the NCP (40 CFR 300):

> *The results of the baseline risk assessment are used to determine whether remediation is necessary, to help provide justification for performing remedial action, and to assist in determining what exposure pathways need to be remediated.*

Woolford and Reeder, 2009, clarifies when a CERCLA remedial action is appropriate (page 5):

> *A CERCLA remedial action generally is appropriate[7] in various circumstances, including a regulatory standard that helps define protectiveness (e.g., a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded; when the estimated risk calculated in a risk assessment exceeds a noncarcinogenic level for an adverse health effect or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use;[8] the noncarcinogenic hazard index is greater than one (using reasonable maximum exposure assumptions for either the current or reasonably anticipated future land use); or the site contaminants cause adverse environmental impacts.[9] It is important to note that all conditions do not need to be present for action and the conditions may be independent of each other.*

EPA guidance provided in Clay, 1991 "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" describes how to use the BRA to make risk management decisions such as determining whether remedial action under CERCLA Section 104 or Section 106 is necessary. Clay, 1991, describes the following conditions when a CERCLA action is generally warranted:

- The BRA indicates that a cumulative site risk to an individual using RME assumptions for either current or future land use exceeds the 10-4 end of the risk range.
- For groundwater actions, MCLs and nonzero maximum contaminant level goals (MCLGs) will generally be used to gauge whether remedial action is warranted.

[7] See EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*
[8] See Clay, 1991, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions"
[9] See EPA 540-R-97-013

- Chemical-specific standards that define acceptable risk levels also may be used to determine whether an exposure is associated with an unacceptable risk to human health and the environment and whether remedial action is warranted.

As stated in the NCP (40 CFR 300.430(a)(iii)(F), "Remedial Investigation/Feasibility Study and Selection of Remedy"), "It is EPA's expectation to return usable groundwaters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site." To determine if an action is warranted, the tap water (residential) scenario is used to calculate cumulative cancer risks and noncancer hazards. The results of these calculations are presented in this chapter and compared to the 10^{-4} risk threshold for radionuclides, the 10^{-5} risk threshold for hazardous chemicals, and an HI of 1 for noncancer hazards.

Additionally, human health protection was evaluated in Chapter 4 and summarized in Appendix D. The evaluation compared individual groundwater contaminant concentrations, for analytes detected above background and action levels (Table 4-36) within the groundwater OU, to existing federal or state MCLs or nonzero MCLGs. Individual groundwater contaminant concentrations were also compared to MTCA (WAC 173-340-720, "Groundwater Cleanup Standards") risk-based criteria. The results of the tap water (residential) scenario and the results of the analysis performed in Chapter 4 (Appendix D) are used to identify COPCs for which remedial action is warranted.

Aquatic receptor protection was evaluated in Chapter 4 (Appendix D) by comparing groundwater concentrations throughout the OU and at the point of discharge to the AWQC established under Section 304 or Section 303 of the *Clean Water Act of 1972*, as well as Washington State surface water quality standards. The point of compliance for surface water cleanup levels is defined in MTCA (WAC 173-340-730(7)(a), "Surface Water Cleanup Standards") as the point or points at which hazardous substances are released to surface waters of the state. The MTCA (WAC 173-340-730(7)(b)) criteria indicate that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup standards. Although groundwater concentrations were compared to AWQC or state surface water quality standards, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone to determine the potential for impact to aquatic receptors.

In addition to the comparison of groundwater concentrations to surface water quality criteria and standards, the CRC (DOE/RL-2010-117) included an ecological risk assessment that combined both screening and baseline elements. The CRC concluded that nine COECs (aluminum, chromium, Cr(VI), lead, manganese, nickel, nitrate, selenium, and uranium) were within sediment, pore water, island soil, and shoreline sediment near the 100 and 300 areas. Groundwater concentrations from 100-KR4 OU monitoring wells were evaluated to determine if these COECs were at levels that could be of concern to aquatic receptors.

The following analyses are performed to identify COPCs that warrant evaluation of remedial alternatives in the FS:

- Groundwater concentrations are compared to MTCA (WAC 173-340-720) to determine if individual concentrations are greater than cleanup levels based on a target HQ of 1.
- Groundwater concentrations are compared to MTCA (WAC 173-340-720) to determine if individual concentrations are greater than cleanup levels based on a target risk level of 1 in 1,000,000 (1×10^{-6}).
- Individual groundwater measurements are compared to DWSs to identify concentrations greater than these standards (see Chapter 4 and Appendix D for comparison results).

- Cumulative cancer risks and noncancer hazards for chemicals based on the results of the EPA tap water (residential) scenario are compared to MTCA HHRA Procedures (WAC 173-340-708(5)(a)) cumulative cancer threshold of 1×10^{-5} and the noncancer HI threshold of 1 (see Section 6.3.5 for the risk characterization results).

- Cumulative cancer risks for radiological analytes based on the results of the EPA tap water (residential) scenario are compared to the upper end of the NCP (40 CFR 300) risk range (1×10^{-4} to 1×10^{-6}) for cumulative carcinogenic site risk to an individual based on RME to return groundwater to its highest beneficial use (see Section 6.3.5 for the risk characterization results).

- The sum of fractions (SOFs) and a 4 mrem/yr dose equivalent were calculated for beta particle and photon emitters. Current MCLs for beta particle and photon emitters are based on an annual dose equivalent of 4 mrem to the total body or any internal organ (see Section 6.3.5 for the results of this evaluation).

The results presented in Appendix D (evaluation of measured groundwater concentrations) indicate that individual concentrations of seven contaminants in the 100-KR-4 OU exceed action (screening) levels that are listed in Table 4-36. The residential tap water scenario also identifies multiple contaminants in individual monitoring wells that exceed the MTCA HHRA Procedures (WAC 173-340-708(5)(a)) cumulative cancer and noncancer hazard thresholds. The MTCA HHRA Procedures (WAC 173-340-708(5)(a) and (6)(b)) require that cleanup levels be adjusted downward to take into account exposure to multiple hazardous substances or multiple pathways of exposure. This adjustment needs to be made only if, without this adjustment, the HI would exceed 1, or the total ELCR would exceed 1 in 100,000 (1×10^{-5}).

Additionally, several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. DOE has requested that each Tribe provide an exposure scenario that reflects their traditional activities. At this time, the CTUIR (Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways*) and the Yakama Nation (Ridolfi Inc., 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment*) have provided scenarios. A quantitative risk assessment is included for both Tribal use scenarios to evaluate each of the potentially complete groundwater exposure pathways. The results for the Native American Risk Assessment are provided in ECF-100KR4-17-0083, *Native American Risk Assessment for the 100-KR-4 Groundwater Operable Unit* in Appendix G. Appendix G (Section G.5) provides a summary of this evaluation. A quantitative evaluation of human health risk to a resident from exposure to tap water is included for comparison to the Native American Risk Assessment. The results of the tap water risk assessment are provided in ECF-100KR4-17-0082, *Tap Water Risk Assessment for the 100-KR-4 Groundwater Operable Unit* (Appendix G).

6.3.1 Findings of the River Corridor Baseline Risk Assessment

The RCBRA (DOE/RL-2007-21) provides a screening level groundwater risk assessment for the 100-KR-4 Groundwater OU to evaluate potential risks associated with groundwater exposure. The results of the groundwater screening-level risk assessment indicate potential risk above EPA thresholds within the 100-KR-4 Groundwater OU. Noncancer chemical hazard results were also above the EPA's threshold value of 1.

Uncertainties associated with the groundwater data set were identified in the RCBRA (DOE/RL-2007-21). These uncertainties relate to the ability of the groundwater data set collected from 1998 to 2008 to represent current baseline conditions and potential exposure within the groundwater OU. Analytical data used for the screening level assessment were collected to fulfill a variety of state and federal regulations, including RCRA, CERCLA, the *Atomic Energy Act of 1954*, and Section 173 of the

Washington Administrative Code. While the monitoring data can be used for risk assessment purposes, there are uncertainties associated with its use. Specifically, target analytes, sampling frequencies, and method detection limits (or reporting limits) are different between programs because the information is used to meet different requirements.

As a result of the uncertainties identified in the RCBRA (DOE/RL-2007-21), the Integrated Work Plan (DOE/RL-2008-46) added activities to reduce uncertainties, verify conclusions of the HHRA presented in the RCBRA, and ensure that no contaminants were inadvertently overlooked based on the use of the existing data set. Section 3.6.5.1 of the Integrated Work Plan identified the following activities to reduce uncertainties:

- Identify existing and/or install new monitoring wells that are spatially representative of the groundwater. This set of wells will represent locations where a receptor potentially could contact groundwater.
- Conduct multiple rounds of sampling to obtain temporal representation of the unconfined aquifer from influence of river stage. Additional rounds of sampling at spatially representative monitoring wells will represent current groundwater conditions and capture the influence of river fluctuations on COPC concentrations.
- Analyze all spatially representative monitoring wells for a focused list of groundwater COPCs identified for each round of sampling. Analyzing each of the monitoring wells for COPCs will provide a data set that is representative of potential releases to the groundwater.
- Evaluate sample results from characterization activities to support final remedial action decisions for groundwater.

The RCBRA (DOE/RL-2007-21) evaluated exposure to groundwater for three residential scenarios (Subsistence Farmer, CTUIR Resident, and Yakama Resident scenarios). Direct exposure to contaminants in groundwater was evaluated for household uses of groundwater in each of these scenarios, such as drinking and cooking (ingestion) and bathing (dermal absorption). If VOCs were measured in groundwater, indirect exposure by inhalation of VOCs in air may occur while bathing or when using groundwater in the home for other purposes. The inhalation pathway for VOCs associated with household use of groundwater is evaluated for VOCs that are identified as COPCs in groundwater. Additionally, ingestion, inhalation, and dermal exposures to COPCs in groundwater used in a sweat lodge were evaluated in the CTUIR Resident and Yakama Resident scenarios.

The results of the screening level groundwater risk assessment provided in the RCBRA (DOE/RL-2007-21) identified carbon-14, Cr(VI), nitrate, strontium-90, tritium, and uranium in the 100-KR-4 Groundwater OU as the primary contributors to risk through ingestion and dermal contact with groundwater.

6.3.2 Data Analysis

This section describes the sources of data used in the groundwater risk assessment (Section 6.3.2.1), the DQA and data validation process (Section 6.3.2.2), the identification of analytes for 95% UCL calculation (Section 6.3.2.3), and the evaluation process used to identify COPCs in groundwater that could be used as a resource for potential human exposures (Section 6.3.2.4). During this groundwater risk assessment, analytes were evaluated to identify COPCs and to prioritize those estimated to pose an unacceptable risk and warrant evaluation of remedial alternatives in the FS.

6.3.2.1 Sources of Analytical Data Used in the Risk Assessment

This groundwater risk assessment includes groundwater samples collected and analyzed using the methods documented in the following:

- DOE/RL-2008-46-ADD2, 100-K Work Plan
- DOE/RL-2009-41, 100-K SAP
- DOE/RL-2013-29, *Sampling and Analysis Plan for the 100-KR-4 Groundwater Operable Unit Monitoring*

The groundwater data set used for this RI consists of sampling and analysis data from 82 monitoring and extraction wells within the 100-KR-4 Groundwater OU. In total, 79 wells are evaluated individually, and 3 wells (199-K-35, 199-K-195, and 199-K-205) are evaluated collectively. Wells 199-K-35, 199-K-195, and 199-K-205 were sequentially drilled near the 183.1KW Head House area as replacements during the time period evaluated. The analytical data for these wells were combined to represent one well location.

Monitoring wells are evaluated in this section based on the location of the screen placement. In total, 20 monitoring wells are screened at the top of the unconfined aquifer, 20 monitoring wells are screened across the upper unconfined aquifer, three monitoring wells are screened across the lower unconfined aquifer, one monitoring well is screened in the upper and lower unconfined aquifer, nine monitoring wells are screened across the entire aquifer, and two monitoring wells are screened in the uppermost water bearing unit in the RUM. Wells 199-K-35, 199-K-195, and 199-K-205 are considered to be screened across the upper unconfined aquifer. One extraction well is screened across the top of the unconfined aquifer, nine extraction wells are screened across the upper unconfined aquifer, and fourteen extraction wells are screened across the entire aquifer.

The well network represents locations where human receptors could potentially encounter groundwater within the OU. The primary exposure pathway for humans is through groundwater obtained from a residential or community water well, assuming development of the land for future human habitation. Table 6-17 provides a list of the wells included in the BRA. Well 199-K-109A was originally included to define strontium-90 contamination near the KE FSB; however, no samples were collected from this well during the time period evaluated, therefore it is not included in the well dataset. Figure 6-3 shows well locations within the 100-KR-4 OU.

Table 6-17. 100-KR-4 Groundwater OU Monitoring and Extraction Wells by Screening Interval

Monitoring Wells Screened Across Top of the Unconfined Aquifer		
199-K-106A	199-K-140	199-K-29
199-K-107A	199-K-18	199-K-30
199-K-108A	199-K-19	199-K-32A
199-K-110A	199-K-200	199-K-34
199-K-111A	199-K-201	199-K-36
199-K-132	199-K-22	699-73-61
199-K-139	199-K-23	--

Table 6-17. 100-KR-4 Groundwater OU Monitoring and Extraction Wells by Screening Interval

Extraction Well Screened Across Top of the Unconfined Aquifer		
199-K-137	--	--
Monitoring Wells Screened Across Upper Unconfined Aquifer		
199-K-11	199-K-186	199-K-21
199-K-117A	199-K-187	199-K-221
199-K-125A	199-K-188	199-K-222
199-K-138	199-K-191	199-K-31
199-K-142	199-K-194	199-K-37
199-K-173	199-K-20	699-72-73
199-K-183	199-K-204	--
Combined Wells Screened Across Upper Unconfined Aquifer*		
199-K-35	199-K-195	199-K-205
Extraction Wells Screened Across Upper Unconfined Aquifer		
199-K-113A	199-K-144	199-K-148
199-K-114A	199-K-146	199-K-161
199-K-141	199-K-147	199-K-178
Monitoring Wells Screened Across Lower Unconfined Aquifer		
199-K-168	199-K-184	199-K-190
Monitoring Well Screened Across Upper and Lower Unconfined Aquifer		
199-K-193	--	--
Monitoring Wells Screened Across Entire Aquifer		
199-K-151	199-K-189	199-K-207
199-K-157	199-K-202	199-K-209
199-K-185	199-K-203	199-K-223
Extraction Wells Screened Across Entire Aquifer		
199-K-116A	199-K-154	199-K-182
199-K-120A	199-K-163	199-K-208
199-K-145	199-K-165	199-K-210
199-K-152	199-K-166	199-K-224
199-K-153	199-K-171	--

Table 6-17. 100-KR-4 Groundwater OU Monitoring and Extraction Wells by Screening Interval

Monitoring Wells Screened Across Ringold Upper Mud		
199-K-192	199-K-32B	--

*Wells 199-K-35, 199-K-195, and 199-K-205 were sequentially installed near the 183.1KW Headhouse as replacements for each other during the time period evaluated. The datasets from these wells were combined to calculate a single set of EPCs.

EPC = exposure point concentration
OU = operable unit

The data set contains the analytical results from groundwater samples collected during the 8-year period from October 2009 through April 2017. The data set used is consistent with the evaluation presented in Chapter 4, Appendix D and is considered representative of current groundwater conditions. The data set includes the Integrated Work Plan representative spatial and temporal samples collected between October 22, 2009, and June 30, 2010, and routine groundwater samples collected to monitor P&T operations and known groundwater contamination. Routine groundwater sample and analysis activities for this data set were performed in accordance with the requirements of documents listed in Table 2-4 of DOE/RL-2013-33, *Remedial Design/Remedial Action Work Plan for the 100-KR-4 Groundwater Operable Unit Interim Action*, which have been consolidated and superseded by DOE/RL-2013-29, *Sampling and Analysis Plan for the 100-KR-4 Groundwater Operable Unit Monitoring*. Samples were collected in accordance with DOE/RL-2013-36, *100-KR-4 Groundwater Operable Unit Well Installation Sampling and Analysis Plan*, and the subsequent addendums.

Samples are generally collected to target specific times of the year to capture the temporal fluctuations of river stage. For the 100-KR-4 OU, routine groundwater monitoring samples are collected to target high, low and transitional river stages.

6.3.2.2 Data Quality Assessment and Data Validation

All sampling and analysis data reside in the HEIS database. To support the use of the data in the RI, the data has been validated through several DQAs. Samples collected in support of the Integrated Work Plan are included in the DQA located in Appendix D. For routine groundwater monitoring, a DQA is performed on an annual basis and is documented in the annual Hanford Site groundwater monitoring report (e.g., DOE/RL-2016-67). DQAs have also been performed on samples collected in support of DOE/RL-2013-36, and the subsequent addendums. The results of these DQAs are documented in:

- SGW-60149 – *Report for Soil Borings and Well installations in the UPR-100-K-1 and 116-KE-3 Waste Sites*
- SGW-61212 – *Data Quality Assessment for 100-KR-4 Groundwater Operable Unit Wells Installed in Calendar Year 2014 and 2015*
- SGW-61544 - *Data Quality Assessment for 100-KR-4 Groundwater Operable Unit Wells Installed in Calendar Year 2014 and 2016.*

The objective of the DQAs was to determine whether the data can support the BRA and the selection of remedial alternatives for the 100-KR-4 OU. The DQA process follows general DQA guidelines established in EPA/240/B-06/002, *Data Quality Assessment: A Reviewer's Guide* (EPA QA/G-9R), and EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners* (EPA QA-G9S).

Conclusions of the DQA determined that the groundwater data are the right type and of sufficient quality and quantity to support the BRA and selection of remedial alternatives.

6.3.2.2.1 Analytical Data Processing

The groundwater data set used for the groundwater BRA includes the analytical results from samples collected from 82 monitoring or extraction wells. In total, 79 wells are evaluated individually, and 3 wells (199-K-35, 199-K-195, and 199-K-205) are evaluated collectively as described in Section 6.3.2.1. Table 6-17 list the wells based on the location of the screen placement. Figure 6-4 shows the locations of the wells included in the BRA.

Using the validated data set described in Section 6.3.2.2, the analytical data set was processed to obtain a single set of results per sampling location and time of collection.

The data set contained a total of 68,771 records and 297 analytes prior to analytical data processing. After analytical data processing and reduction (as described in the following sections), the data set used for computation of EPCs contained 35,310 records and 65 analytes. The data processing steps and the numbers of records associated with each step are presented in Figure 6-4. The pre-processed data set included the following types of information:

- Data qualification and data validation flags, including rejected results and tentatively identified compounds (TICs)
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

The analytical data were processed using the steps described in the following discussion and, thus, identify one set of results per sampling location and date of sample collection. Descriptions of the data processing steps follow.

Sample Results. Analytical results from unfiltered samples are used in identifying COPCs; the results from filtered samples that may have been collected in support of other monitoring or compliance programs are not included in the dataset. Unfiltered sample results represent total concentrations of the analytes, while filtered sample results represent only dissolved concentrations. Use of filtered sampling results might lead to underestimation of chemical and radiological concentrations (e.g., in water from an unfiltered tap).

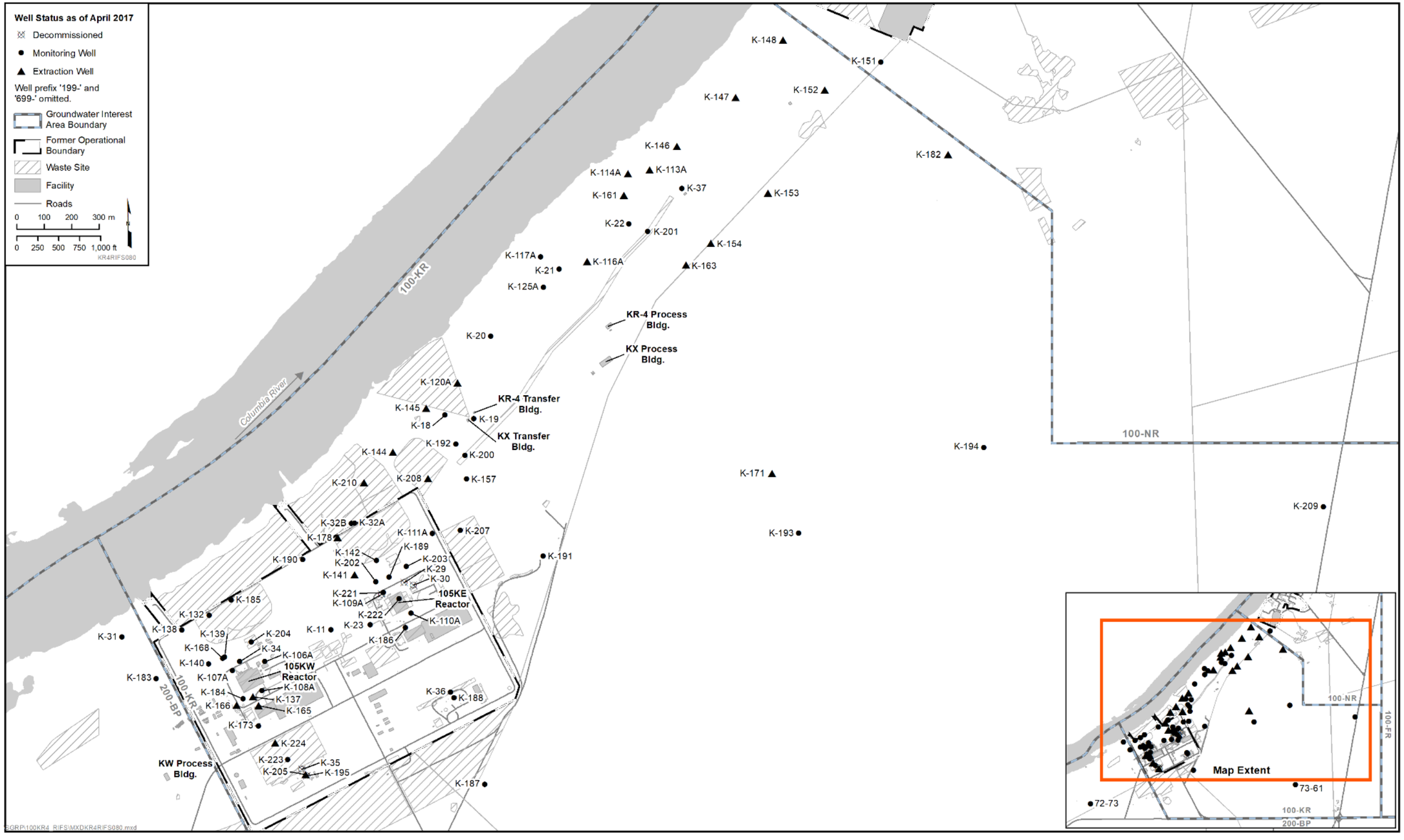

Figure 6-3. Groundwater Well Locations within the 100-KR-4 Groundwater OU

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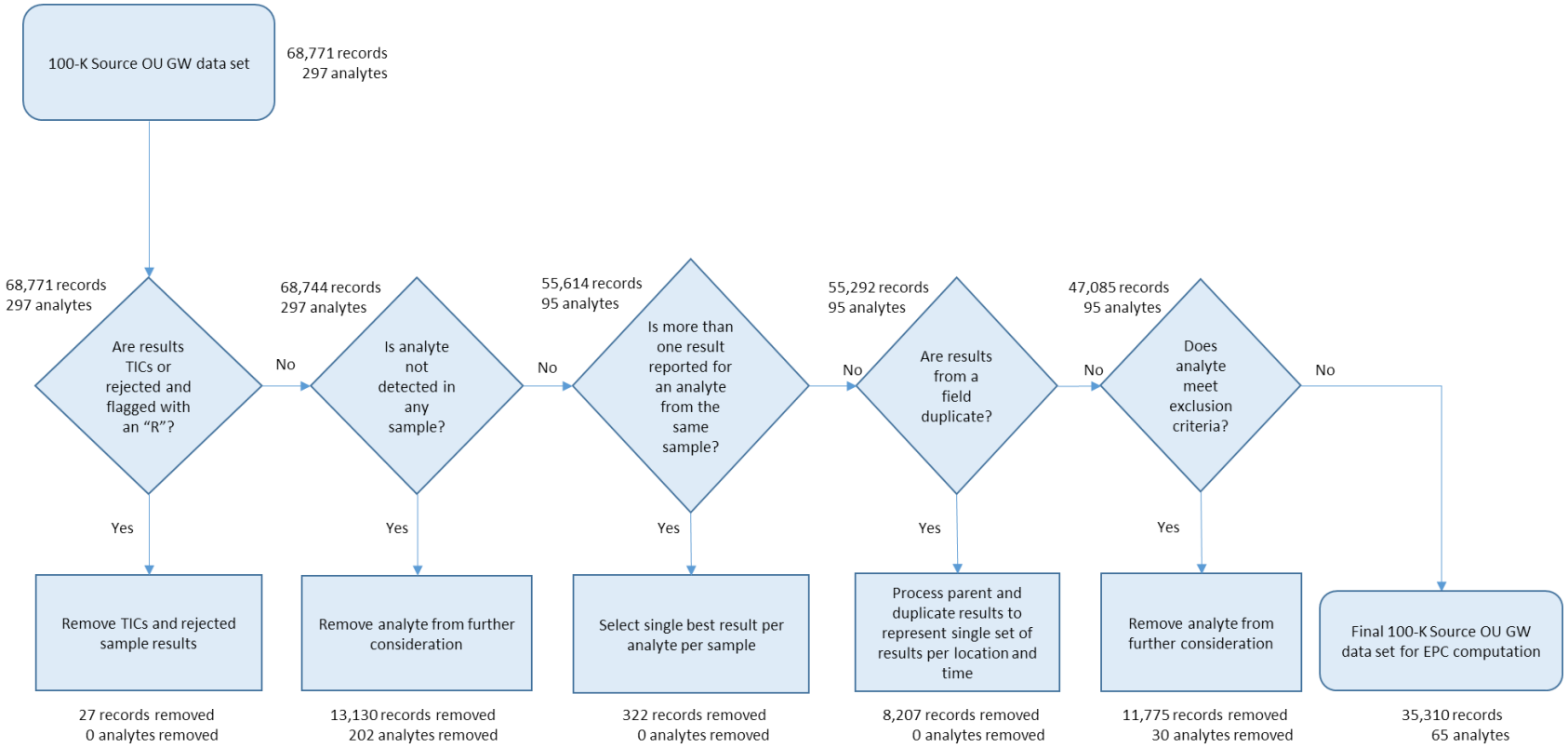

Figure 6-4. Data Processing and Reduction Steps and Identification of Analytes for 95% UCL Calculation for the 100-KR-4 Groundwater OU Data Set

The risk assessment guide (EPA/540/1-89/002), addresses this issue in providing guidance on estimating exposure concentrations in groundwater:

> *While filtration of ground-water samples provides useful information for understanding chemical transport within an aquifer, the use of filtered samples for estimating exposure is very controversial, because these data may underestimate chemical concentrations in water from an unfiltered tap. Therefore, data from unfiltered samples should be used to estimate exposure concentrations.*

Note that the filtered metal results are included in the dataset used for comparison of groundwater concentrations to state surface water quality standards and federal AWQC used to determine if filtered concentrations could impact aquatic receptors (Chapter 4, Appendix D).

Laboratory Flags and Data Validation or Review Qualifiers. Analytical data are received from the laboratory with data qualification flags. Tentatively identified compounds are also flagged by the laboratory. Validation and review qualifiers are assigned during the data validation and review process.

The following rules determine how flagged and/or qualified sample results are used to calculate EPCs.

- Sample results flagged with a "U" data qualifier or combinations of qualifiers that include a "U," such as a "UJ," are considered nondetected results.
- Sample results without a "U" data qualifier, including results with no data qualifier or with a "J" data qualifier, are considered detected concentrations.
- Sample results identified as a "TIC" by the reporting laboratory are not used in the EPC computations.
- Sample results that are rejected and flagged with an "R" validation or review qualifier are not used in the EPC calculations.

where:

U = Analyzed for but not detected above limiting criteria

J = Estimated value

R = Do not use. Further review indicates the result is not valid.

Identify Nondetected Analytes. Chemicals and radionuclides that have been analyzed for but not detected in any of the samples from the 100-KR-4 Groundwater OU (collected from appropriate locations with adequate detection limits) were eliminated. All analytes detected at least once were carried forward to the next step.

In total, 202 analytes were not detected in samples from the 100-KR-4 OU. These analytes are listed in Appendix G (Table G-57) with the sampling dates and both minimum and maximum detection limits.

Analytes Reported by Numerous Analytical Methods. Often analytes are reported by more than one analytical method. Therefore, multiple results for an analyte at the same location and sample date are possible. Because multiple sets of analytical results cannot be used to quantify risk (i.e., this would result in multiple counting of a chemical), the set of data that best represents the actual concentration are retained. The results are processed to select the method that provides the most reliable results. Considerations for determining data to be retained include method-associated sample size, detection frequency, and detection limits. The most conservative (i.e., health protective) use of these types of data is

the goal. Larger sample size, higher detection frequencies, and lower detection limits are given higher priority for method selection.

For example, lead may be analyzed using EPA Method 200.8 (EPA-600/R-94/111), with an EQL of 2 µg/L, or EPA Method 6010 in SW-846, with an EQL of 50 µg/L. For a sample with lead concentrations reported using both methods, the result reported by EPA Method 200.8 (EPA-600/R-94/111) is selected over EPA Method 6010 (SW-846) because of the more sensitive detection limit.

Field Duplicate Results. Field duplicates samples are collected in the field and analyzed by the laboratory as unique samples. The parent sample and field duplicate sample are collected from the same location (i.e., monitoring well) on the same date, resulting in more than one sample per location and date. The following criteria are used to reduce multiple sample results for an individual location/date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

6.3.2.3 Identification of Analytes for 95 Percent UCL Calculation

After extracting and processing the data set, the data set is further reduced by identifying a subset of analytes (COPCs) that are processed through ProUCL to calculate UCLs (described in Section 6.3.3.4) and then included in the risk characterization step of the risk assessment (Section 6.3.5). Analytes that meet exclusion criteria are not carried forward for the statistical calculations and EPC selection. The number of records associated with excluded analytes is presented in Figure 6-4.

6.3.2.3.1 Apply Exclusion Criteria

To identify analytes for UCL calculation, certain exclusion criteria are applied. Analytes that met one or more of the exclusion criteria were eliminated. The eliminated analytes are listed in Appendix G (Table G-58). Analytes that did not meet any of the exclusion criteria were carried forward to the statistical calculations. The exclusion criteria include the following:

- Naturally occurring radionuclides associated with background radiation
- Radionuclides that have half-lives of <3 years and daughter products are not significant risk contributors
- Essential nutrients (minerals)
- Analytes without known toxicity information

One naturally occurring radionuclide (potassium-40) associated with background radiation was measured in groundwater from the 100-KR-4 OU and was eliminated. Potassium-40 was detected in 36 of 635 groundwater samples collected (5.7% frequency).

Radioisotopes with half-lives ≤3 years and daughter products are not significant risk contributors are eliminated from further consideration because only a small fraction of their original activity remains after 30 years of decay since operations have ceased. One radioisotope met this exclusion criterion (cesium-134). Cesium-134 was detected in one of 635 groundwater samples collected (0.16% frequency).

Essential nutrients are those analytes considered essential for human nutrition. The essential nutrients calcium, magnesium, potassium, and sodium were detected in samples in the 100-KR-4 OU but are excluded from further consideration.

Analytes without known toxicity information were eliminated further from consideration for UCL calculations. Because toxicological information is not available, 18 analytes were eliminated from further consideration.

6.3.2.4 Evaluation Processes for Contaminant of Potential Concern Identification

The identification of groundwater COPCs that warrants evaluation of remedial alternatives in the FS for the 100-KR-4 OU is a three-step process. Analytical measurements from groundwater data collected over the past 8 years were evaluated using the following strategy:

- Compare individual measurements from the 8-year data set to action levels (provided in Chapter 4, Appendix D, Section D.1.1, Tables D-2 and D-3) to identify COPCs throughout the 100-KR-4 OU (Figure 6-5). This analysis was performed (as discussed in Chapter 4, Appendix D) to support the COPC identification process used in this BRA (see step 2 below). The results of this comparison are provided in the summary and conclusions of this chapter (Section 6.5).

- Calculate cumulative ELCR and noncancer hazards based on the EPA residential tap water scenario using EPCs from the 8-year data set (Figure 6-6 and Figure 6-7). The groundwater BRA provides a comprehensive evaluation of cumulative cancer risks and noncancer hazards. The results are used to identify the analytes that are the primary cancer risk and noncancer hazard drivers at each individual well location. The results of this evaluation are provided in Section 6.3.5.4.

- Calculate the SOFs and 4 mrem/yr annual cumulative dose equivalent for beta particle and photon emitters. Current MCLs for beta particle and photon emitters are based on an annual cumulative dose equivalent of 4 mrem to the total body or any internal organ. The results of this evaluation are provided in Section 6.3.5.4.

The first step of this groundwater risk assessment is data evaluation to select the COPCs for protection of human health and the environment. A preliminary COPC evaluation was conducted to support the 100-K Work Plan (DOE/RL-2008-46-ADD2) and the 100-K SAP (DOE/RL-2009-41). The work plan effort evaluated groundwater analytical data from the 100-KR-4 Groundwater OU collected over a 16-year period (1992 to 2008) and resulted in the identification of 34 COPCs, which are listed in Table 6-18.

As described previously in Section 6.3.2.1, sampling data from 82 wells are included in this groundwater risk assessment and they represent locations where human or ecological receptors could potentially encounter groundwater within the OU. The primary exposure pathway for humans is through groundwater obtained from a residential or community water well, assuming development of the land for future human habitation.

The exposure assessment, including the methodology used to calculate EPCs, is discussed in Section 6.3.3, and the toxicity assessment is presented in Section 6.3.4. Section 6.3.5 describes the risk characterization step for the EPA tap water scenario and calculation of cumulative annual dose.

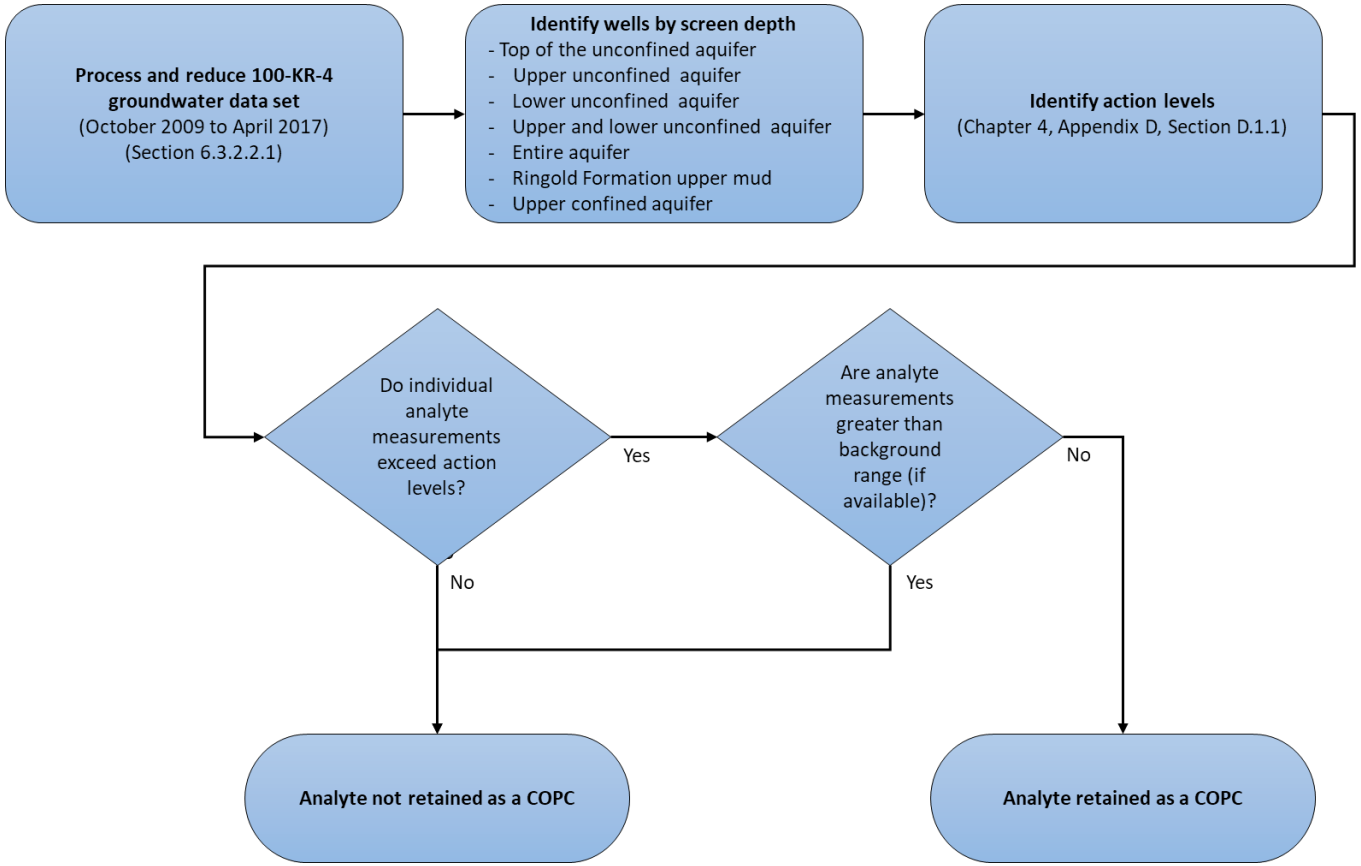

Figure 6-5. Individual Contaminant Evaluation Process for the 100-KR-4 Groundwater OU

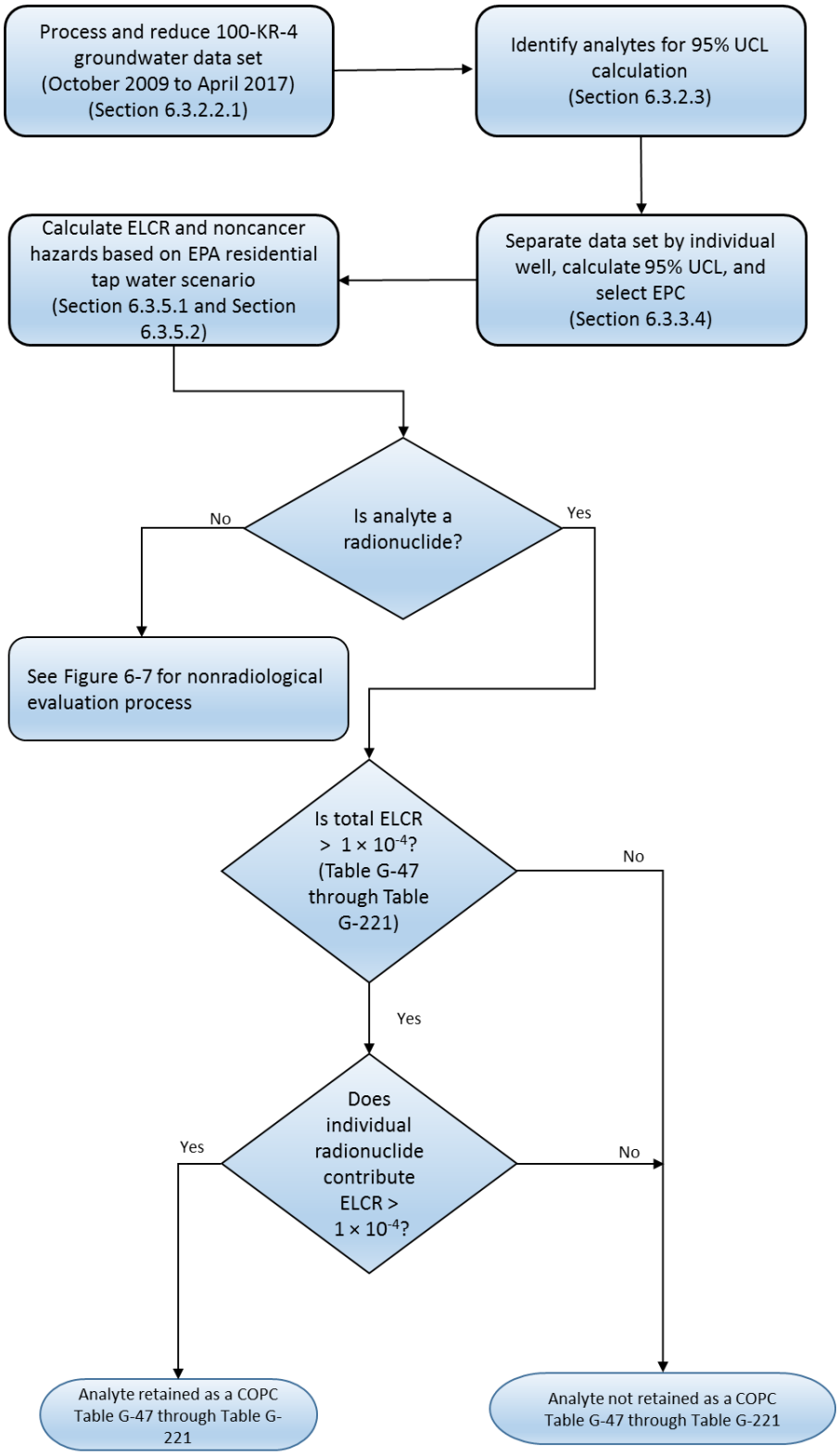

Figure 6-6. EPA Tap Water Scenario Risk Assessment Process for Radionuclides

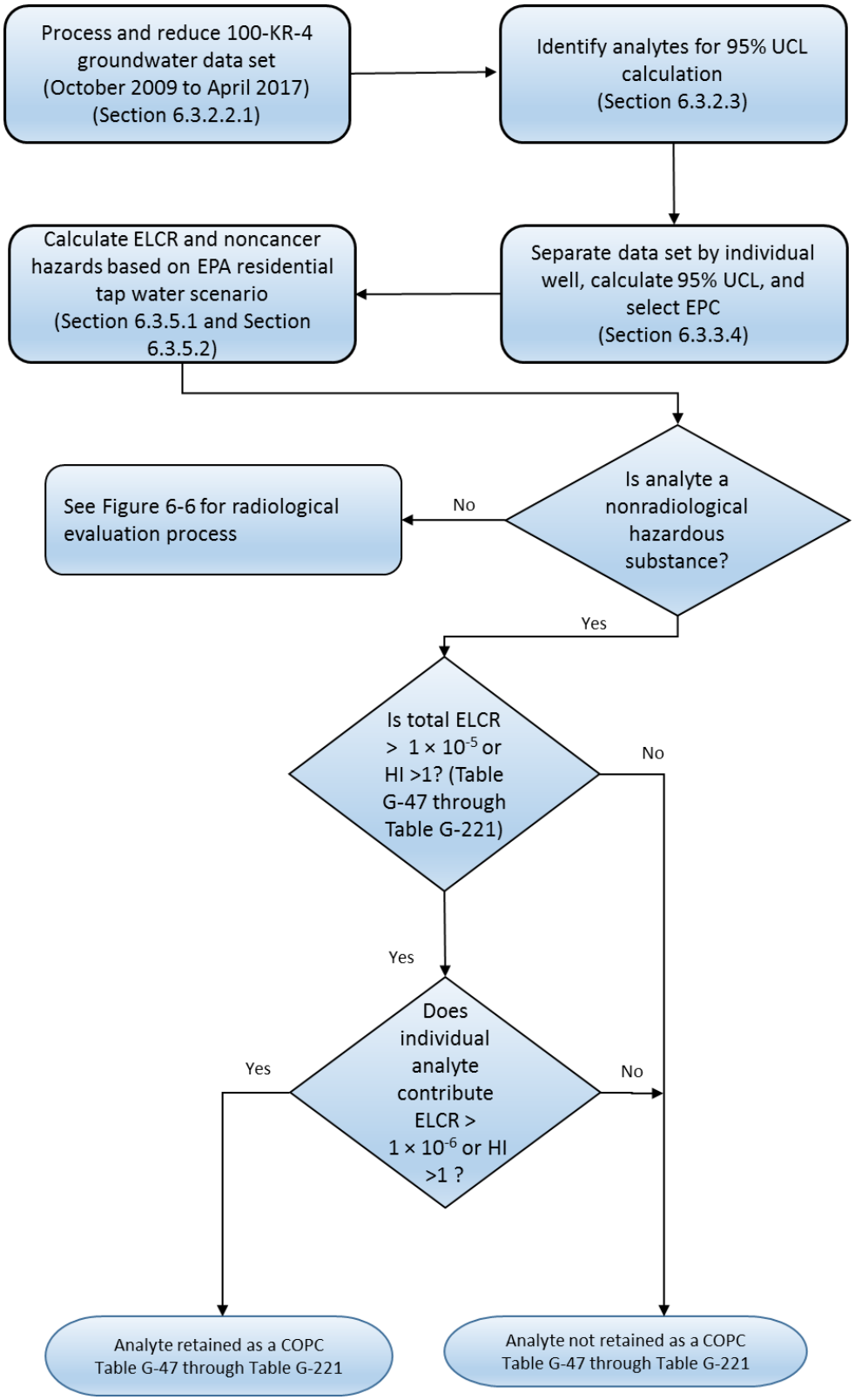

Figure 6-7. EPA Tap Water Scenario Risk Assessment Process for Nonradionuclides

Table 6-18. List of Historical Contaminants of Potential Concern in the 100-KR-4 Groundwater OU

Metals			
Antimony	Arsenic	Barium	Beryllium
Cadmium	Chromium	Cobalt	Copper
Cr(VI)	Lead	Manganese	Mercury
Nickel	Selenium	Thallium	Uranium
Vanadium	Zinc	--	--
Volatile Organic Compounds			
1,1-Dichloroethene	1,1,2-Trichloroethane	Benzene	Carbon tetrachloride
Chloroform	Tetrachloroethene	Trichloroethene	Vinyl chloride
Radiological			
Carbon-14	Tritium	Strontium-90	--
Anions			
Chloride	Fluoride	Nitrate (as N)	Nitrite (as N)
Sulfate	--	--	--

Source: DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*, Table 1-3.

Cr(VI) = hexavalent chromium
OU = operable unit

6.3.3 Exposure Assessment

The exposure assessment component of the risk assessment typically identifies the populations that may be exposed, the routes by which these receptors may become exposed, and the magnitude, frequency, and duration of potential exposures.

An exposure pathway can be described as the physical course that a COPC takes from the point of release to a receptor. The route of exposure is the means by which a COPC enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A contaminant source (or release point)
- A mechanism of chemical release
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete; therefore, it creates no risk or hazard.[10] Figure G-2 (Appendix G) schematically presents the exposure pathway analysis in the form of a human and ecological CEM.

6.3.3.1 Contaminant Sources

The primary sources of contamination in the 100-K Source OU were two water-cooled nuclear reactors (KE and KW) and the structures (e.g., fuel storage basins) and processes (e.g., sodium dichromate process) associated with reactor operations. A discussion of primary and secondary contaminant sources is provided in Sections 4.2 and 5.3 and 5.4.

6.3.3.2 Release Mechanisms and Environmental Transport Media

The primary COPC release mechanisms and transport pathways at 100-K are discussed in Sections 5.3 and 5.4, and include the following:

- Migration of contaminated liquids through the vadose zone column via infiltration, percolation, or leaching to the groundwater
- Direct contact with groundwater containing COPCs (receptor contact with groundwater replaces release and transport)
- Volatilization of COPCs in groundwater from showering or household activities (receptor contact with groundwater replaces release and transport)
- Discharge of groundwater to the Columbia River through upwelling and seeps

6.3.3.3 Potentially Complete Human Exposure Pathways and Receptors

There currently are no complete exposure pathways to human or ecological receptors from groundwater contaminants in excess of DWSs within the 100-KR-4 Groundwater OU. Groundwater within the 100-KR-4 Groundwater OU is not used as a source of potable water. Discharge of contaminated groundwater to the Columbia River does present a potential for exposure of aquatic receptors to groundwater contamination.

Potential human receptors are assumed to be hypothetical future residential groundwater users, including Native American subsistence users. Ecological receptors are limited to aquatic organisms in the Columbia River that may be exposed to contaminants in groundwater that discharges into the river through upwelling and seeps. Groundwater data from aquifer tubes were collected and analyzed as part of this RI; this evaluation is provided in Chapter 4 and Appendix D.

Potential routes of exposure to human receptors from groundwater contaminants in the 100-KR-4 Groundwater OU include the following:

- Ingestion of contaminated water by drinking or in food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminants in groundwater
- External radiation exposure (immersion) from radioactive contaminants in groundwater

[10] With the exception of external irradiation from radionuclides, environmental contaminants must cross a cellular barrier and enter the body of a receptor for exposure to occur.

The EPA tap water (residential) exposure scenario is used to evaluate exposure to humans from the above exposure pathways and routes. A description of the EPA tap water (residential) scenario follows:

The Columbia River, which forms a discharge boundary for groundwater within the 100-KR-4 OU, represents a potentially complete exposure pathway to both human receptors and aquatic ecological receptors.

Aquatic receptor protection is determined by comparing the groundwater and pore water concentrations at the point of discharge to surface water to the water quality criteria established under Sections 304 or 303 of the *Clean Water Act of 1972*, as well as Washington State water quality standards. The point of compliance for surface water cleanup levels is defined in MTCA (WAC 173-340-730(7)(a)) as the point or points at which hazardous substances are released to surface waters of the state. The MTCA criteria (WAC 173-340-730(7)(b)) indicate that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels. A description of the federal and state standards used to evaluate protection of aquatic receptors is provided in Chapter 4, Appendix D.

6.3.3.3.1 EPA Tap Water Scenario (Residential)

As described in Regional Screening Levels (EPA, 2017), the EPA tap water scenario reflects an RME scenario. The EPA tap water scenario is consistent with a residential exposure scenario because it incorporates default residential exposure assumptions. Potentially complete exposure routes for the EPA tap water scenario include exposure of adult and children residents to groundwater used as a drinking water source and include the following:

- Ingestion of drinking water
- Inhalation of volatiles when showering and other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (e.g., washing dishes) – chemicals only
- External exposure to immersion in tap water – radionuclides only

A summary of the exposure assumptions used for the tap water (residential) scenario is provided in Appendix G (Table G-59). A detailed description of the EPA tap water scenario is provided in ECF-100KR4-17-0082.

6.3.3.4 Exposure Point Concentrations

Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (OSWER Directive 9285.6-10), states that, "…an exposure point concentration (EPC) is a conservative estimate of the average chemical concentration in an exposure medium." OSWER Publication 9285.7-08I, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, states that, "…because of the uncertainty associated with estimating the true average concentration at a site, the 95% UCL of the arithmetic mean should be used for this variable." Use of the 95% UCL of the arithmetic mean yields risk estimates that correspond to an RME. Instances where a value different from a UCL is used as the EPC are clearly identified and the reasons and justifications for the departure are provided in this risk assessment.

Calculating UCL for EPCs (OSWER Directive 9285.6-10) further states the following:

> *The EPC is determined for each individual exposure unit within a site. An exposure unit is the area throughout which a receptor moves and encounters an environmental medium for the duration of the exposure. Unless there is site-specific evidence to the contrary, an*

individual receptor is assumed to be equally exposed to media within all portions of the exposure unit over the time frame of the risk assessment.

For this groundwater risk assessment, the terms "exposure unit" and "exposure area" are considered operationally equivalent. Each individual well included in this groundwater BRA is identified as an exposure area.

6.3.3.4.1 Percent Upper Confidence Limit (95 and 97.5) Calculation Methodology

Calculating UCL for EPCs (OSWER Directive 9285.6-10) is the most recent EPA guidance for UCL calculation, and ProUCL 5.1 serves as the companion software package for this guidance. ProUCL 5.1 contains rigorous parametric and nonparametric statistical methods (including bootstrap methods) that can be used on data sets without nondetect results and on data sets with nondetect results (results reported below detection limits). Both ProUCL and Calculating UCL for EPCs (OSWER Directive 9285.6-10) were used to calculate the UCLs for the 100-KR-4. ProUCL 5.1 user guidance is provided in EPA/600/R-07/041, *ProUCL Version 5.1 User Guide*.

6.3.3.4.2 Distributional Methods

Normal and lognormal are the most common data distributions for calculating UCLs. The following provides brief descriptions of recommended UCL calculation methods for these distribution types, as described in Calculating UCL for EPCs (OSWER Directive 9285.6-10).

- ***Normal distribution.*** If the data are normally distributed, then the one-sided (1-α) UCL of the arithmetic mean should be computed using the Student's t-statistic.

- ***Lognormal distribution.*** EPA had recommended use of the Land method to compute the UCL of the arithmetic mean for lognormally distributed data. This method uses the H-statistic (tables for that were published by Land). Land's approach is known to be sensitive to deviations from lognormality, and to commonly yield estimated UCLs substantially larger than appropriate when distributions are not truly lognormal (i.e., if variance or skewness is large).

  EPA also suggests the use of the Chebyshev inequality method to estimate UCLs, which should be appropriate for a variety of distributions as long as the skewness is not very large. The one-sided version of the Chebyshev inequality method is appropriate in this context. It can be applied to the sample mean to obtain a distribution-free estimate of the UCL for the population mean when the population variance or standard deviation is known. In practice, however, these values are not known and must be estimated from data.

  For lognormally distributed data sets, use of the minimum-variance unbiased estimators for the mean and variance is suggested to obtain a UCL of the arithmetic mean. This approach may yield an estimated UCL that is more useful than that obtained from the Land method (when the underlying distribution of concentrations is lognormal). EPA points out that for highly skewed lognormal data with small sample size and large standard deviation, the Chebyshev 97.5% UCL may be more appropriate than the 95% UCL, because the Chebyshev 95% UCL may not provide adequate coverage of the mean. As skewness increases further, the Chebyshev methods are not recommended.

6.3.3.4.3 Nonparametric or Distribution-Free Methods

There are distribution-free approaches to computing UCLs that do not make specific assumptions about the shape of the underlying distribution of concentrations. The following are brief descriptions of recommended methods that are described in Calculating UCL for EPCs (OSWER Directive 9285.6-10).

- **Central limit theorem (adjusted):** If the sample size is sufficiently large, the central limit theorem implies that the mean will be normally distributed, no matter how complex the underlying distribution of concentrations might be. This is the case, even if the underlying distribution is strongly skewed,

has outliers, or is a mixture of different populations, as long as it is stationary (not changing over time), has finite variance, and the samples are collected independently and randomly. However, the theorem does not specify how many samples are sufficient for normality to hold. When sample size is moderate or small, the mean will generally not be normally distributed, and this non-normality is intensified by the skewness of the underlying distribution. An approach suggested in Chen, 1995, "Testing the Mean of Skewed Distributions" accounts for positive skewness. EPA/600/S-97/006, *The Lognormal Distribution in Environmental Applications*, and Calculating UCL for EPCs (OSWER Directive 9285.6-10) refer to this approach the "adjusted central limit theorem" method. They suggest that it is an appropriate alternative to the distribution-specific Land's method, even if the distribution is lognormal, when the standard deviation is <1 and sample size is larger than 100.

- **Bootstrap resampling:** Bootstrap procedures are robust, nonparametric statistical methods that can be used to construct approximate confidence limits for the population mean. In these procedures, repeated samples of size "n" are drawn with replacement from a given set of observations. The process is repeated a large number of times (e.g., thousands), and each time an estimate of the desired unknown parameter (e.g., the sample mean) is computed. Different variations of the bootstrap procedure are available.

- **Jackknife procedure:** Like the bootstrap procedure, the jackknife technique is a robust procedure based on resampling. In this procedure, repeated samples are drawn from a given set of observations by omitting each observation in turn, yielding "n" data sets of size *n-1*. An estimate of the desired unknown parameter (e.g., sample mean) is then computed for each sample. When the standard estimators are used for the mean and standard deviation, this procedure reduces to the UCL based on the Student's t-statistic. However, when other estimators (e.g., minimum-variance unbiased estimators) are used, this jackknife procedure does not reduce to the UCL based on Student's t-statistic.

- **Chebyshev inequality method:** EPA suggests the use of the Chebyshev inequality method to estimate UCLs, which should be appropriate for a variety of distributions, as long as the skewness is not very large. The one-sided version of the Chebyshev inequality method is appropriate in this context. It can be applied to the sample mean to obtain a distribution-free estimate of the UCL for the population mean when the population variance or standard deviation is known. In practice, however, these values are not known and must be estimated from the data.

6.3.3.4.4 Minimum Data Size Requirements

Some decision statistics computed by ProUCL 5.1 require a minimum sample size. The following limitations of ProUCL apply to data sets with nondetects (i.e., censored data sets):

- A UCL is not calculated for data sets with less than three results.
- For data sets of at least three results, a UCL is not calculated when there is only one detected result in the data set.
- For data sets of at least four results, only Kaplan-Meier method-based UCLs are generated when there are only two detected results.
- For data sets of at least five results, most parametric and nonparametric (except for gamma distribution-based) UCLs are generated when there are at least three detected values.
- For data sets of at least five results, all parametric and nonparametric UCLs are generated when there are four or more detected values.

ProUCL generates warning messages for all small (i.e., sample size <8 to 10) data sets processed, informing the user about potential deficiencies in the data set.

6.3.3.4.5 Use of Maximum Detected Concentrations to Estimate the Exposure Point Concentration

The EPC defaults to the maximum detected concentration when any of the following conditions are met:

- A valid 95% UCL cannot be calculated because of a limited number of results (<3)
- A valid 95% UCL is greater than the maximum detected concentration and the 97.5% Chebyshev (Mean, Sd) UCL either was not calculated by ProUCL, or its value was also greater than the maximum detected concentration

ProUCL notes that the EPC term represents the average exposure contracted by a receptor over a long exposure duration, and this term should be estimated by an average value (e.g., the 95% UCL) and not by the maximum observed concentration. Use of maximum observed concentrations results in risk estimates that correspond to maximum possible exposures; such estimates effectively make the assumption that a drinking water supply well will be drilled at the location of the maximum detected concentration all of the time. The following provides additional information regarding when a maximum detected concentration is selected as the EPC in this evaluation.

OSWER Publication 9285.7-08I states that for exposure units with limited amounts of data or extreme variability in measured or modeled data, the calculated UCL can be greater than the highest measured or modeled concentration. In these cases, if additional data cannot practicably be obtained, the highest measured or modeled value can be used as the concentration term. It further states that sampling data have shown that data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration (i.e., there is a large difference between the sample mean and the UCL). ProUCL has minimum size requirements to compute decision statistics. For data sets of at least three results, a UCL is not calculated when there is only one detected result in the data set. For small data sets where a UCL cannot be calculated, the EPC defaults to the maximum detected concentration. ProUCL generates warning messages regarding the potential deficiencies associated with a small data set.

Some of the methods described in this section can produce very high estimates of the UCL. Calculating UCL for EPCs (OSWER Directive 9285.6-10) acknowledges that the Land method can produce extremely high values for the UCL when data exhibit high variance and the sample size is small. OSWER Publication 9285.7-08I recognizes the problem of extremely high UCLs and recommends defaulting to the maximum detected concentration when the calculated UCL exceeds this value. ProUCL, however, suggest that an alternative UCL (i.e., Chebyshev inequality) be selected as an EPC instead of the maximum detected concentration when the recommended UCL exceeds the maximum detected concentration.

In this risk assessment, when the recommended UCL exceeds the maximum detected concentration, a 97.5% Chebyshev (Mean, Sd) UCL is selected as the EPC, if it is available and if its value is less than the maximum detected concentration. If the 97.5% Chebyshev (Mean, Sd) UCL is available but is greater than the maximum detected concentration, the maximum detected concentration is selected as the EPC for risk characterization and the use of the 97.5% Chebyshev (Mean, Sd) UCL as an EPC is evaluated in the risk assessment uncertainty evaluation. When the recommended UCL exceeds the maximum detected concentration and a Chebyshev (Mean, Sd) UCL is not available, the maximum detected concentration is selected as the EPC. ProUCL generates a warning message when the recommended UCL exceeds the maximum observed concentration.

6.3.3.4.6 Develop ProUCL Input Files

Input files that are compatible with ProUCL 5.1 are created using the data sets for each exposure area and are written to a Microsoft Excel® file in *.xlsx format. The *.xlsx files are then imported directly into

® Microsoft Excel is a registered trademark of Microsoft Corporation, Redmond, Washington.

ProUCL 5.1 for calculation of UCLs and summary statistics. Batch processing is implemented to facilitate this process due to the large data sets associated with each exposure area within the 100-KR-4 Groundwater OU. The batch processing steps performed for ProUCL processing and data extraction are as follows.

1. Batch processing of the *.xlsx files through ProUCL 5.1 to generate a raw statistics output file and a UCL output file for each exposure area
2. Batch processing of the raw statistics and UCL output files to extract the following information (if available) into a Microsoft Excel spreadsheet (*.xlsx file):
    a. Well name
    b. Analyte name and Chemical Abstracts Service number
    c. Total number of sample results, total number of detects, and total number of nondetects
    d. Minimum and maximum detection limits for each detected analyte (when available)[11]
    e. Minimum and maximum detected concentrations for each analyte
    f. Mean, median and coefficient of variation for each analyte
    g. Recommended UCL value, UCL basis, and comments and/or warning statements for each analyte

6.3.3.4.7 Selection of Exposure Point Concentrations

The following provides a summary of the decision logic described in the previous sections that is used for selecting EPCs for each detected analyte:

- If a single 95% UCL is recommended and it is less than or equal to the maximum concentration, then the recommended 95% UCL value is selected as the EPC.
- If more than one 95% UCL is recommended and the highest recommended 95% UCL is less than or equal to the maximum detected concentration, then the highest recommended UCL is selected as the EPC.
- If a single 95% UCL is recommended and it is greater than the maximum concentration, or if more than one 95% UCL is recommended and the highest recommended 95% UCL is greater than the maximum concentration, then the following decision logic is applied to the decision statistic:
- If a 97.5% Chebyshev (Mean, Sd) UCL was calculated and its value is less than or equal to the maximum detected concentration, select the 97.5% Chebyshev (Mean, Sd) UCL as the EPC.
- If the 97.5% Chebyshev (Mean, Sd) UCL was calculated and its value is greater than the maximum detected concentration, select the maximum detected concentration as the EPC.
- If a 97.5% Chebyshev (Mean, Sd) UCL was not calculated, select the maximum detected concentration as the EPC.

Selection of the EPC value using the above decision logic is presented in Figure 6-8. A summary of the EPCs for each of the individual wells is provided in Appendix G (Table G-60).

[11] Minimum and maximum detection limits are summarized in the ProUCL output only when a non-detect result is reported.

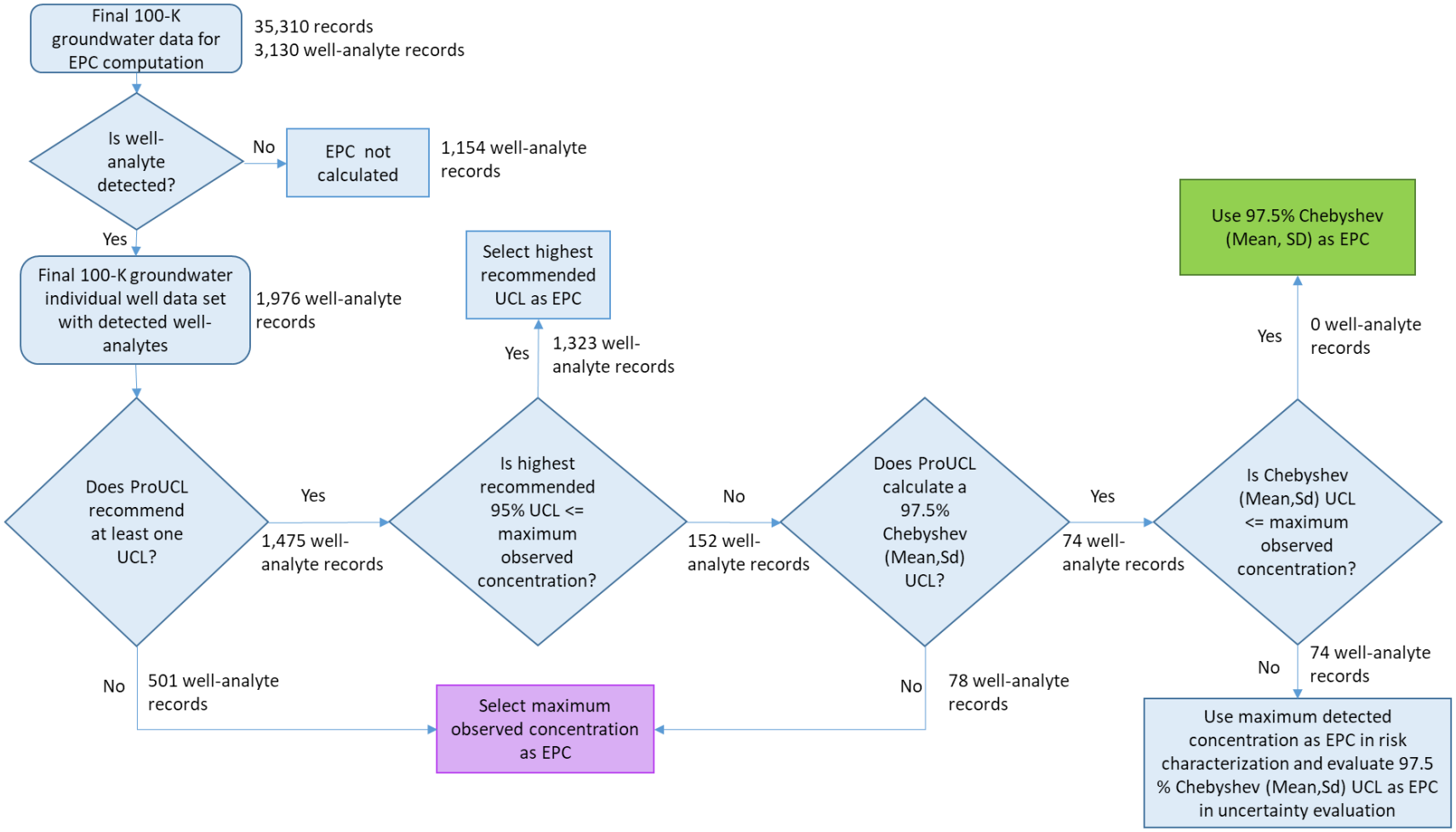

Figure 6-8. EPC Selection Logic

The process used to calculate EPCs for each individual well is documented in ECF-100KR4-17-0081, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit*, which is provided in Appendix G. ECF-100KR4-17-0081 documents the data processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs.

6.3.4 Toxicity Assessment

The toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with contaminant exposure. The toxicity assessment contains two steps (hazard characterization and dose-response evaluation), as discussed in the following subsections. Hazard characterization and the dose-response evaluation process was previously discussed in Section 6.2.4 of this report.

6.3.4.1 Toxicity Values

The sources of toxicity values for human health are the same as those described in Section 6.2.4.2 of this report. The cancer slope factors and the reference dose values used in this groundwater BRA are summarized in Appendix G (Table G-61). Cancer slope factors for radionuclides are also summarized in Appendix G (Table G-61).

6.3.5 Risk Characterization

Risk characterization is completed by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values established in the toxicity assessment) to provide numerical estimates of potential health effects. The quantification approach differs for potential noncancer and cancer effects, as described in the following subsections.

Although the risk assessment produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them. For the purpose of this risk characterization step, the potential for unacceptable human health risk is defined using the following risk thresholds.

- ELCR values are compared to the target range of 10^{-6} to 10^{-4} that is generally used by regulatory agencies.
- MTCA HHRA Procedures (WAC 173-340-708(5)) state that a cumulative cancer risks resulting from multiple hazardous substances should not exceed 1×10^{-5} for unrestricted use. ELCR values within or exceeding this target range require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.
- MTCA HHRA Procedures (WAC 173-340-708(5)) state that an HI (the sum of the ratios of the chemical intake to the RfDs for all COPCs) >1 indicates that some potential exists for adverse noncancer health effects associated with exposure to COPCs.

6.3.5.1 Cancer Risk Estimation Method

To estimate the cancer risks from exposure to an individual carcinogen from the ingestion and dermal contact routes (chemicals only) and inhalation and immersion (radionuclides only) exposure routes considered, the following equation is used:

$$Risk = CDI \times SF$$

where:

Risk = ELCR for an individual chemical or radioisotope (unitless)

CDI = *chronic daily intake averaged over a lifetime* ($\frac{mg}{kg-day}$ *or pCi*)

SF = cancer slope factor ($\frac{risk}{\frac{mg}{kg-day}}$ *or* $\frac{risk}{pCi}$).

To estimate the cancer risks from exposure to an individual carcinogen from the inhalation exposure route (chemicals only), the following equation is used:

$$Risk = CDI \times IUR$$

where:

Risk = ELCR for an individual chemical (unitless)

CDI = chronic daily intake averaged over a lifetime ($\frac{\mu g}{m^3}$)

IUR = inhalation unit risk ($\frac{risk}{\frac{\mu g}{m^3}}$).

Although synergistic or antagonistic interactions might occur between cancer causing contaminants and other chemicals, information is generally lacking in the toxicological literature for quantitative prediction of the effects of these potential interactions. Therefore, cancer risks are treated as additive within an exposure route in this assessment. This is consistent with EPA guidelines on chemical mixtures (EPA/630/P-03/001B). For estimating the cancer risks from exposure to multiple carcinogens from a single exposure routes, the following equation is used.

$$Risk_T = \sum_i^N Risk_i$$

where:

$Risk_T$ = total cancer risk from route of exposure

$Risk_i$ = cancer risk for the ith chemical

N = number of chemicals or number of radionuclides.

6.3.5.2 Noncancer Hazard Estimation Method

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (i.e., its RfD). The ratio of the chronic daily intake divided by RfD is termed the HQ.

When the HQ for a chemical exceeds 1 (i.e., exposure exceeds RfD), a concern exists for potential noncancer health effects. To estimate the HQ from the ingestion and dermal contact (chemicals only) exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{CDI}{RfD}$$

where:

HQ = HQ for individual chemical (unitless)

CDI = chronic daily intake ($\frac{mg}{kg-day}$)

RfD = reference dose ($\frac{mg}{kg-day}$).

To estimate the HQ from the inhalation (chemicals only) exposure route considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{CDI}{RfC}$$

where:

HQ = HQ for individual chemical (unitless)

CDI = chronic daily intake ($\frac{mg}{m^3}$)

RfC = reference concentration ($\frac{mg}{m^3}$).

When the HQ for a chemical exceeds 1 (i.e., exposure exceeds RfD), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple chemicals, an HI approach was used in accordance with EPA/540/1-89/002. This approach assumes that the noncancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not accounted for. The HI may exceed 1, even if all of the individual HQs are <1. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect. The HI is calculated as follows:

$$HI = \sum_{i}^{N} \frac{E_i}{RfD_i}$$

where:

HI = hazard index

E_i = daily intake of the ith chemical ($\frac{mg}{kg-day}$)

RfDi = reference dose of the ith chemical ($\frac{mg}{kg-day}$)

N = number of chemicals.

6.3.5.3 Estimating the Sum of Fractions and 4 mrem/yr Annual Cumulative Dose Equivalent

An annual cumulative dose equivalent of 4 mrem to the total body or any internal organ from beta and photon emitters is considered protective of human health. The SOF is used to determine whether the contribution of each radioisotope is greater than the annual cumulative dose equivalent of 4 mrem to the body or any internal organ. The following equation is used to determine if the 4 mrem standard is exceeded when a mixture of radioisotopes is present:

$$Sum\ of\ \ Fractions = \left(\frac{A\left(\frac{pCi}{L}\right)}{MCL_A\left(\frac{pCi}{L}\right)} + \frac{B\left(\frac{pCi}{L}\right)}{MCL_B\left(\frac{pCi}{L}\right)} + \bullet\bullet\bullet \right)$$

where:

A = The EPC activity concentration of specific beta/photon emitting nuclide A

B = The EPC activity concentration of specific beta/photon emitting nuclide B

MCL_A = The derived single-nuclide beta/photon emitting MCL-equivalent activity concentration for nuclide A

MCL_B = The derived single-nuclide beta/photon emitting MCL-equivalent activity concentration for nuclide B.

The 4 mrem standard is not exceeded if the SOF is <1. The SOF is converted to an annual cumulative dose equivalent by multiplying the SOF by 4 mrem.

6.3.5.4 Risk Characterization Results of the EPA Tap Water Scenario

This section summarizes the results for each of the exposure pathways associated with use of groundwater as drinking water (tap water source). As described in Regional Screening Levels (EPA, 2017), the EPA tap water scenario reflects an RME scenario. The EPA tap water scenario is consistent with a residential exposure scenario because it incorporates default residential exposure assumptions. The results of the tap water risk assessment are provided in ECF-100KR4-17-0082 in Appendix G. Potential routes of exposure to groundwater include ingestion, dermal contact (chemicals only), inhalation of volatiles during showering or from other household activities, and immersion in tap water (radionuclides only).

Results from this analysis are used to provide baseline groundwater conditions for all analytes with available toxicity information. Summaries of the risk estimates by exposure route are provided in the following subsections for each individual well. As discussed in Section 6.3.2.3 and shown in Figure 6-6 and Figure 6-7, all analytes that have reported concentrations and have available toxicity values are included in the calculation of cancer risks and noncancer hazards. The critical effects listed for contaminants that contribute to the noncancer HI were obtained from IRIS, and the critical effect for lithium was obtained from the PPRTVs derived by the EPA Superfund Health Risk Technical Support Center for the EPA Superfund program. Additional details, including analyte-specific cancer risk and noncancer hazard contributions for each well, are provided in Appendix G (Tables G-66 through G-225).

6.3.5.4.1 Monitoring Wells Screened Across Top of the Unconfined Aquifer

At the top of the unconfined aquifer, 20 monitoring wells are screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened at the top of the unconfined aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-62 through G-101).

Well 199-K-106A. Table 6-19 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-106A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-62 and G-63).

Table 6-19. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-106A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	7.2×10^{-5}	Arsenic (ELCR = 7.0×10^{-5}, 0.20%) Carbon-14 (ELCR = 3.2×10^{-2}, 90%) Chloroform (ELCR = 3.3×10^{-6}, 0.01%) Trichloroethene (ELCR = 4.8×10^{-6}, 0.01%) Tritium (ELCR = 3.3×10^{-3}, 9.4%)	5.3	2-Propanol (HQ = 0.90, 12%) Arsenic (HQ = 0.61, 8.3%) Bromomethane (HQ = 0.21, 2.9%) Fluoride (HQ = 0.21, 2.8%) Lithium (HQ = 0.73, 9.9%) Nitrate (HQ = 0.45, 6.2%) Thallium (HQ = 2.5, 34%) Trichloroethene (HQ = 1.2, 16%) Uranium (HQ = 0.14, 1.9%) Vanadium (HQ = 0.13, 1.8%)
	Dermal Contact	7.3×10^{-7}		0.11	
	Inhalation of Volatiles	5.4×10^{-6}		1.9	
	Total Risk	7.9×10^{-5}		Total HI	7.3
Radionuclides	Ingestion	7.3×10^{-4}		--	
	Immersion	1.1×10^{-12}			
	Inhalation of Volatiles	3.5×10^{-2}			
	Total Risk	$\mathbf{3.5\times10^{-2}}$			
Total Cumulative ELCR		$\mathbf{3.5\times10^{-2}}$		--	

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-106A is 3.5×10^{-2}. The total ELCR for nonradiological analytes is 7.9×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.5×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.2×10^{-2}, 90% contribution), chloroform (ELCR = 3.3×10^{-6}, 0.01% contribution), trichloroethene (TCE) (ELCR = 4.8×10^{-6}, 0.01% contribution), and tritium (ELCR = 3.3×10^{-3}, 9.4% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.0×10^{-5}, 0.20% contribution) where the EPC (3.6 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-106A without contribution from arsenic is 8.1×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-106A is 7.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.90, 12% contribution), arsenic (HQ = 0.61, 8.3% contribution), bromomethane (HQ = 0.21, 2.9% contribution), fluoride (HQ = 0.21, 2.8% contribution), lithium (HQ = 0.73, 9.9% contribution), nitrate (HQ = 0.45, 6.2% contribution), thallium (HQ = 2.5, 34% contribution), TCE (HQ = 1.2, 16% contribution), uranium (HQ = 0.14, 1.9% contribution), and vanadium (HQ = 0.13, 1.8% contribution). Contribution to HI is elevated for thallium (HQ = 2.5) where the EPC (0.50 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-106A without contribution from arsenic and thallium is 4.2, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Uranium: initial body weight loss and moderate nephrotoxicity
- Vanadium: decreased hair cysteine

With the exception of 2-propanol, TCE, uranium and lithium, exposure to each of the analytes that contribute to the HI of 4.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for uranium and lithium results in an HI of 0.87, which is less than the target HI of 1. Combining the HQs for 2-propanol and TCE results in a HI of 2.1, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-106A are shown in Table 6-20. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 59 mrem/yr, which is greater than the 4 mrem/yr DWS.

Well 199-K-107A. Table 6-21 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-107A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-64 and G-65).

Table 6-20. Summary of 199-K-106A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	22,900	2,000	11.0
Strontium-90	pCi/L	6.3	8.0	0.79
Tritium	pCi/L	48,073	20,000	2.4
			Sum of Fractions	**15**
			Cumulative Annual Dose (mrem)	**59**

DWS = drinking water standard
EPC = exposure point concentration

Table 6-21. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-107A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	6.1×10^{-5}	Arsenic (ELCR = 5.9×10^{-5}, 5.1%) Carbon-14 (ELCR = 9.6×10^{-4}, 83%) Chloroform (ELCR = 1.8×10^{-6}, 0.16%) Trichloroethene (ELCR = 5.1×10^{-6}, 0.44%)	1.8	2-Propanol (HQ = 0.34, 11%) Arsenic (HQ = 0.51, 16%) Fluoride (HQ = 0.15, 4.7%) Hexavalent chromium (HQ = 0.28, 8.9%) Nitrate (HQ = 0.22, 6.8%) Trichloroethene (HQ = 1.3, 40%) Vanadium (HQ = 0.10, 3.1%)
	Dermal Contact	6.7×10^{-7}		0.16	
	Inhalation of Volatiles	4.3×10^{-6}		1.2	
	Total Risk	**6.6×10^{-5}**		**Total HI**	**3.2**
Radionuclides	Ingestion	5.2×10^{-5}		--	
	Immersion	5.9×10^{-13}			
	Inhalation of Volatiles	1.0×10^{-3}			
	Total Risk	**1.1×10^{-3}**			
Total Cumulative ELCR		**1.2×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-107A is 1.2×10^{-3}. The total ELCR for nonradiological analytes is 6.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.1×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 9.6×10^{-4}, 83% contribution), chloroform (ELCR = 1.8×10^{-6}, 0.16% contribution), and TCE (ELCR = 5.1×10^{-6}, 0.44% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 5.9×10^{-5}, 5.1% contribution) where the EPC (3.0 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-107A without contribution from arsenic is 6.9×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-107A is 3.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.34, 11% contribution), arsenic (HQ = 0.51, 16% contribution), fluoride (HQ = 0.15, 4.7% contribution), Cr(VI) (HQ = 0.28, 8.9% contribution), nitrate (HQ = 0.22, 6.8% contribution), TCE (HQ = 1.3, 40% contribution), and vanadium (HQ = 0.10, 3.1% contribution). The HI for well 199-K-107A without contribution from arsenic is 2.7, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of 2-propanol and TCE, exposure to each of the analytes that contribute to the HI of 2.7 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for 2-propanol and TCE results in an HI of 1.6, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-107A are shown in Table 6-22. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 12 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-22. Summary of 199-K-107A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	687	2,000	0.34
Strontium-90	pCi/L	20	8.0	2.5
Technetium-99	pCi/L	37	900	0.041
Tritium	pCi/L	1,355	20,000	0.068
			Sum of Fractions	**2.9**
			Cumulative Annual Dose (mrem)	**12**

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-108A. Table 6-23 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-108A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-66 and G-67).

The total cumulative ELCR for well 199-K-108A is 1.3×10^{-3}. The total ELCR for nonradiological analytes is 5.8×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.2×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.2×10^{-3}, 92% contribution), chloroform (ELCR = 2.0×10^{-6}, 0.16% contribution), and TCE (ELCR = 4.7×10^{-6}, 0.37% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 5.1×10^{-5}, 4.1% contribution) where the EPC (2.6 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-108A without contribution from arsenic is 6.7×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-23. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-108A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	5.3×10^{-5}	Arsenic (ELCR = 5.1×10^{-5}, 4.1%) Carbon-14 (ELCR = 1.2×10^{-3}, 92%) Chloroform (ELCR = 2.0×10^{-6}, 0.16%) Trichloroethene (ELCR = 4.7×10^{-6}, 0.37%)	3.5	Arsenic (HQ = 0.44, 9.7%) Bromomethane (HQ = 0.15, 3.2%) Fluoride (HQ = 0.24, 5.4%) Lithium (HQ = 0.60, 13%) Nitrate (HQ = 0.34, 7.6%) Thallium (HQ = 0.93, 21%) Trichloroethene (HQ = 1.2, 26%) Uranium (HQ = 0.13, 2.8%)
	Dermal Contact	6.1×10^{-7}		0.11	
	Inhalation of Volatiles	4.3×10^{-6}		0.90	
	Total Risk	5.8×10^{-5}		Total HI	4.5
Radionuclides	Ingestion	2.8×10^{-5}		--	
	Immersion	6.8×10^{-14}			
	Inhalation of Volatiles	1.2×10^{-3}			
	Total Risk	1.2×10^{-3}			
Total Cumulative ELCR		1.3×10^{-3}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-108A is 4.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.44, 9.7% contribution), bromomethane (HQ = 0.15, 3.2% contribution), fluoride (HQ = 0.24, 5.4% contribution), lithium (HQ = 0.60, 13% contribution), nitrate (HQ = 0.34, 7.6% contribution), thallium (HQ = 0.93, 21% contribution), TCE (HQ = 1.2, 26% contribution), and uranium (HQ = 0.13, 2.8% contribution). Contribution to HI is elevated for thallium where the EPC (0.19 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-108A without contribution from arsenic and thallium is 3.2, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Uranium: initial body weight loss and moderate nephrotoxicity
- With the exception of uranium and lithium, exposure to each of the analytes that contribute to the HI of 3.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for uranium and lithium results in an HI of 0.73, which is less than the target HI of 1. TCE reports an individual HQ of 1.2, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-108A are shown in Table 6-24. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.3 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-24. Summary of 199-K-108A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	828	2,000	0.41
Strontium-90	pCi/L	0.93	8	0.12
Technetium-99	pCi/L	23.5	900	0.26
Tritium	pCi/L	552	20,000	0.28
			Sum of Fractions	**0.58**
			Cumulative Annual Dose (mrem)	**2.3**

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-110A. Table 6-25 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-110A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-68 and G-69).

The total cumulative ELCR for well 199-K-110A is 5.5×10^{-5}. The total ELCR for nonradiological analytes is 3.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.9×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

Contribution to ELCR is elevated for arsenic (ELCR = 3.6×10^{-5}, 65% contribution) where the EPC (1.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-110A when contribution from arsenic is not included.

The HI for well 199-K-110A is 1.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.31, 17% contribution), cobalt (HQ = 0.64, 35% contribution), Cr(VI) (HQ = 0.17, 9.3% contribution), nickel (HQ = 0.16, 8.6% contribution), and nitrate (HQ = 0.13, 6.9% contribution). The HI for well 199-K-110A without contribution from arsenic is 1.5, which is greater than the target HI of 1.

Table 6-25. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-110A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.6×10^{-5}	Arsenic (ELCR = 3.6×10^{-5}, 65%)	1.8	Arsenic (HQ = 0.31, 17%) Cobalt (HQ = 0.64, 35%) Hexavalent chromium (HQ = 0.17, 9.3%) Nickel (HQ = 0.16, 8.6%) Nitrate (HQ = 0.13, 6.9%)
	Dermal Contact	1.9×10^{-7}		0.07	
	Inhalation of Volatiles	--		--	
	Total Risk	3.6×10^{-5}		Total HI	1.8
Radionuclides	Ingestion	2.7×10^{-7}		--	
	Immersion	--			
	Inhalation of Volatiles	1.9×10^{-5}			
	Total Risk	1.9×10^{-5}			
Total Cumulative ELCR		5.5×10^{-5}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cobalt: thyroid, decreased iodine uptake
- Cr(VI): nasal septum atrophy
- Nickel: decreased body and organ weights
- Nitrate: early clinical signs of methemoglobinemia

Exposure to each of the analytes that contribute to the HI of 1.5 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-110A are shown in Table 6-26. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.056 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-26. Summary of 199-K-110A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Tritium	pCi/L	279	20,000	0.014
			Sum of Fractions	**0.014**
			Cumulative Annual Dose (mrem)	**0.056**

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-111A. Table 6-27 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-111A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-70 and G-71).

Table 6-27. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-111A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.5×10^{-5}	Arsenic (ELCR = 7.5×10^{-5}, 0.79%) Carbon-14 (ELCR = 3.2×10^{-4}, 3.4%) Chloroform (ELCR = 2.4×10^{-6}, 0.02%) Tritium (ELCR = 9.1×10^{-3}, 96%)	12	Antimony (HQ = 0.10, 0.77%) Arsenic (HQ = 0.65, 4.8%) Fluoride (HQ = 0.19, 1.4%) Hexavalent chromium (HQ = 6.9, 51%) Nitrate (HQ = 0.26, 1.9%) Thallium (HQ = 5.0, 37%) Vanadium (HQ = 0.16, 1.2%)
	Dermal Contact	4.2×10^{-7}		1.8	
	Inhalation of Volatiles	2.1×10^{-6}		< 0.01	
	Total Risk	7.8×10^{-5}		**Total HI**	**13**

Table 6-27. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-111A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Radionuclides	Ingestion	1.4×10^{-4}		--	
	Immersion	4.5×10^{-14}			
	Inhalation of Volatiles	9.3×10^{-3}			
	Total Risk	**9.4×10^{-3}**			
Total Cumulative ELCR		**9.5×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-111A is 9.5×10^{-3}. The total ELCR for nonradiological analytes is 7.8×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.4×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.2×10^{-4}, 3.4% contribution), chloroform (ELCR = 2.4×10^{-6}, 0.02% contribution), and tritium (ELCR = 9.1×10^{-3}, 96% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.5×10^{-5}, 0.79% contribution) where the EPC (3.9 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-111A without contribution from arsenic is 2.4×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-111A is 13, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are antimony (HQ = 0.10, 0.77% contribution), arsenic (HQ = 0.65, 4.8% contribution), fluoride (HQ = 0.19, 1.4% contribution), Cr(VI) (HQ = 6.9, 51% contribution), nitrate (HQ = 0.26, 1.9% contribution), thallium (HQ = 5.0, 37% contribution), and vanadium (HQ = 0.16, 1.2% contribution). Contribution to HI is elevated for thallium (HQ = 5.0) where the EPC (1.0 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-111A without contribution from arsenic and thallium is 7.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Antimony: longevity, blood glucose, and cholesterol
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of nitrate and antimony, exposure to each of the analytes that contribute to the HI of 7.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for nitrate and antimony results in an HI of 0.36, which is less than the

target HI of 1. Cr(VI) reports an individual HQ of 6.9, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-111A are shown in Table 6-28. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 27.3 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-28. Summary of Well 199-K-111A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	230	2,000	0.11
Strontium-90	pCi/L	1	8	0.13
Technetium-99	pCi/L	17	900	0.019
Tritium	pCi/L	131,278	20,000	6.6
			Sum of Fractions	6.8
			Cumulative Annual Dose (mrem)	27.3

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-132. Table 6-29 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-132. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-72 and G-73).

The total cumulative ELCR for well 199-K-132 is 6.4×10^{-3}. The total ELCR for nonradiological analytes is 5.5×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 6.3×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 6.0×10^{-3}, 94% contribution), chloroform (ELCR = 1.8×10^{-6}, 0.03% contribution), TCE (ELCR = 6.3×10^{-6}, 0.10% contribution), and tritium (ELCR = 3.4×10^{-4}, 5.4% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.6×10^{-5}, 0.73% contribution) where the EPC (2.4 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-132 without contribution from arsenic is 8.5×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-132 is 6.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.19, 3.1% contribution), arsenic (HQ = 0.40, 6.3% contribution), cyanide (HQ = 2.9, 45% contribution), fluoride (HQ = 0.13, 2.1% contribution), Cr(VI) (HQ = 0.38, 6.0% contribution), methylene chloride (HQ = 0.13, 2.1% contribution), nitrate (HQ = 0.33, 5.2% contribution), and TCE (HQ = 1.6, 25% contribution). The HI for well 199-K-132 without contribution from arsenic is 5.9, which is greater than the target HI of 1.

Table 6-29. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-132 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	4.9×10^{-5}	Arsenic (ELCR = 4.6×10^{-5}, 0.73%) Carbon-14 (ELCR = 6.0×10^{-3}, 94%) Chloroform (ELCR = 1.8×10^{-6}, 0.03%) Trichloroethene (ELCR = 6.3×10^{-6}, 0.10%) Tritium (ELCR = 3.4×10^{-4}, 5.4%)	2.3	2-Propanol (HQ = 0.19, 3.1%) Arsenic (HQ = 0.40, 6.3%) Cyanide (HQ = 2.9, 45%) Fluoride (HQ = 0.13, 2.1%) Hexavalent chromium (HQ = 0.38, 6.0%) Methylene chloride (HQ = 0.13, 2.1%) Nitrate (HQ = 0.33, 5.2%) Trichloroethene (HQ = 1.6, 25%)
	Dermal Contact	7.0×10^{-7}		0.19	
	Inhalation of Volatiles	4.9×10^{-6}		3.8	
	Total Risk	5.5×10^{-5}		**Total HI**	**6.3**
Radionuclides	**Ingestion**	1.4×10^{-4}		--	
	Immersion	4.9×10^{-13}			
	Inhalation of Volatiles	6.2×10^{-3}			
	Total Risk	**6.3×10^{-3}**			
Total Cumulative ELCR		**6.4×10-3**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Cyanide: thyroid enlargement and altered iodide uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Methylene chloride: hepatic effects (hepatic vacuolation, liver foci)
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity

With the exception of 2-propanol and TCE, exposure to each of the analytes that contribute to the HI of 5.9 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for 2-propanol and TCE results in an HI of 1.8, which is greater than

the target HI of 1. Cyanide reports an individual HQ of 2.9, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-132 are shown in Table 6-30. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 11 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-30. Summary of Well 199-K-132 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	4,270	2,000	2.1
Strontium-90	pCi/L	2.2	8	0.28
Technetium-99	pCi/L	28.5	900	0.032
Tritium	pCi/L	4,957	20,000	0.25
			Sum of Fractions	2.7
			Cumulative Annual Dose (mrem)	11

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-139. Table 6-31 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-139. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-74 and G-75).

The total cumulative ELCR for well 199-K-139 is 2.0×10^{-3}. The total ELCR for nonradiological analytes is 8.9×10^{-6}, which is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.0×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.8×10^{-3}, 90% contribution) and tritium (ELCR = 1.8×10^{-4}, 9.0% contribution). Arsenic was not reported at well 199-K-139.

The HI for well 199-K-139 is 3.6, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are fluoride (HQ = 0.19, 5.1% contribution), Cr(VI) (HQ = 1.2, 32% contribution), nitrate (HQ = 0.22, 6.1% contribution), silver (HQ = 0.11, 2.9% contribution), and TCE (HQ = 1.8, 49% contribution).

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Silver: argyria (dermal)
- TCE: developmental immunotoxicity

Table 6-31. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-139 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	3.1×10^{-6}	Carbon-14 (ELCR = 1.8×10^{-3}, 90%) Tritium, (ELCR = 1.8×10^{-4}, 9.0%)	2.0	Fluoride (HQ = 0.19, 5.1%) Hexavalent chromium (HQ = 1.2, 32%) Nitrate (HQ = 0.22, 6.1%) Silver (HQ = 0.11, 2.9%) Trichloroethene (HQ = 1.8, 49%)
	Dermal Contact	4.9×10^{-7}		0.40	
	Inhalation of Volatiles	5.3×10^{-6}		1.2	
	Total Risk	**8.9×10^{-6}**		**Total HI**	**3.6**
Radionuclides	**Ingestion**	6.3×10^{-5}		--	
	Immersion	4.6×10^{-13}			
	Inhalation of Volatiles	2.0×10^{-3}			
	Total Risk	**2.0×10^{-3}**			
Total Cumulative ELCR		**2.0×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Exposure to each of the analytes that contribute to the HI of 3.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cr(VI) reports an individual HQ of 1.2, which is greater than the target HI of 1. TCE reports an individual HQ of 1.8, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-139 are shown in Table 6-32. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 10 mrem/yr, which is greater than the 4 mrem/yr DWS.

Well 199-K-140. Table 6-33 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-140. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-76 and G-77).

Table 6-32. Summary of Well 199-K-139 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	1,296	2,000	0.65
Strontium-90	pCi/L	14.2	8	1.8
Technetium-99	pCi/L	36.3	900	0.04
Tritium	pCi/L	2,617	20,000	0.13
			Sum of Fractions	2.6
			Cumulative Annual Dose (mrem)	10.4

DWS = drinking water standard
EPC = exposure point concentration

Table 6-33. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-140 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	6.5×10^{-5}	Arsenic (ELCR = 6.3×10^{-5}, 5.9%) Carbon-14 (ELCR = 8.7×10^{-4}, 82%) Chloroform (ELCR = 1.8×10^{-6}, 0.17%) Trichloroethene (ELCR = 6.3×10^{-6}, 0.59%) Tritium (ELCR = 1.2×10^{-4}, 11%)	1.9	2-Propanol (HQ = 0.23, 7.0%) Arsenic (HQ = 0.54, 16%) Fluoride (HQ = 0.14, 4.3%) Hexavalent chromium (HQ = 0.30, 9.1%) Nitrate (HQ = 0.18, 5.4%) Trichloroethene (HQ = 1.6, 47%) Vanadium (HQ = 0.12, 3.6%)
	Dermal Contact	7.8×10^{-7}		0.17	
	Inhalation of Volatiles	4.9×10^{-6}		1.3	
	Total Risk	**7.1×10^{-5}**		**Total HI**	**3.4**
Radionuclides	**Ingestion**	2.3×10^{-5}		--	
	Immersion	7.8×10^{-14}			
	Inhalation of Volatiles	9.7×10^{-4}			
	Total Risk	**9.9×10^{-4}**			
Total Cumulative ELCR		1.1×10^{-3}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-140 is 1.1×10^{-3}. The total ELCR for nonradiological analytes is 7.1×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.9×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 8.7×10^{-4}, 82% contribution), chloroform (ELCR = 1.8×10^{-6}, 0.17% contribution), TCE (ELCR = 6.3×10^{-6}, 0.59% contribution), and tritium (ELCR = 1.2×10^{-4}, 11% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.3×10^{-5}, 5.9% contribution) where the EPC (3.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-140 without contribution from arsenic is 8.1×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-140 is 3.4, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.23, 7.0% contribution), arsenic (HQ = 0.54, 16% contribution), fluoride (HQ = 0.14, 4.3% contribution), Cr(VI) (HQ = 0.30, 9.1% contribution), nitrate (HQ = 0.18, 5.4% contribution), TCE (HQ = 1.6, 47% contribution), and vanadium (HQ = 0.12, 3.6% contribution). The HI for well 199-K-140 without contribution from arsenic is 2.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal weight
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of 2-propanol and TCE, exposure to each of the analytes that contribute to the HI of 2.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for 2-propanol and TCE results in an HI of 1.8, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-140 are shown in Table 6-34. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.5 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-34. Summary of Well 199-K-140 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	623	2,000	0.31
Strontium-90	pCi/L	1.9	8	0.24
Tritium	pCi/L	1,710	20,000	0.086
			Sum of Fractions	0.63
			Cumulative Annual Dose (mrem)	2.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-18. Table 6-35 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-18. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-78 and G-79).

Table 6-35. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-18 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	4.9×10^{-5}	Arsenic (ELCR = 4.8×10^{-5}, 0.45%) Chloroform (ELCR = 9.5×10^{-6}, 0.09%) Tritium (ELCR = 1.1×10^{-2}, 99%)	3.7	Arsenic (HQ = 0.42, 9.3%) Bromomethane (HQ = 0.13, 3.0%) Hexavalent chromium (HQ = 2.5, 57%) Lithium (HQ = 0.63, 14%) Nitrate (HQ = 0.32, 7.2%) Vanadium (HQ = 0.10, 2.3%)
	Dermal Contact	3.3×10^{-7}		0.69	
	Inhalation of Volatiles	8.6×10^{-6}		0.11	
	Total Risk	**5.8×10^{-5}**		**Total HI**	**4.5**
Radionuclides	Ingestion	1.5×10^{-4}		--	
	Immersion	2.3×10^{-14}			
	Inhalation of Volatiles	1.1×10^{-2}			
	Total Risk	**1.1×10^{-2}**			
Total Cumulative ELCR		**1.1×10^{-2}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-18 is 1.1×10^{-2}. The total ELCR for nonradiological analytes is 5.8×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.1×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are chloroform (ELCR = 9.5×10^{-6}, 0.09% contribution) and tritium (ELCR = 1.1×10^{-2}, 99% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.8×10^{-5}, 0.45% contribution) where the EPC (2.5 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-18 without contribution from arsenic is 9.5×10^{-6}, which is equal to the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-18 is 4.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.42, 9.3% contribution), bromomethane (HQ = 0.13, 3.0% contribution), Cr(VI) (HQ = 2.5, 57% contribution), lithium (HQ = 0.63, 14% contribution), nitrate (HQ = 0.32, 7.2% contribution), and vanadium (HQ = 0.10, 2.3% contribution). The HI for well 199-K-18 without contribution from arsenic is 4.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 4.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 2.7, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-18 are shown in Table 6-36. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 32 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-36. Summary of Well 199-K-18 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	27.9	2,000	0.014
Nickel-63	pCi/L	4.2	50	0.085
Technetium-99	pCi/L	55	900	0.061
Tritium	pCi/L	154,000	20,000	7.7
			Sum of Fractions	7.9
			Cumulative Annual Dose (mrem)	31.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-19. Table 6-37 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-19. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-80 and G-81).

The total cumulative ELCR for well 199-K-19 is 3.5×10^{-4}. The total ELCR for nonradiological analytes is 1.9×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.3×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are tritium (ELCR = 2.8×10^{-4}, 80% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.9×10^{-5}, 5.4% contribution) where the EPC (0.98 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-19 when contribution from arsenic is not included.

Table 6-37. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-19 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.9×10^{-5}	Arsenic (ELCR = 1.9×10^{-5}, 5.4%) Tritium (ELCR = 2.8×10^{-4}, 80%)	0.93	--
	Dermal Contact	1.0×10^{-7}		0.06	
	Inhalation of Volatiles	--		--	
	Total Risk	**1.9×10^{-5}**		**Total HI**	**0.98**
Radionuclides	**Ingestion**	2.6×10^{-5}		--	
	Immersion	4.1×10^{-13}			
	Inhalation of Volatiles	3.0×10^{-4}			
	Total Risk	**3.3×10^{-4}**			
Total Cumulative ELCR		**3.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-19 is 0.98, which is less than the MTCA (WAC 173-340-708(5)) target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-19 are shown in Table 6-38. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 8.3 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-38. Summary of Well 199-K-19 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	20.9	2,000	0.01
Strontium-90	pCi/L	14.9	8	1.9
Tritium	pCi/L	4,000	20,000	0.2
			Sum of Fractions	2.1
			Cumulative Annual Dose (mrem)	8.3

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-200. Table 6-39 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-200. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-82 and G-83).

Table 6-39. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-200 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	5.6×10^{-7}	Strontium-90 (ELCR = 2.8×10^{-4}, 54%) Tritium (ELCR = 2.0×10^{-4}, 39%)	0.74	--
	Dermal Contact	4.1×10^{-8}		0.09	
	Inhalation of Volatiles	4.3×10^{-6}		< 0.01	
	Total Risk	**4.9×10^{-6}**		**Total HI**	**0.85**
Radionuclides	**Ingestion**	2.9×10^{-4}		--	
	Immersion	5.5×10^{-12}			
	Inhalation of Volatiles	2.3×10^{-4}			
	Total Risk	**5.2×10^{-4}**			
Total Cumulative ELCR		**5.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-200 is 5.3×10^{-4}. The total ELCR for nonradiological analytes is 4.9×10^{-6}, which is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are strontium-90 (ELCR = 2.8×10^{-4}, 54% contribution) and tritium (ELCR = 2.0×10^{-4}, 39% contribution). Arsenic was not reported at well 199-K-200.

The HI for well 199-K-200 is 0.85, which is less than the MTCA (WAC 173-340-708(5)) target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-200 are shown in Table 6-40. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 101 mrem/yr, which is greater than the 4 mrem/yr DWS.

Well 199-K-201. Table 6-41 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-201. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-84 and G-85).

The total cumulative ELCR for well 199-K-201 is 1.6×10^{-4}. The total ELCR for nonradiological analytes is 4.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.1×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-40. Summary of Well 199-K-200 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	24.6	2,000	0.012
Strontium-90	pCi/L	200	8	25
Tritium	pCi/L	2,940	20,000	0.15
			Sum of Fractions	25.2
			Cumulative Annual Dose (mrem)	101

DWS = drinking water standard
EPC = exposure point concentration

Table 6-41. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-201 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	4.1×10^{-5}	Arsenic (ELCR = 4.1×10^{-5}, 26%) Chloroform (ELCR = 3.7×10^{-6}, 2.4%)	2.4	Arsenic (HQ = 0.35, 12%) Fluoride (HQ = 0.10, 3.3%) Hexavalent chromium (HQ = 2.1, 70%) Nitrate (HQ = 0.22, 7.4%)
	Dermal Contact	2.4×10^{-7}		0.56	
	Inhalation of Volatiles	3.4×10^{-6}		< 0.01	
	Total Risk	**4.4×10^{-5}**		**Total HI**	**3.0**
Radionuclides	**Ingestion**	2.1×10^{-5}		--	
	Immersion	3.7×10^{-13}			
	Inhalation of Volatiles	9.3×10^{-5}			
	Total Risk	**1.1×10^{-4}**			
Total Cumulative ELCR		**1.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributor to the total cumulative ELCR is chloroform (ELCR = 3.7×10^{-6}, 2.4% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.1×10^{-5}, 26% contribution) where the EPC (2.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-201 without contribution from arsenic is 3.8×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-201 is 3.0, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.35, 12% contribution), fluoride (HQ = 0.10, 3.3% contribution), Cr(VI) (HQ = 2.1, 70% contribution), and nitrate (HQ = 0.22, 7.4% contribution). The HI for well 199-K-201 without contribution from arsenic is 2.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia

Exposure to each of the analytes that contribute to the HI of 2.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cr(VI) has an HQ of 2.1, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-201 are shown in Table 6-42. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 6.9 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-42. Summary of Well 199-K-201 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	13	2,000	0.0065
Strontium-90	pCi/L	13.2	8	1.6
Technetium-99	pCi/L	7.4	900	0.0082
Tritium	pCi/L	1,100	20,000	0.055
			Sum of Fractions	1.7
			Cumulative Annual Dose (mrem)	6.9

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-22. Table 6-43 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-22. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-86 and G-87).

The total cumulative ELCR for well 199-K-22 is 1.6×10^{-4}. The total ELCR for nonradiological analytes is 3.6×10^{-6}, which is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.6×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 1.1×10^{-4}, 68% contribution). Arsenic was not reported at well 199-K-22.

The HI for well 199-K-22 is 3.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are bromomethane (HQ = 0.13, 3.9% contribution), Cr(VI) (HQ = 1.7, 52% contribution), lithium (HQ = 0.53, 16% contribution), manganese (HQ = 0.14, 4.4% contribution), nitrate (HQ = 0.19, 5.8% contribution), and vanadium (HQ = 0.16, 4.7% contribution).

Table 6-43. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-22 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.1×10^{-7}	Tritium (ELCR = 1.1×10^{-4}, 68%)	2.7	Bromomethane, (HQ = 0.13, 3.9%) Hexavalent chromium, (HQ = 1.7, 52%) Lithium, (HQ = 0.53, 16%) Manganese, (HQ = 0.14, 4.4%) Nitrate, (HQ = 0.19, 5.8%) Vanadium, (HQ = 0.16, 4.7%)
	Dermal Contact	2.7×10^{-8}		0.50	
	Inhalation of Volatiles	3.2×10^{-6}		0.10	
	Total Risk	**3.6×10^{-6}**		**Total HI**	**3.3**
Radionuclides	Ingestion	2.9×10^{-5}		--	
	Immersion	3.9×10^{-13}			
	Inhalation of Volatiles	1.3×10^{-4}			
	Total Risk	**1.6×10^{-4}**			
Total Cumulative ELCR		**1.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

With the exception of Cr(VI), bromomethane, manganese, and lithium, exposure to each of the analytes that contribute to the HI of 3.3 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 1.9, which is greater than the target HI of 1. Combining the HQs for manganese and lithium results in an HI of 0.67, which is less than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-22 are shown in Table 6-44. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 6.7 mrem/yr, which is greater than the 4 mrem/yr DWS.

Well 199-K-23. Table 6-45 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-23. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-88 and G-89).

Table 6-44. Summary of Well 199-K-22 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	15	2,000	0.0075
Strontium-90	pCi/L	10.8	8	1.4
Technetium-99	pCi/L	220	900	0.24
Tritium	pCi/L	1,570	20,000	0.079
			Sum of Fractions	1.7
			Cumulative Annual Dose (mrem)	6.7

DWS = drinking water standard EPC = exposure point concentration

Table 6-45. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-23 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	6.3×10^{-5}	Arsenic (ELCR = 6.4×10^{-5}, 34%) Carbon-14 (ELCR = 1.1×10^{-4}, 60%)	14	Arsenic (HQ = 0.55, 3.9%) Cobalt (HQ = 0.10, 0.73%) Fluoride (HQ = 0.12, 0.84%) Hexavalent chromium (HQ = 1.3, 8.9%) Manganese (HQ = 0.13, 0.94%) Nitrate (HQ = 0.43, 3.0%) Thallium (HQ = 11, 78%) Uranium (HQ = 0.11, 0.76%)
	Dermal Contact	3.4×10^{-7}		0.42	
	Inhalation of Volatiles	--		--	
	Total Risk	**6.4×10^{-5}**		**Total HI**	**14**
Radionuclides	Ingestion	4.3×10^{-6}		--	
	Immersion	3.8×10^{-14}			
	Inhalation of Volatiles	1.2×10^{-4}			
	Total Risk	**1.2×10^{-4}**			
Total Cumulative ELCR		**1.9×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-23 is 1.9×10^{-4}. The total ELCR for nonradiological analytes is 6.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is carbon-14 (ELCR = 1.1×10^{-4}, 60% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.4×10^{-5}, 34% contribution) where the EPC (3.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-23 when contribution from arsenic is not included.

The HI for well 199-K-23 is 14, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.55, 3.9% contribution), cobalt (HQ = 0.10, 0.73% contribution), fluoride (HQ = 0.12, 0.84% contribution), Cr(VI) (HQ = 1.3, 8.9% contribution), manganese (HQ = 0.13, 0.94% contribution), nitrate (HQ = 0.43, 3.0% contribution), thallium (HQ = 11, 78% contribution), and uranium (HQ = 0.11, 0.76% contribution). Contribution to HI is elevated for thallium (HQ = 11) where the EPC (2.2 µg/L) is greater than the range of background concentrations (minimum, maximum, and 90th percentile) of 0.883, 1.73, and 1.67 µg/L for filtered groundwater samples. Thallium was detected in one of six samples from this well and all filtered thallium sample results were less than the 90th percentile value. The HI for well 199-K-23 without contribution from arsenic and thallium is 2.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia
- Uranium: initial body weight loss and moderate nephrotoxicity

Exposure to each of the analytes that contribute to the HI of 2.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cr(VI) reports an individual HQ of 1.3, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-23 are shown in Table 6-46. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.81 mrem/yr, which is less than the 4 mrem/yr DWS.

Well 199-K-29. Table 6-47 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-29. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-90 and G-91).

The total cumulative ELCR for well 199-K-29 is 1.3×10^{-2}. There were no carcinogenic nonradiological analytes measured; therefore, nonradiological cancer risks are not reported for this well. The total ELCR for radiological analytes is 1.3×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-46. Summary of Well 199-K-23 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	81.1	2,000	0.041
Strontium-90	pCi/L	1.2	8	0.16
Tritium	pCi/L	129	20,000	0.0064
			Sum of Fractions	0.2
			Cumulative Annual Dose (mrem)	0.81

DWS = drinking water standard
EPC = exposure point concentration

Table 6-47. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-29 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	--	Carbon-14 (ELCR = 4.4×10^{-3}, 33%) Tritium (ELCR = 9.0×10^{-3}, 67%)	0.60	--
	Dermal Contact	--		0.01	
	Inhalation of Volatiles	--		--	
	Total Risk	--		**Total HI**	**0.61**
Radionuclides	**Ingestion**	2.2×10^{-4}		--	
	Immersion	1.3×10^{-13}			
	Inhalation of Volatiles	1.3×10^{-2}			
	Total Risk	**1.3×10^{-2}**			
Total Cumulative ELCR		**1.3×10^{-2}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 4.4×10^{-3}, 33% contribution) and tritium (ELCR = 9.0×10^{-3}, 67% contribution). Arsenic was not analyzed for in well 199-K-29.

The HI for well 199-K-29 is 0.61, which is less than the MTCA (WAC 173-340-708(5)) target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-29 are shown in Table 6-48. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 32 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-48. Summary of Well 199-K-29 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	3,120	2,000	1.6
Technetium-99	pCi/L	6.8	900	0.0076
Tritium	pCi/L	130,000	20,000	6.5
			Sum of Fractions	8.1
			Cumulative Annual Dose (mrem)	32.3

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-30. Table 6-49 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-30. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-92 and G-93).

Table 6-49. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-30 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	--	Carbon-14 (ELCR = 5.7×10^{-3}, 23%) Tritium (ELCR = 1.9×10^{-2}, 77%)	0.84	--
	Dermal Contact	--		0.05	
	Inhalation of Volatiles	--		--	
	Total Risk	--		**Total HI**	**0.89**
Radionuclides	**Ingestion**	4.0×10^{-4}		--	
	Immersion	2.0×10^{-10}			
	Inhalation of Volatiles	2.5×10^{-2}			
	Total Risk	**2.5×10^{-2}**			
Total Cumulative ELCR		**2.5×10^{-2}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-30 is 2.5×10^{-2}. There were no carcinogenic nonradiological analytes measured; therefore, nonradiological cancer risks are not reported for this well. The total ELCR for radiological analytes is 2.5×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 5.7×10^{-3}, 23% contribution) and tritium (ELCR = 1.9×10^{-2}, 77% contribution).

The HI for well 199-K-30 is 0.89, which is less than the MTCA (WAC 173-340-708(5)) target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-30 are shown in Table 6-50. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 65 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-50. Summary of Well 199-K-30 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	4,110	2,000	2.1
Cobalt-60	pCi/L	12	100	0.12
Nickel-63	pCi/L	4.4	50	0.088
Tritium	pCi/L	280,000	20,000	14
			Sum of Fractions	16.3
			Cumulative Annual Dose (mrem)	65.1

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-32A. Table 6-51 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-32A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-94 and G-95).

The total cumulative ELCR for well 199-K-32A is 1.1×10^{-3}. The total ELCR for nonradiological analytes is 4.2×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.0×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are bromodichloromethane (ELCR = 1.2×10^{-6}, 0.11% contribution), carbon-14 (ELCR = 3.8×10^{-4}, 36% contribution), chloroform (ELCR = 1.0×10^{-5}, 0.99% contribution), and tritium (ELCR = 6.2×10^{-4}, 59% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 3.0×10^{-5}, 2.9% contribution) where the EPC (1.6 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-32A without contribution from arsenic is 1.2×10^{-5}, which is greater than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-32A is 1.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.26, 14% contribution), bromomethane (HQ = 0.13, 6.8% contribution), Cr(VI) (HQ = 0.29, 15% contribution), lithium (HQ = 0.40, 21% contribution), nitrate (HQ = 0.21, 11% contribution), and silver (HQ = 0.13, 7.0% contribution). The HI for well 199-K-32A without contribution from arsenic is 1.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- Silver: argyria (dermal)

Table 6-51. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-32A – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.1×10^{-5}	Arsenic (ELCR = 3.0×10^{-5}, 2.9%) Bromodichloromethane (ELCR = 1.2×10^{-6}, 0.11%) Carbon-14 (ELCR = 3.8×10^{-4}, 36%) Chloroform (ELCR = 1.0×10^{-5}, 0.99%) Tritium (ELCR = 6.2×10^{-4}, 59%)	1.6	Arsenic (HQ = 0.26, 14%) Bromomethane (HQ = 0.13, 6.8%) Hexavalent chromium (HQ = 0.29, 15%) Lithium (HQ = 0.40, 21%) Nitrate (HQ = 0.21, 11%) Silver (HQ = 0.13, 7.0%)
	Dermal Contact	2.7×10^{-7}		0.10	
	Inhalation of Volatiles	1.1×10^{-5}		0.16	
	Total Risk	**4.2×10^{-5}**		**Total HI**	1.9
Radionuclides	Ingestion	2.1×10^{-5}		--	
	Immersion	9.1×10^{-14}			
	Inhalation of Volatiles	9.9×10^{-4}			
	Total Risk	**1.0×10^{-3}**			
Total Cumulative ELCR		**1.1×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 1.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 0.42, which is less than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-32A are shown in Table 6-52. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 3.8 mrem/yr, which is less than the 4 mrem/yr DWS.

Well 199-K-34. Table 6-53 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-34. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-96 and G-97).

The total cumulative ELCR for well 199-K-34 is 5.7×10^{-3}. The total ELCR for nonradiological analytes is 4.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.7×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-52. Summary of Well 199-K-32A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	275	2,000	0.14
Strontium-90	pCi/L	2.7	8	0.34
Technetium-99	pCi/L	11.5	900	0.013
Tritium	pCi/L	8,990	20,000	0.45
			Sum of Fractions	0.94
			Cumulative Annual Dose (mrem)	3.8

DWS = drinking water standard
EPC = exposure point concentration

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 5.5×10^{-3}, 95% contribution), chloroform (ELCR = 1.9×10^{-6}, 0.03% contribution), TCE (ELCR = 3.5×10^{-6}, 0.06% contribution), and tritium (ELCR = 1.6×10^{-4}, 2.7% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.0×10^{-5}, 0.70% contribution) where the EPC (2.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-34 without contribution from arsenic is 5.3×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-34 is 4.6, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.31, 6.9% contribution), arsenic (HQ = 0.35, 7.7% contribution), cobalt (HQ = 0.74, 16% contribution), fluoride (HQ = 0.19, 4.2% contribution), Cr(VI) (HQ = 0.44, 9.8% contribution), lithium (HQ = 0.50, 11% contribution), nickel (HQ = 0.43, 9.4% contribution), nitrate (HQ = 0.32, 7.0% contribution), TCE (HQ = 0.87, 19% contribution), and uranium (HQ = 0.10, 2.2% contribution). The HI for well 199-K-34 without contribution from arsenic is 4.2, which is greater than the target HI of 1.

Table 6-53. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-34 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	4.2×10^{-5}	Arsenic (ELCR = 4.0×10^{-5}, 0.70%) Carbon-14 (ELCR = 5.5×10^{-3}, 95%) Chloroform (ELCR = 1.9×10^{-6}, 0.03%) Trichloroethene (ELCR = 3.5×10^{-6}, 0.06%) Tritium (ELCR = 1.6×10^{-4}, 2.7%)	3.5	2-Propanol (HQ = 0.31, 6.9%) Arsenic (HQ = 0.35, 7.7%) Cobalt (HQ = 0.74, 16%) Fluoride (HQ = 0.19, 4.2%) Hexavalent chromium (HQ = 0.44, 9.8%) Lithium (HQ = 0.50, 11%) Nickel (HQ = 0.43, 9.4%) Nitrate (HQ = 0.32, 7.0%) Trichloroethene (HQ = 0.87, 19%) Uranium (HQ = 0.10, 2.2%)
	Dermal Contact	4.7×10^{-7}		0.19	
	Inhalation of Volatiles	3.5×10^{-6}		0.90	
	Total Risk	**4.6×10^{-5}**		**Total HI**	**4.6**
Radionuclides	Ingestion	1.8×10^{-4}		--	
	Immersion	1.3×10^{-12}			
	Inhalation of Volatiles	5.5×10^{-3}			
	Total Risk	**5.7×10^{-3}**			
Total Cumulative ELCR		**5.7×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal weight
- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nickel: decreased body and organ weights

- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Uranium: initial body weight loss and moderate nephrotoxicity

With the exception of 2-propanol, TCE, uranium, lithium, and nickel, exposure to each of the analytes that contribute to the HI of 4.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for uranium and lithium results in an HI of 0.60, which is less than the target HI of 1. Combining the HQs for uranium and nickel results in an HI of 0.53, which is less than the target HI of 1. Combining the HQs for 2-propanol and TCE results in a HI of 1.2, which is greater than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-34 are shown in Table 6-54. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 29 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-54. Summary of Well 199-K-34 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	3,920	2,000	2
Strontium-90	pCi/L	40.9	8	5.1
Technetium-99	pCi/L	26.9	900	0.03
Tritium	pCi/L	2,270	20,000	0.11
			Sum of Fractions	7.2
			Cumulative Annual Dose (mrem)	28.9

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-36. Table 6-55 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-36. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-98 and G-99).

The total cumulative ELCR for well 199-K-36 is 3.1×10^{-4}. The total ELCR for nonradiological analytes is 1.1×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.0×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.7×10^{-4}, 53% contribution) and chloroform (ELCR = 3.2×10^{-6}, 1.0% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.1×10^{-4}, 35% contribution) where the EPC (5.6 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-36 without contribution from arsenic is 4.0×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-55. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-36 – Monitoring Well Screened Across the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.1×10^{-4}	Arsenic (ELCR = 1.1×10^{-4}, 35%) Carbon-14 (ELCR = 1.7×10^{-4}, 53%) Chloroform (ELCR = 3.2×10^{-6}, 1.0%)	6.3	Arsenic (HQ = 0.94, 12%) Bromomethane (HQ = 0.13, 1.7%) Cobalt (HQ = 0.24, 3.0%) Fluoride (HQ = 0.30, 3.8%) Hexavalent chromium (HQ = 4.6, 59%) Lithium (HQ = 0.50, 6.4%) Nickel (HQ = 0.20, 2.5%) Nitrate (HQ = 0.20, 2.5%) Trichloroethene (HQ = 0.21, 2.7%) Vanadium (HQ = 0.15, 1.9%)
	Dermal Contact	6.6×10^{-7}		1.3	
	Inhalation of Volatiles	3.3×10^{-6}		0.24	
	Total Risk	**1.1×10^{-4}**		**Total HI**	**7.8**
Radionuclides	**Ingestion**	7.8×10^{-6}		--	
	Immersion	6.8×10^{-14}			
	Inhalation of Volatiles	1.9×10^{-4}			
	Total Risk	**2.0×10^{-4}**			
Total Cumulative ELCR		3.1×10^{-4}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-36 is 7.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.94, 12% contribution), bromomethane (HQ = 0.13, 1.7% contribution), cobalt (HQ = 0.24, 3.0% contribution), fluoride (HQ = 0.30, 3.8% contribution), Cr(VI) (HQ = 4.6, 59% contribution), lithium (HQ = 0.50, 6.4% contribution), nickel (HQ = 0.20, 2.5% contribution), nitrate (HQ = 0.20, 2.5% contribution), TCE (HQ = 0.21, 2.7% contribution), and vanadium (HQ = 0.15, 1.9% contribution). The HI for well 199-K-36 without contribution from arsenic is 6.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nickel: decreased body and organ weights
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 6.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 4.7, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-36 are shown in Table 6-56. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.4 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-56. Summary of Well 199-K-36 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	119	2,000	0.059
Strontium-90	pCi/L	2	8	0.25
Technetium-99	pCi/L	19.1	900	0.021
Tritium	pCi/L	455	20,000	0.023
			Sum of Fractions	0.35
			Cumulative Annual Dose (mrem)	1.4

DWS = drinking water standard
EPC = exposure point concentration

Well 699-73-61. Table 6-57 provides a summary of the cancer risks and noncancer hazards by exposure route for well 699-73-61. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-100 and G-101).

Table 6-57. Summary of Cancer Risks and Noncancer Hazards for Well 699-73-61 – Monitoring Well Screened at the Top of the Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.6×10^{-5}	Arsenic (ELCR = 3.6×10^{-5}, 63%)	1.6	Arsenic (HQ = 0.31, 18%) Fluoride (HQ = 0.19, 11%) Lithium (HQ = 0.25, 14%) Manganese (HQ = 0.13, 7.7%) Trichloroethene (HQ = 0.15, 9.0%) Vanadium (HQ = 0.17, 9.8%) Zinc (HQ = 0.20, 11%)
	Dermal Contact	2.4×10^{-7}		0.05	
	Inhalation of Volatiles	9.2×10^{-7}		0.11	
	Total Risk	**3.7×10^{-5}**		Total HI	**1.7**
Radionuclides	Ingestion	2.8×10^{-6}		--	
	Immersion	1.5×10^{-13}			
	Inhalation of Volatiles	1.7×10^{-5}			
	Total Risk	**2.0×10^{-5}**			
Total Cumulative ELCR		**5.7×10^{-5}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 699-73-61 is 5.7×10^{-5}. The total ELCR for nonradiological analytes is 3.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.0×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 3.6×10^{-5}, 63% contribution) where the EPC (1.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 699-73-61 without contribution from arsenic is 1.3×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 699-73-61 is 1.7, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.31, 18% contribution), fluoride (HQ = 0.19, 11% contribution), lithium (HQ = 0.25, 14% contribution), manganese (HQ = 0.13, 7.7% contribution), TCE (HQ = 0.15, 9.0% contribution), vanadium (HQ = 0.17, 9.8% contribution), and zinc (HQ = 0.20, 11% contribution). The HI for well 699-73-61 without contribution from arsenic is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Lithium: nervous system and kidney effects
- Manganese: nervous system effects
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine
- Zinc: decreases in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity in healthy adult male and female volunteers

With the exception of manganese and lithium and TCE and zinc, exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for manganese and lithium results in an HI of 0.38, which is less than the target HI of 1. Combining the HQs for TCE and zinc results in an HI of 0.35, which is less than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 699-73-61 are shown in Table 6-58. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.11 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-58. Summary of Well 699-73-61 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Technetium-99	pCi/L	13	900	0.014
Tritium	pCi/L	245.5	20,000	0.012
			Sum of Fractions	0.027
			Cumulative Annual Dose (mrem)	0.11

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.2 Extraction Well 199-K-137 Screened Across Top of the Unconfined Aquifer

Across the top of the unconfined aquifer, one extraction well is screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the top of the unconfined aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-102 and G-103).

Well 199-K-137. Table 6-59 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-137.

The total cumulative ELCR for well 199-K-137 is 1.5×10^{-3}. The total ELCR for nonradiological analytes is 5.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.5×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-59. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-137 – Extraction Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	5.1×10^{-5}	Arsenic (ELCR = 4.8×10^{-5}, 3.2%) Carbon-14 (ELCR = 1.4×10^{-3}, 89%) Chloroform (ELCR = 2.4×10^{-6}, 0.16%) Trichloroethene (ELCR = 6.2×10^{-6}, 0.41%)	2.5	Arsenic (HQ = 0.42, 10%) Fluoride (HQ = 0.16, 4.0%) Hexavalent chromium (HQ = 1.3, 33%) Nitrate (HQ = 0.19, 4.8%) Trichloroethene (HQ = 1.6, 39%) Vanadium (HQ = 0.14, 3.6%)
	Dermal Contact	7.0×10^{-7}		0.45	
	Inhalation of Volatiles	5.4×10^{-6}		1.1	
	Total Risk	**5.7×10^{-5}**		**Total HI**	**4.0**
Radionuclides	Ingestion	3.2×10^{-5}		--	
	Immersion	5.3×10^{-14}			
	Inhalation of Volatiles	1.4×10^{-3}			
	Total Risk	**1.5×10^{-3}**			
Total Cumulative ELCR		**1.5×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.4×10^{-3}, 89% contribution), chloroform (ELCR = 2.4×10^{-6}, 0.16% contribution), and TCE (ELCR = 6.2×10^{-6}, 0.41% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.8×10^{-5}, 3.2% contribution) where the EPC (2.5 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-137 without contribution from arsenic is 8.6×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-137 is 4.0, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.42, 10% contribution), fluoride (HQ = 0.16, 4.0% contribution), Cr(VI) (HQ = 1.3, 33% contribution), nitrate (HQ = 0.19, 4.8% contribution), TCE (HQ = 1.6, 39% contribution), and vanadium (HQ = 0.14, 3.6% contribution). The HI for well 199-K-137 without contribution from arsenic is 3.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect

- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 3.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cr(VI) reports an individual HQ of 1.3, which is greater than the target HI of 1. TCE reports an individual HQ of 1.6, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-137 are shown in Table 6-60. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.4 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-60. Summary of Well 199-K-137 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	966	2,000	0.48
Technetium-99	pCi/L	36.8	900	0.041
Tritium	pCi/L	1,460	20,000	0.073
			Sum of Fractions	0.6
			Cumulative Annual Dose (mrem)	2.4

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.3 Wells Screened Across the Upper Unconfined Aquifer.

Across the upper unconfined aquifer, 20 monitoring wells are screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the upper unconfined aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-104 through G-143).

Well 199-K-11. Table 6-61 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-11. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-104 and G-105).

The total cumulative ELCR for well 199-K-11 is 3.6×10^{-4}. The total ELCR for nonradiological analytes is 1.4×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.8×10^{-4}, 51% contribution), chloroform (ELCR = 4.8×10^{-6}, 1.3% contribution), and TCE (ELCR = 6.8×10^{-6}, 1.9% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.3×10^{-4}, 36% contribution) where the EPC (6.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L.

The nonradiological ELCR for well 199-K-11 without contribution from arsenic is 1.2×10^{-5}, which is greater than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-61. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-11– Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.3×10^{-4}	Arsenic (ELCR = 1.3×10^{-4}, 36%) Carbon-14 (ELCR = 1.8×10^{-4}, 51%) Chloroform (ELCR = 4.8×10^{-6}, 1.3%) Trichloroethene (ELCR = 6.8×10^{-6}, 1.9%)	3.3	Arsenic (HQ = 1.1, 24%) Bromomethane (HQ = 0.13, 2.7%) Fluoride (HQ = 0.20, 4.1%) Hexavalent chromium (HQ = 0.38, 8.0%) Lithium (HQ = 0.40, 8.4%) Nitrate (HQ = 0.32, 6.8%) Trichloroethene (HQ = 1.7, 36%) Uranium (HQ = 0.10, 2.0%) Vanadium (HQ = 0.24, 5.1%)
	Dermal Contact	1.2×10^{-6}		0.22	
	Inhalation of Volatiles	7.9×10^{-6}		1.2	
	Total Risk	**1.4×10^{-4}**		**Total HI**	**4.8**
Radionuclides	Ingestion	6.0×10^{-6}		--	
	Immersion	1.8×10^{-14}			
	Inhalation of Volatiles	2.1×10^{-4}			
	Total Risk	**2.2×10^{-4}**			
Total Cumulative ELCR		**3.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-11 is 4.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 1.1, 24% contribution), bromomethane (HQ = 0.13, 2.7% contribution), fluoride (HQ = 0.20, 4.1% contribution), Cr(VI) (HQ = 0.38, 8.0% contribution), lithium (HQ = 0.40, 8.4% contribution), nitrate (HQ = 0.32, 6.8% contribution), TCE (HQ = 1.7, 36% contribution), uranium (HQ = 0.10, 2.0% contribution), and vanadium (HQ = 0.24, 5.1% contribution). The HI for well 199-K-11 without contribution from arsenic is 3.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Uranium: initial body weight loss and moderate nephrotoxicity
- Vanadium: decreased hair cysteine

With the exception of Cr(VI), bromomethane, uranium, and lithium, exposure to each of the analytes that contribute to the HI of 3.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 0.51, which is less than the target HI of 1. Combining the HQs for uranium and lithium results in an HI of 0.50, which is less than the target HI of 1. TCE reports an individual HQ of 1.7, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-11 are shown in Table 6-62. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.5 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-62. Summary of Well 199-K-11 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	130	2,000	0.065
Technetium-99	pCi/L	32.1	900	0.036
Tritium	pCi/L	494	20,000	0.025
			Sum of Fractions	0.13
			Cumulative Annual Dose (mrem)	0.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-117A. Table 6-63 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-117A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-106 and G-107).

The total cumulative ELCR for well 199-K-117A is 3.9×10^{-5}. The total ELCR for nonradiological analytes is 1.9×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.1×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 1.9×10-5, 47% contribution) where the EPC (0.97 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-117A when contribution from arsenic is not included.

Table 6-63. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-117A – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.9×10^{-5}	Arsenic (ELCR = 1.9×10^{-5}, 47%)	12	Arsenic (HQ = 0.16, 1.3%) Bromomethane (HQ = 0.15, 1.2%) Thallium (HQ = 12, 95%)
	Dermal Contact	9.9×10^{-8}		0.08	
	Inhalation of Volatiles	--		0.11	
	Total Risk	**1.9×10^{-5}**		**Total HI**	**13**
Radionuclides	Ingestion	3.7×10^{-6}		--	
	Immersion	6.7×10^{-14}			
	Inhalation of Volatiles	1.7×10^{-5}			
	Total Risk	**2.1×10^{-5}**			
Total Cumulative ELCR		**3.9×10^{-5}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-117A is 13, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.16, 1.3% contribution), bromomethane (HQ = 0.15, 1.2% contribution), and thallium (HQ = 12, 95% contribution). Contribution to HI is elevated for thallium (HQ = 12) where the EPC (2.4 µg/L) is greater than the range of background concentrations (minimum, maximum, and 90th percentile) of 0.883, 1.73, and 1.67 µg/L for filtered groundwater samples. Thallium was detected in one of 28 unfiltered samples and 2 of 28 filtered samples from this well. The presence of thallium is likely naturally occurring due to the sporadic nature of the detections and because only one sample result was greater than the 90th percentile value. The HI for well 199-K-117A without contribution from arsenic and thallium is 0.45, which is less than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-17A are shown in Table 6-64. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.3 mrem/yr, which is less than the 4 mrem/yr DWS.

Well 199-K-125A. Table 6-65 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-125A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-108 and G-109).

Table 6-64. Summary of Well 199-K-117A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	2.4	8	0.3
Tritium	pCi/L	248	20,000	0.012
			Sum of Fractions	0.32
			Cumulative Annual Dose (mrem)	1.3

DWS = drinking water standard
EPC = exposure point concentration

Table 6-65. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-125A – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	8.3×10^{-5}	Arsenic (ELCR = 8.4×10^{-5}, 15%) Tritium (ELCR = 4.1×10^{-4}, 75%)	4.5	Arsenic (HQ = 0.72, 16%) Fluoride (HQ = 0.13, 2.9%) Iron (HQ = 0.11, 2.4%) Nitrate (HQ = 0.10, 2.2%) Thallium (HQ = 2.9, 64%) Vanadium (HQ = 0.16, 3.6%)
	Dermal Contact	4.4×10^{-7}		0.07	
	Inhalation of Volatiles	--		--	
	Total Risk	**8.4×10^{-5}**		**Total HI**	**4.5**
Radionuclides	**Ingestion**	9.5×10^{-6}		--	
	Immersion	5.4×10^{-14}			
	Inhalation of Volatiles	4.6×10^{-4}			
	Total Risk	**4.6×10^{-4}**			
Total Cumulative ELCR		**5.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-125A is 5.5×10^{-4}. The total ELCR for nonradiological analytes is 8.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.6×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 4.1×10^{-4}, 75% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 8.4×10^{-5}, 15% contribution) where the EPC (4.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-125A when contribution from arsenic is not included.

The HI for well 199-K-125A is 4.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.72, 16% contribution), fluoride (HQ = 0.13, 2.9% contribution), iron (HQ = 0.11, 2.4% contribution), nitrate (HQ = 0.10, 2.2% contribution), thallium (HQ = 2.9, 64% contribution), and vanadium (HQ = 0.16, 3.6% contribution). Contribution to HI is elevated for thallium (HQ = 5.0) where the EPC (0.58 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-125A without contribution from arsenic and thallium is 0.90, which is less than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-125A are shown in Table 6-66. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-66. Summary of Well 199-K-125A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	35.2	2,000	0.018
Strontium-90	pCi/L	1.9	8	0.24
Tritium	pCi/L	5,950	20,000	0.3
			Sum of Fractions	0.55
			Cumulative Annual Dose (mrem)	2.2

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-138. Table 6-67 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-138. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-110 and G-111).

The total cumulative ELCR for well 199-K-138 is 9.1×10^{-4}. The total ELCR for nonradiological analytes is 5.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.6×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 7.6×10^{-4}, 84% contribution), chloroform (ELCR = 2.0×10^{-6}, 0.21% contribution), TCE (ELCR = 5.9×10^{-6}, 0.65% contribution), and tritium (ELCR = 9.6×10^{-5}, 11% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.3×10^{-5}, 4.7% contribution) where the EPC (2.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-138 without contribution from arsenic is 7.9×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-67. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-138 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	4.5×10^{-5}	Arsenic (ELCR = 4.3×10^{-5}, 4.7%) Carbon-14 (ELCR = 7.6×10^{-4}, 84%) Chloroform (ELCR = 2.0×10^{-6}, 0.21%) Trichloroethene (ELCR = 5.9×10^{-6}, 0.65%) Tritium (ELCR = 9.6×10^{-5}, 11%)	1.6	2-Propanol (HQ = 0.31, 10%) Arsenic (HQ = 0.37, 12%) Fluoride (HQ = 0.16, 5.3%) Hexavalent chromium (HQ = 0.33, 11%) Nitrate (HQ = 0.18, 5.8%) Trichloroethene (HQ = 1.5, 48%) Vanadium (HQ = 0.12, 3.9%)
	Dermal Contact	6.4×10^{-7}		0.17	
	Inhalation of Volatiles	4.8×10^{-6}		1.3	
	Total Risk	5.0×10^{-5}		Total HI	3.1
Radionuclides	Ingestion	2.2×10^{-5}		--	
	Immersion	7.3×10^{-14}			
	Inhalation of Volatiles	8.4×10^{-4}			
	Total Risk	8.6×10^{-4}			
Total Cumulative ELCR		9.1×10^{-4}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-138 is 3.1, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.31, 10% contribution), arsenic (HQ = 0.37, 12% contribution), fluoride (HQ = 0.16, 5.3% contribution), Cr(VI) (HQ = 0.33, 11% contribution), nitrate (HQ = 0.18, 5.8% contribution), TCE (HQ = 1.5, 48% contribution), and vanadium (HQ = 0.12, 3.9% contribution). The HI for well 199-K-138 without contribution from arsenic is 2.7, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of 2-propanol and TCE, exposure to each of the analytes that contribute to the HI of 2.7 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for 2-propanol and TCE results in an HI of 1.8, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-138 are shown in Table 6-68. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-68. Summary of Well 199-K-138 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	546	2,000	0.27
Strontium-90	pCi/L	1.2	8	0.16
Technetium-99	pCi/L	42.5	900	0.047
Tritium	pCi/L	1,390	20,000	0.069
			Sum of Fractions	0.55
			Cumulative Annual Dose (mrem)	2.2

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-142. Table 6-69 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-142. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-112 and G-113).

The total cumulative ELCR for well 199-K-142 is 4.3×10^{-4}. The total ELCR for nonradiological analytes is 1.0×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.3×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.1×10^{-4}, 71% contribution) and chloroform (ELCR = 5.4×10^{-6}, 1.3% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.6×10^{-5}, 22% contribution) where the EPC (4.9 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-142 without contribution from arsenic is 6.3×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-142 is 5.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.83, 16% contribution), bromomethane (HQ = 0.13, 2.4% contribution), fluoride (HQ = 0.20, 3.8% contribution), Cr(VI) (HQ = 0.23, 4.5% contribution), thallium (HQ = 3.3, 63% contribution), and vanadium (HQ = 0.26, 4.9% contribution). Contribution to HI is elevated for thallium (HQ = 3.3) where the EPC (0.66 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-142 without contribution from arsenic and thallium is 1.1, which is greater than the target HI of 1.

Table 6-69. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-142 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.6×10^{-5}	Arsenic (ELCR = 9.6×10^{-5}, 22%) Carbon-14 (ELCR = 3.1×10^{-4}, 71%) Chloroform (ELCR = 5.4×10^{-6}, 1.3%)	5.0	Arsenic (HQ = 0.83, 16%) Bromomethane (HQ = 0.13, 2.4%) Fluoride (HQ = 0.20, 3.8%) Hexavalent chromium (HQ = 0.23, 4.5%) Thallium (HQ = 3.3, 63%) Vanadium (HQ = 0.26, 4.9%)
	Dermal Contact	5.6×10^{-7}		0.12	
	Inhalation of Volatiles	5.6×10^{-6}		0.10	
	Total Risk	**1.0×10^{-4}**		**Total HI**	**5.2**
Radionuclides	Ingestion	1.3×10^{-5}		--	
	Immersion	4.9×10^{-14}			
	Inhalation of Volatiles	3.2×10^{-4}			
	Total Risk	**3.3×10^{-4}**			
Total Cumulative ELCR		**4.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Vanadium: decreased hair cysteine

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 1.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 0.36, which is less than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-142 are shown in Table 6-70. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-70. Summary of Well 199-K-142 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	222	2,000	0.11
Strontium-90	pCi/L	1.4	8	0.18
Tritium	pCi/L	228	20,000	0.011
			Sum of Fractions	0.3
			Cumulative Annual Dose (mrem)	1.2

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-173. Table 6-71 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-173. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-114 and G-115).

The total cumulative ELCR for well 199-K-173 is 8.5×10^{-4}. The total ELCR for nonradiological analytes is 7.8×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 7.7×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 6.7×10^{-4}, 79% contribution), chloroform (ELCR = 1.5×10^{-6}, 0.17% contribution), TCE (ELCR = 5.8×10^{-6}, 0.68% contribution), and tritium (ELCR = 9.5×10^{-5}, 11% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.1×10^{-5}, 8.4% contribution) where the EPC (3.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-173 without contribution from arsenic is 7.3×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-173 is 21, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are antimony (HQ = 0.15, 0.70% contribution), arsenic (HQ = 0.61, 3.0% contribution), fluoride (HQ = 0.18, 0.85% contribution), Cr(VI) (HQ = 9.0, 44% contribution), nitrate (HQ = 0.16, 0.78% contribution), thallium (HQ = 8.5, 41% contribution), TCE (HQ = 1.4, 7.0% contribution), and vanadium (HQ = 0.15, 0.71% contribution). Contribution to HI is elevated for thallium (HQ = 8.5) where the EPC (1.7 µg/L) is within the range of background concentrations (minimum, maximum, and 90th percentile) of 0.883, 1.73, and 1.67 µg/L for filtered groundwater samples. The HI for well 199-K-173 without contribution from arsenic and thallium is 11, which is greater than the target HI of 1.

Table 6-71. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-173 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.3×10^{-5}	Arsenic (ELCR = 7.1×10^{-5}, 8.4%) Carbon-14 (ELCR = 6.7×10^{-4}, 79%) Chloroform (ELCR = 1.5×10^{-6}, 0.17%) Trichloroethene (ELCR = 5.8×10^{-6}, 0.68%) Tritium (ELCR = 9.5×10^{-5}, 11%)	17	Antimony (HQ = 0.15, 0.70%) Arsenic (HQ = 0.61, 3.0%) Fluoride (HQ = 0.18, 0.85%) Hexavalent chromium (HQ = 9.0, 44%) Nitrate (HQ = 0.16, 0.78%) Thallium (HQ = 8.5, 41%) Trichloroethene (HQ = 1.4, 7.0%) Vanadium (HQ = 0.15, 0.71%)
	Dermal Contact	7.8×10^{-7}		2.5	
	Inhalation of Volatiles	4.3×10^{-6}		1.1	
	Total Risk	**7.8×10^{-5}**		**Total HI**	**21**
Radionuclides	**Ingestion**	2.0×10^{-5}		--	
	Immersion	8.3×10^{-14}			
	Inhalation of Volatiles	7.5×10^{-4}			
	Total Risk	**7.7×10^{-4}**			
Total Cumulative ELCR		**8.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Antimony: longevity, blood glucose, and cholesterol
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of nitrate and antimony, exposure to each of the analytes that contribute to the HI of 12 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for nitrate and antimony results in an HI of 0.31, which is less than the target HI of 1. Cr(VI) reports an individual HQ of 9.0, which is greater than the target HI of 1. TCE

reports an individual HQ of 1.4, which is greater than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-173 are shown in Table 6-72. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.3 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-72. Summary of Well 199-K-173 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	480	2,000	0.24
Strontium-90	pCi/L	1.7	8	0.21
Technetium-99	pCi/L	42.8	900	0.048
Tritium	pCi/L	1,380	20,000	0.069
			Sum of Fractions	0.57
			Cumulative Annual Dose (mrem)	2.3

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-183. Table 6-73 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-183. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-116 and G-117).

The total cumulative ELCR for well 199-K-183 is 8.5×10^{-4}. The total ELCR for nonradiological analytes is 8.1×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 7.7×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 6.5×10^{-4}, 77% contribution), chloroform (ELCR = 1.6×10^{-6}, 0.19% contribution), TCE (ELCR = 6.0×10^{-6}, 0.70% contribution), and tritium (ELCR = 1.1×10^{-4}, 13% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.4×10^{-5}, 8.7% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-183 without contribution from arsenic is 7.6×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-183 is 10, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.64, 6.1% contribution), fluoride (HQ = 0.14, 1.3% contribution), Cr(VI) (HQ = 0.18, 1.7% contribution), nitrate (HQ = 0.18, 1.7% contribution), thallium (HQ = 7.5, 72% contribution), TCE (HQ = 1.5, 14% contribution), and vanadium (HQ = 0.13, 1.2% contribution). Contribution to HI is elevated for thallium (HQ = 7.5) where the EPC (1.5 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-183 without contribution from arsenic and thallium is 2.3, which is greater than the target HI of 1.

Table 6-73. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-183 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.6×10^{-5}	Arsenic (ELCR = 7.4×10^{-5}, 8.7%) Carbon-14 (ELCR = 6.5×10^{-4}, 77%) Chloroform (ELCR = 1.6×10^{-6}, 0.19%) Trichloroethene (ELCR = 6.0×10^{-6}, 0.70%) Tritium (ELCR = 1.1×10^{-4}, 13%)	9.3	Arsenic (HQ = 0.64, 6.1%) Fluoride (HQ = 0.14, 1.3%) Hexavalent chromium (HQ = 0.18, 1.7%) Nitrate (HQ = 0.18, 1.7%) Thallium (HQ = 7.5, 72%) Trichloroethene (HQ = 1.5, 14%) Vanadium (HQ = 0.13, 1.2%)
	Dermal Contact	8.1×10^{-7}		0.17	
	Inhalation of Volatiles	4.5×10^{-6}		1.0	
	Total Risk	**8.1×10^{-5}**		**Total HI**	**10**
Radionuclides	**Ingestion**	1.9×10^{-5}		--	
	Immersion	6.3×10^{-14}			
	Inhalation of Volatiles	7.5×10^{-4}			
	Total Risk	**7.7×10^{-4}**			
Total Cumulative ELCR		**8.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 2.3 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. TCE reports an individual HQ of 1.5, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-183 are shown in Table 6-74. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.9 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-74. Summary of Well 199-K-183 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	464	2,000	0.23
Strontium-90	pCi/L	0.8	8	0.1
Technetium-99	pCi/L	55.8	900	0.062
Tritium	pCi/L	1,620	20,000	0.081
			Sum of Fractions	0.48
			Cumulative Annual Dose (mrem)	1.9

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-186. Table 6-75 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-186. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-118 and G-119).

The total cumulative ELCR for well 199-K-186 is 2.6×10^{-4}. The total ELCR for nonradiological analytes is 9.1×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.7×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.4×10^{-4}, 55% contribution) and chloroform (ELCR = 6.0×10^{-6}, 2.3% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 8.4×10^{-5}, 32% contribution) where the EPC (4.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-186 without contribution from arsenic is 6.9×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-186 is 2.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.72, 32% contribution), cobalt (HQ = 0.19, 8.2% contribution), fluoride (HQ = 0.16, 7.2% contribution), Cr(VI) (HQ = 0.48, 21% contribution), TCE (HQ = 0.23, 10% contribution), and vanadium (HQ = 0.15, 6.8% contribution). The HI for well 199-K-186 without contribution from arsenic is 1.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

Table 6-75. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-186 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	8.4×10^{-5}	Arsenic (ELCR = 8.4×10^{-5}, 32%) Carbon-14 (ELCR = 1.4×10^{-4}, 55%) Chloroform (ELCR = 6.0×10^{-6}, 2.3%)	1.9	Arsenic (HQ = 0.72, 32%) Cobalt (HQ = 0.19, 8.2%) Fluoride (HQ = 0.16, 7.2%) Hexavalent chromium (HQ = 0.48, 21%) Trichloroethene (HQ = 0.23, 10%) Vanadium (HQ = 0.15, 6.8%)
	Dermal Contact	5.5×10^{-7}		0.17	
	Inhalation of Volatiles	5.9×10^{-6}		0.16	
	Total Risk	**9.1×10^{-5}**		**Total HI**	**2.3**
Radionuclides	Ingestion	4.5×10^{-6}		--	
	Immersion	2.4×10^{-14}			
	Inhalation of Volatiles	1.7×10^{-4}			
	Total Risk	**1.7×10^{-4}**			
Total Cumulative ELCR		**2.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-186 are shown in Table 6-76. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.65 mrem/yr, which is less than the 4 mrem/yr DWS.

Well 199-K-187. Table 6-77 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-187. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-120 and G-121).

The total cumulative ELCR for well 199-K-187 is 1.5×10^{-4}. The total ELCR for nonradiological analytes is 9.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.7×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

Table 6-76. Summary of Well 199-K-186 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	103	2,000	0.051
Strontium-90	pCi/L	0.74	8	0.092
Tritium	pCi/L	384	20,000	0.019
			Sum of Fractions	0.16
			Cumulative Annual Dose (mrem)	0.65

DWS = drinking water standard
EPC = exposure point concentration

The major contributors to the total cumulative ELCR are chloroform (ELCR = 9.5×10^{-7}, 0.62% contribution) and TCE (ELCR = 2.2×10^{-6}, 1.4% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.2×10^{-5}, 61% contribution) where the EPC (4.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-187 without contribution from arsenic is 3.2×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-187 is 5.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.80, 14% contribution), fluoride (HQ = 0.20, 3.5% contribution), Cr(VI) (HQ = 0.35, 6.0% contribution), nitrate (HQ = 0.16, 2.7% contribution), thallium (HQ = 3.2, 55% contribution), TCE (HQ = 0.55, 9.6% contribution), and vanadium (HQ = 0.16, 2.7% contribution). Contribution to HI is elevated for thallium (HQ = 3.2) where the EPC (0.63 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-187 without contribution from arsenic and thallium is 1.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

- Exposure to each of the analytes that contribute to the HI of 1.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1 for each contributor.

- EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-187 are shown in Table 6-78. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-77. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-187 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.3×10^{-5}	Arsenic (ELCR = 9.2×10^{-5}, 61%) Chloroform (ELCR = 9.5×10^{-7}, 0.62%) Trichloroethene (ELCR = 2.2×10^{-6}, 1.4%)	5.2	Arsenic (HQ = 0.80, 14%) Fluoride (HQ = 0.20, 3.5%) Hexavalent chromium, (HQ = 0.35, 6.0%) Nitrate (HQ = 0.16, 2.7%) Thallium (HQ = 3.2, 55%) Trichloroethene (HQ = 0.55, 9.6%) Vanadium (HQ = 0.16, 2.7%)
	Dermal Contact	6.5×10^{-7}		0.17	
	Inhalation of Volatiles	2.0×10^{-6}		0.37	
	Total Risk	**9.6×10^{-5}**		**Total HI**	**5.8**
Radionuclides	Ingestion	5.8×10^{-6}		--	
	Immersion	6.7×10^{-14}			
	Inhalation of Volatiles	5.1×10^{-5}			
	Total Risk	**5.7×10^{-5}**			
Total Cumulative ELCR		**1.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Well 199-K-188. Table 6-79 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-188. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-122 and G-123).

The total cumulative ELCR for well 199-K-188 is 2.4×10^{-4}. The total ELCR for nonradiological analytes is 8.3×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.6×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 1.2×10^{-4}, 51% contribution), chloroform (ELCR = 1.4×10^{-6}, 0.59% contribution), and TCE (ELCR = 2.7×10^{-6}, 1.1% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.9×10^{-5}, 32% contribution) where the EPC (4.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-188 without contribution from arsenic is 4.1×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-78. Summary of Well 199-K-187 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	1.7	8	0.22
Technetium-99	pCi/L	50.1	900	0.056
Tritium	pCi/L	746	20,000	0.037
			Sum of Fractions	0.31
			Cumulative Annual Dose (mrem)	1.2

DWS = drinking water standard
EPC = exposure point concentration

Table 6-79. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-188 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	8.0×10^{-5}	Arsenic (ELCR = 7.9×10^{-5}, 32%) Carbon-14 (ELCR = 1.2×10^{-4}, 51%) Chloroform (ELCR = 1.4×10^{-6}, 0.59%) Trichloroethene (ELCR = 2.7×10^{-6}, 1.1%)	2.1	Arsenic (HQ = 0.68, 25%) Fluoride (HQ = 0.35, 13%) Hexavalent chromium (HQ = 0.68, 24%) Nitrate (HQ = 0.14, 5.2%) Trichloroethene, (HQ = 0.67, 24%) Vanadium (HQ = 0.15, 5.3%)
	Dermal Contact	6.1×10^{-7}		0.24	
	Inhalation of Volatiles	2.7×10^{-6}		0.45	
	Total Risk	**8.3×10^{-5}**		**Total HI**	**2.8**
Radionuclides	**Ingestion**	5.6×10^{-6}		--	
	Immersion	3.5×10^{-14}			
	Inhalation of Volatiles	1.6×10^{-4}			
	Total Risk	**1.6×10^{-4}**			
Total Cumulative ELCR		**2.4×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-188 is 2.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.68, 25% contribution), fluoride (HQ = 0.35,

13% contribution), Cr(VI) (HQ = 0.68, 24% contribution), nitrate (HQ = 0.14, 5.2% contribution), TCE (HQ = 0.67, 24% contribution), and vanadium (HQ = 0.15, 5.3% contribution). The HI for well 199-K-188 without contribution from arsenic is 2.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 2.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-188 are shown in Table 6-80. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.78 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-80. Summary of Well 199-K-188 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	89.1	2,000	0.045
Strontium-90	pCi/L	0.76	8	0.095
Technetium-99	pCi/L	27	900	0.03
Tritium	pCi/L	494	20,000	0.025
			Sum of Fractions	0.19
			Cumulative Annual Dose (mrem)	0.78

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-191. Table 6-81 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-191. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-124 and G-125).

The total cumulative ELCR for well 199-K-191 is 5.2×10^{-4}. The total ELCR for nonradiological analytes is 8.3×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.3×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are chloroform (ELCR = 3.3×10^{-6}, 0.63% contribution) and tritium (ELCR = 4.2×10^{-4}, 82% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.9×10^{-5}, 15% contribution) where the EPC (4.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-191 without

contribution from arsenic is 3.3×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-81. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-191 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.9×10^{-5}	Arsenic (ELCR = 7.9×10^{-5}, 15%) Chloroform (ELCR = 3.3×10^{-6}, 0.63%) Tritium (ELCR = 4.2×10^{-4}, 82%)	1.7	Arsenic (HQ = 0.68, 39%) Fluoride (HQ = 0.23, 13%) Hexavalent chromium (HQ = 0.13, 7.5%) Nitrate (HQ = 0.11, 6.3%) Thallium (HQ = 0.10, 5.7%) Vanadium (HQ = 0.13, 7.7%)
	Dermal Contact	4.5×10^{-7}		0.07	
	Inhalation of Volatiles	3.0×10^{-6}		< 0.01	
	Total Risk	**8.3×10^{-5}**		**Total HI**	**1.7**
Radionuclides	**Ingestion**	7.5×10^{-6}		--	
	Immersion	2.9×10^{-14}			
	Inhalation of Volatiles	4.2×10^{-4}			
	Total Risk	**4.3×10^{-4}**			
Total Cumulative ELCR		**5.2×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-191 is 1.7, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.68, 39% contribution), fluoride (HQ = 0.23, 13% contribution), Cr(VI) (HQ = 0.13, 7.5% contribution), nitrate (HQ = 0.11, 6.3% contribution), thallium (HQ = 0.10, 5.7% contribution), and vanadium (HQ = 0.13, 7.7% contribution). Contribution to HI is elevated for thallium (HQ = 0.10) where the EPC (0.02 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-191 without contribution from arsenic and thallium is 0.96, which is less than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-191 are shown in Table 6-82. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.7 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-82. Summary of Well 199-K-191 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	7	2,000	0.0035
Strontium-90	pCi/L	1	8	0.13
Tritium	pCi/L	6,070	20,000	0.3
			Sum of Fractions	0.43
			Cumulative Annual Dose (mrem)	1.7

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-194. Table 6-83 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-194. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-126 and G-127).

The total cumulative ELCR for well 199-K-194 is 1.9×10^{-4}. The total ELCR for nonradiological analytes is 1.0×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.3×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

The major contributor to the total cumulative ELCR is chloroform (ELCR = 4.1×10^{-6}, 2.2% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.9×10^{-5}, 53% contribution) where the EPC (5.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-194 without contribution from arsenic is 4.7×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-194 is 3.6, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 1,2,4-trichlorobenzene (HQ = 0.16, 4.5% contribution), arsenic (HQ = 0.86, 24% contribution), cobalt (HQ = 0.88, 25% contribution), fluoride (HQ = 0.24, 6.6% contribution), Cr(VI) (HQ = 0.27, 7.4% contribution), thallium (HQ = 0.65, 18% contribution), and vanadium (HQ = 0.20, 5.5% contribution). Contribution to HI is elevated for thallium (HQ = 0.65) where the EPC (0.13 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-194 without contribution from arsenic and thallium is 2.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 1,2,4-Trichlorobenzene: increased adrenal weights; vacuolization of zona fasciculata in the cortex
- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Vanadium: decreased hair cysteine

Table 6-83. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-194 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	9.9×10^{-5}	Arsenic (ELCR = 9.9×10^{-5}, 53%) Chloroform (ELCR = 4.1×10^{-6}, 2.2%)	3.3	1,2,4-Trichlorobenzene (HQ = 0.16, 4.5%) Arsenic (HQ = 0.86, 24%) Cobalt (HQ = 0.88, 25%) Fluoride (HQ = 0.24, 6.6%) Hexavalent chromium (HQ = 0.27, 7.4%) Thallium (HQ = 0.65, 18%) Vanadium (HQ = 0.20, 5.5%)
	Dermal Contact	8.8×10^{-7}		0.11	
	Inhalation of Volatiles	3.7×10^{-6}		0.16	
	Total Risk	**1.0×10^{-4}**		**Total HI**	**3.6**
Radionuclides	**Ingestion**	2.5×10^{-6}		--	
	Immersion	2.5×10^{-14}			
	Inhalation of Volatiles	8.1×10^{-5}			
	Total Risk	**8.3×10^{-5}**			
Total Cumulative ELCR		**1.9×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Exposure to each of the analytes that contribute to the HI of 2.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-194 are shown in Table 6-84. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.67 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-84. Summary of Well 199-K-194 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	6.2	2,000	0.0031
Strontium-90	pCi/L	0.88	8	0.11
Tritium	pCi/L	1,050	20,000	0.053
			Sum of Fractions	0.17
			Cumulative Annual Dose (mrem)	0.67

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-20. Table 6-85 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-20. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-128 and G-129).

Table 6-85. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-20 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	4.6×10^{-5}	Arsenic (ELCR = 4.6×10^{-5}, 6.2%) Chloroform (ELCR = 3.3×10^{-6}, 0.45%) Tritium (ELCR = 6.5×10^{-4}, 88%)	2.7	Arsenic (HQ = 0.40, 14%) Iron (HQ = 0.43, 15%) Lithium (HQ = 0.13, 4.8%) Manganese (HQ = 0.12, 4.4%) Nitrate (HQ = 0.11, 3.9%) Thallium (HQ = 1.1, 39%) Vanadium (HQ = 0.12, 4.2%)
	Dermal Contact	2.7×10^{-7}		0.06	
	Inhalation of Volatiles	3.0×10^{-6}		< 0.01	
	Total Risk	**5.0×10^{-5}**		**Total HI**	2.8
Radionuclides	**Ingestion**	2.4×10^{-5}		--	
	Immersion	2.8×10^{-13}			
	Inhalation of Volatiles	6.7×10^{-4}			
	Total Risk	**6.9×10^{-4}**			
Total Cumulative ELCR		**7.4×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-20 is 7.4×10^{-4}. The total ELCR for nonradiological analytes is 5.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 6.9×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are chloroform (ELCR = 3.3×10^{-6}, 0.45% contribution) and tritium (ELCR = 6.5×10^{-4}, 88% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.6×10^{-5}, 6.2% contribution) where the EPC (2.4 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-20 without contribution from arsenic is 3.3×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-20 is 2.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.40, 14% contribution), iron (HQ = 0.43, 15% contribution), lithium (HQ = 0.13, 4.8% contribution), manganese (HQ = 0.12, 4.4% contribution), nitrate (HQ = 0.11, 3.9% contribution), thallium (HQ = 1.1, 39% contribution), and vanadium (HQ = 0.12, 4.2% contribution). Contribution to HI is elevated for thallium (HQ = 1.1) where the EPC (0.22 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-20 without contribution from arsenic and thallium is 1.3, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Iron: GI tract; adverse gastrointestinal effects
- Lithium: nervous system and kidney effects
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of manganese and lithium, exposure to each of the analytes that contribute to the HI of 1.3 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for manganese and lithium results in an HI of 0.26, which is less than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-20 are shown in Table 6-86. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 6.9 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-86. Summary of Well 199-K-20 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	18.3	2,000	0.0091
Strontium-90	pCi/L	10	8	1.3
Tritium	pCi/L	9,410	20,000	0.47
			Sum of Fractions	1.7
			Cumulative Annual Dose (mrem)	6.9

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-204. Table 6-87 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-204. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-130 and G-131).

The total cumulative ELCR for well 199-K-204 is 2.5×10^{-2}. The total ELCR for nonradiological analytes is 4.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.5×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-87. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-204 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	4.1×10^{-5}	Arsenic (ELCR = 3.9×10^{-5}, 0.15%) Carbon-14 (ELCR = 2.5×10^{-2}, 98%) Chloroform (ELCR = 2.5×10^{-6}, 0.01%) Trichloroethene (ELCR = 5.0×10^{-6}, 0.02%) Tritium (ELCR = 4.2×10^{-4}, 1.6%)	2.6	Arsenic (HQ = 0.33, 4.5%) Cyanide (HQ = 4.4, 60%) Fluoride (HQ = 0.20, 2.7%) Manganese (HQ = 0.28, 3.7%) Nitrate (HQ = 0.30, 4.1%) Trichloroethene (HQ = 1.2, 17%) Uranium (HQ = 0.12, 1.6%) Vanadium (HQ = 0.17, 2.3%)
	Dermal Contact	5.6×10^{-7}		0.14	
	Inhalation of Volatiles	4.9×10^{-6}		4.8	
	Total Risk	**4.6×10^{-5}**		**Total HI**	**7.5**
Radionuclides	**Ingestion**	5.3×10^{-4}		--	
	Immersion	7.2×10^{-13}			
	Inhalation of Volatiles	2.5×10^{-2}			
	Total Risk	**2.5×10^{-2}**			
Total Cumulative ELCR		**2.5×10^{-2}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 2.5×10^{-2}, 98% contribution), chloroform (ELCR = 2.5×10^{-6}, 0.01% contribution), TCE (ELCR = 5.0×10^{-6}, 0.02% contribution), and tritium (ELCR = 4.2×10^{-4}, 1.6% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 3.9×10^{-5}, 0.15% contribution) where the EPC (2.0 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-204 without

contribution from arsenic is 7.5×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-204 is 7.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.33, 4.5% contribution), cyanide (HQ = 4.4, 60% contribution), fluoride (HQ = 0.20, 2.7% contribution), manganese (HQ = 0.28, 3.7% contribution), nitrate (HQ = 0.30, 4.1% contribution), TCE (HQ = 1.2, 17% contribution), uranium (HQ = 0.12, 1.6% contribution), and vanadium (HQ = 0.17, 2.3% contribution). The HI for well 199-K-204 without contribution from arsenic is 7.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cyanide: thyroid enlargement and altered iodide uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Uranium: initial body weight loss and moderate nephrotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 7.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cyanide reports an individual HQ of 4.4, which is greater than the target HI of 1. TCE reports an individual HQ of 1.2, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-204 are shown in Table 6-88. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 37 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-88. Summary of Well 199-K-204 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	17,800	2,000	8.9
Technetium-99	pCi/L	9.9	900	0.011
Tritium	pCi/L	6,010	20,000	0.3
			Sum of Fractions	9.2
			Cumulative Annual Dose (mrem)	36.8

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-21. Table 6-89 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-21. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-132 and G-133).

Table 6-89. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-21 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.9×10^{-5}	Arsenic (ELCR = 1.9×10^{-5}, 12%)	7.4	Arsenic (HQ = 0.17, 2.2%) Cobalt (HQ = 0.11, 1.4%) Hexavalent chromium (HQ = 0.28, 3.7%) Manganese (HQ = 0.49, 6.4%) Nitrate (HQ = 0.15, 1.9%) Thallium (HQ = 6.0, 80%)
	Dermal Contact	1.0×10^{-7}		0.16	
	Inhalation of Volatiles	--		--	
	Total Risk	**1.9×10^{-5}**		**Total HI**	**7.5**
Radionuclides	**Ingestion**	4.6×10^{-5}		--	
	Immersion	1.3×10^{-12}			
	Inhalation of Volatiles	1.0×10^{-4}			
	Total Risk	**1.5×10^{-4}**			
Total Cumulative ELCR		**1.7×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-21 is 1.7×10^{-4}. The total ELCR for nonradiological analytes is 1.9×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.5×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 1.9×10^{-5}, 12% contribution) where the EPC (1.0 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-21 when contribution from arsenic is not included.

The HI for well 199-K-21 is 7.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.17, 2.2% contribution), cobalt (HQ = 0.11, 1.4% contribution), Cr(VI) (HQ = 0.28, 3.7% contribution), manganese (HQ = 0.49, 6.4% contribution), nitrate (HQ = 0.15, 1.9% contribution), and thallium (HQ = 6.0, 80% contribution). Contribution to HI is elevated for thallium (HQ = 6.0) where the EPC (1.2 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-21 without contribution from arsenic and thallium is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cobalt: thyroid, decreased iodine uptake
- Cr(VI): nasal septum atrophy
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia

Exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each analyte individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-21 are shown in Table 6-90. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 14 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-90. Summary of Well 199-K-21 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	9.2	2,000	0.0046
Strontium-90	pCi/L	27	8	3.4
Tritium	pCi/L	1,290	20,000	0.065
			Sum of Fractions	3.4
			Cumulative Annual Dose (mrem)	13.8

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-221. Table 6-91 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-221. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-134 and G-135).

The total cumulative ELCR for well 199-K-221 is 4.5×10^{-3}. The total ELCR for nonradiological analytes is 4.5×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.4×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 2.6×10^{-3}, 57% contribution) and tritium (ELCR = 1.9×10^{-3}, 41% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.5×10^{-5}, 1.0% contribution) where the EPC (2.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-221 when contribution from arsenic is not included.

Table 6-91. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-221 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	4.4×10^{-5}	Arsenic (ELCR = 4.5×10^{-5}, 1.0%) Carbon-14 (ELCR = 2.6×10^{-3}, 57%) Tritium (ELCR = 1.9×10^{-3}, 41%)	1.6	Arsenic (HQ = 0.38, 21%) Fluoride (HQ = 0.15, 8.3%) Hexavalent chromium (HQ = 0.67, 37%) Nitrate (HQ = 0.22, 12%) Uranium (HQ = 0.24, 13%)
	Dermal Contact	2.4×10^{-7}		0.19	
	Inhalation of Volatiles	--		--	
	Total Risk	**4.5×10^{-5}**		**Total HI**	**1.8**
Radionuclides	Ingestion	9.3×10^{-5}		--	
	Immersion	2.8×10^{-13}			
	Inhalation of Volatiles	4.3×10^{-3}			
	Total Risk	**4.4×10^{-3}**			
Total Cumulative ELCR		**4.5×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-221 is 1.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.38, 21% contribution), fluoride (HQ = 0.15, 8.3% contribution), Cr(VI) (HQ = 0.67, 37% contribution), nitrate (HQ = 0.22, 12% contribution), and uranium (HQ = 0.24, 13% contribution). The HI for well 199-K-221 without contribution from arsenic is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Uranium: initial body weight loss and moderate nephrotoxicity

Exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-221 are shown in Table 6-92. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 13 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-92. Summary of Well 199-K-221 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	1,830	2,000	0.92
Strontium-90	pCi/L	6.5	8	0.82
Technetium-99	pCi/L	64.1	900	0.071
Tritium	pCi/L	26,700	20,000	1.3
			Sum of Fractions	3.1
			Cumulative Annual Dose (mrem)	12.6

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-222. Table 6-93 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-222. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-136 and G-137).

Table 6-93. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-222 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	5.0×10^{-5}	Arsenic (ELCR = 5.0×10^{-5}, 9.3%) Carbon-14 (ELCR = 3.0×10^{-4}, 56%) Strontium-90 (ELCR = 1.6×10^{-4}, 30%)	1.4	Arsenic (HQ = 0.43, 28%) Fluoride (HQ = 0.15, 9.7%) Hexavalent chromium (HQ = 0.44, 28%) Nitrate (HQ = 0.17, 11%)
	Dermal Contact	2.7×10^{-7}		0.13	
	Inhalation of Volatiles	--		--	
	Total Risk	**5.0×10^{-5}**		**Total HI**	**1.5**
Radionuclides	**Ingestion**	1.7×10^{-4}		--	
	Immersion	3.1×10^{-12}			
	Inhalation of Volatiles	3.2×10^{-4}			
	Total Risk	**4.9×10^{-4}**			
Total Cumulative ELCR		**5.4×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-222 is 5.4×10^{-4}. The total ELCR for nonradiological analytes is 5.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.9×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.0×10^{-4}, 56% contribution) and strontium-90 (ELCR = 1.6×10^{-4}, 30% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 5.0×10^{-5}, 9.3% contribution) where the EPC (2.6 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-222 when contribution from arsenic is not included.

The HI for well 199-K-222 is 1.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.43, 28% contribution), fluoride (HQ = 0.15, 9.7% contribution), Cr(VI) (HQ = 0.44, 28% contribution), and nitrate (HQ = 0.17, 11% contribution). The HI for well 199-K-222 without contribution from arsenic is 1.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia

Exposure to each of the analytes that contribute to the HI of 1.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-222 are shown in Table 6-94. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 57 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-94. Summary of Well 199-K-222 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	215	2,000	0.11
Strontium-90	pCi/L	113	8	14.1
Tritium	pCi/L	403	20,000	0.02
			Sum of Fractions	14.2
			Cumulative Annual Dose (mrem)	56.9

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-31. Table 6-95 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-31. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-138 and G-139).

Table 6-95. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-31 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	5.1×10^{-5}	Arsenic (ELCR = 4.9×10^{-5}, 7.1%) Carbon-14 (ELCR = 5.1×10^{-4}, 74%) Chloroform (ELCR = 1.5×10^{-6}, 0.21%) Trichloroethene (ELCR = 5.1×10^{-6}, 0.75%) Tritium (ELCR = 1.2×10^{-4}, 17%)	11	Arsenic (HQ = 0.42, 3.4%) Bromomethane (HQ = 0.13, 1.0%) Fluoride (HQ = 0.17, 1.4%) Hexavalent chromium (HQ = 0.15, 1.2%) Lithium (HQ = 0.43, 3.5%) Nitrate (HQ = 0.18, 1.5%) Thallium (HQ = 9.0, 74%) Trichloroethene (HQ = 1.3, 10%) Vanadium (HQ = 0.15, 1.2%)
	Dermal Contact	6.2×10^{-7}		0.17	
	Inhalation of Volatiles	4.0×10^{-6}		0.96	
	Total Risk	**5.5×10^{-5}**		**Total HI**	**12**
Radionuclides	**Ingestion**	1.8×10^{-5}		--	
	Immersion	7.5×10^{-14}			
	Inhalation of Volatiles	6.1×10^{-4}			
	Total Risk	**6.3×10^{-4}**			
Total Cumulative ELCR		**6.8×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-31 is 6.8×10^{-4}. The total ELCR for nonradiological analytes is 5.5×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 6.3×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 5.1×10^{-4}, 74% contribution), chloroform (ELCR = 1.5×10^{-6}, 0.21% contribution), TCE (ELCR = 5.1×10^{-6}, 0.75% contribution), and tritium (ELCR = 1.2×10^{-4}, 17% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.9×10^{-5}, 7.1% contribution) where the EPC (2.5 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-31 without

contribution from arsenic is 6.6×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-31 is 12, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.42, 3.4% contribution), bromomethane (HQ = 0.13, 1.0% contribution), fluoride (HQ = 0.17, 1.4% contribution), Cr(VI) (HQ = 0.15, 1.2% contribution), lithium (HQ = 0.43, 3.5% contribution), nitrate (HQ = 0.18, 1.5% contribution), thallium (HQ = 9.0, 74% contribution), TCE (HQ = 1.3, 10% contribution), and vanadium (HQ = 0.15, 1.2% contribution). Contribution to HI is elevated for thallium (HQ = 9.0) where the EPC (1.8 µg/L) is greater than the range of background concentrations (minimum, maximum, and 90th percentile) of 0.883, 1.73, and 1.67 µg/L for filtered groundwater samples. Thallium was detected in one of 17 unfiltered samples and 1 of 17 filtered samples from this well. The presence of thallium is likely naturally occurring due to the sporadic nature of the detections. The HI for well 199-K-31 without contribution from arsenic and thallium is 2.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 2.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 0.27, which is less than the target HI of 1. TCE reports an individual HQ of 1.3, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-31 are shown in Table 6-96 The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.0 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-96. Summary of Well 199-K-31 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	362	2,000	0.18
Strontium-90	pCi/L	1.2	8	0.15
Technetium-99	pCi/L	69.6	900	0.077
Tritium	pCi/L	1,710	20,000	0.086
			Sum of Fractions	0.49
			Cumulative Annual Dose (mrem)	2.0

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-37. Table 6-97 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-37. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-140 and G-141).

Table 6-97. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-37 – Monitoring Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	7.2×10^{-5}	Arsenic (ELCR = 7.2×10^{-5}, 57%) Bis(2-ethylhexyl) phthalate (ELCR = 1.4×10^{-5}, 11%) Chloroform (ELCR = 2.5×10^{-6}, 2.0%)	1.8	Arsenic (HQ = 0.62, 28%) Bis(2-ethylhexyl) phthalate (HQ = 0.18, 8.0%) Fluoride (HQ = 0.14, 6.3%) Hexavalent chromium (HQ = 0.73, 33%) Lithium (HQ = 0.15, 6.8%) Vanadium (HQ = 0.15, 6.8%)
	Dermal Contact	1.4×10^{-5}		0.39	
	Inhalation of Volatiles	2.3×10^{-6}		< 0.01	
	Total Risk	**8.8×10^{-5}**		**Total HI**	**2.2**
Radionuclides	Ingestion	8.8×10^{-6}		--	
	Immersion	3.4×10^{-13}			
	Inhalation of Volatiles	3.0×10^{-5}			
	Total Risk	**3.8×10^{-5}**			
Total Cumulative ELCR		**1.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-37 is 1.3×10^{-4}. The total ELCR for nonradiological analytes is 8.8×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.8×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

The major contributors to the total cumulative ELCR are bis(2-ethylhexyl) phthalate (ELCR = 1.4×10^{-5}, 11% contribution) and chloroform (ELCR = 2.5×10^{-6}, 2.0% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.2×10^{-5}, 57% contribution) where the EPC (3.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. Bis(2-ethylhexyl) phthalate was detected in one of two samples collected, the single occurrence (1.2 µg/L) was reported with a "J" flag indicating that it is an estimated concentration. Additionally, bis(2-ethylhexyl) phthalate is a common laboratory contaminant that is introduced in the laboratory and is not associated with a site release or groundwater plume. The nonradiological ELCR for well 199-K-37 without contribution from arsenic and bis(2-ethylhexyl)

phthalate is 2.5×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-37 is 2.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.62, 28% contribution), bis(2-ethylhexyl) phthalate (HQ = 0.18, 8.0% contribution), fluoride (HQ = 0.14, 6.3% contribution), Cr(VI) (HQ = 0.73, 33% contribution), lithium (HQ = 0.15, 6.8% contribution), and vanadium (HQ = 0.15, 6.8% contribution). The HI for well 199-K-37 without contribution from arsenic and bis(2-ethylhexyl) phthalate is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-37 are shown in Table 6-98. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.9 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-98. Summary of Well 199-K-37 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	4.5	2,000	0.0022
Strontium-90	pCi/L	3.7	8	0.46
Tritium	pCi/L	345	20,000	0.017
			Sum of Fractions	0.48
			Cumulative Annual Dose (mrem)	1.9

DWS = drinking water standard
EPC = exposure point concentration

Well 699-72-73. Table 6-99 provides a summary of the cancer risks and noncancer hazards by exposure route for well 699-72-73. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-142 and G-143).

The total cumulative ELCR for well 699-72-73 is 8.9×10^{-4}. The total ELCR for nonradiological analytes is 8.5×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.0×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-99. Summary of Cancer Risks and Noncancer Hazards for Well 699-72-73 – Monitoring Well Screened Across Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	8.3×10^{-5}	Arsenic (ELCR = 8.3×10^{-5}, 9.4%) Trichloroethene (ELCR = 1.4×10^{-6}, 0.16%) Tritium (ELCR = 8.0×10^{-4}, 90%)	6.6	Arsenic (HQ = 0.72, 10%) Bromomethane (HQ = 0.13, 1.8%) Fluoride (HQ = 0.32, 4.5%) Hexavalent chromium (HQ = 0.17, 2.5%) Lithium (HQ = 0.48, 6.8%) Nitrate (HQ = 0.15, 2.1%) Thallium (HQ = 4.3, 61%) Trichloroethene (HQ = 0.35, 4.9%) Vanadium (HQ = 0.17, 2.5%)
	Dermal Contact	5.4×10^{-7}		0.12	
	Inhalation of Volatiles	7.2×10^{-7}		0.33	
	Total Risk	**8.5×10^{-5}**		Total HI	**7.0**
Radionuclides	Ingestion	1.3×10^{-5}		--	
	Immersion	1.4×10^{-14}			
	Inhalation of Volatiles	7.9×10^{-4}			
	Total Risk	**8.0×10^{-4}**			
Total Cumulative ELCR		**8.9×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributors to the total cumulative ELCR are TCE (ELCR = 1.4×10^{-6}, 0.16% contribution) and tritium (ELCR = 8.0×10^{-4}, 90% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 8.3×10^{-5}, 9.4% contribution) where the EPC (4.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 699-72-73 without contribution from arsenic is 1.4×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 699-72-73 is 7.0, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.72, 10% contribution), bromomethane (HQ = 0.13, 1.8% contribution), fluoride (HQ = 0.32, 4.5% contribution), Cr(VI) (HQ = 0.17, 2.5% contribution), lithium (HQ = 0.48, 6.8% contribution), nitrate (HQ = 0.15, 2.1% contribution), thallium

(HQ = 4.3, 61% contribution), TCE (HQ = 0.35, 4.9% contribution), and vanadium (HQ = 0.17, 2.5% contribution). Contribution to HI is elevated for thallium (HQ = 4.3) where the EPC (0.86 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 699-72-73 without contribution from arsenic and thallium is 2.0, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 2.0 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 0.30, which is less than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 699-72-73 are shown in Table 6-100. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.5 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-100. Summary of Well 699-72-73 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Technetium-99	pCi/L	34.5	900	0.038
Tritium	pCi/L	116,000	20,000	0.58
			Sum of Fractions	0.62
			Cumulative Annual Dose (mrem)	2.5

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.4 Combined Wells 199-K-35, 199-K-195, 199-K-205 Screened Across the Upper Unconfined Aquifer

Across the upper unconfined aquifer, one combined well is screened. A summary of the cancer risks and noncancer hazards by exposure route for the combined well screened across the upper unconfined aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-144 and G-145).

Well 199-K-35, K-195, K-205. Table 6-101 provides a summary of the cancer risks and noncancer hazards by exposure route for wells 199-K-35, K-195, K-205.

Table 6-101. Summary of Cancer Risks and Noncancer Hazards for Wells 199-K-35, 199-K-195, and 199-K-205 – Combined Wells Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	8.1×10^{-5}	Arsenic (ELCR = 7.8×10^{-5}, 13%) Carbon-14 (ELCR = 4.2×10^{-4}, 69%) Chloroform (ELCR = 1.8×10^{-6}, 0.29%) Trichloroethene (ELCR = 6.7×10^{-6}, 1.1%)	8.6	Arsenic (HQ = 0.67, 5.5%) Fluoride (HQ = 0.20, 1.7%) Hexavalent chromium (HQ = 9.0, 74%) Nitrate (HQ = 0.21, 1.7%) Silver (HQ = 0.10, 0.79%) Trichloroethene (HQ = 1.7, 14%) Vanadium (HQ = 0.12, 0.99%)
	Dermal Contact	8.9×10^{-7}		2.4	
	Inhalation of Volatiles	5.1×10^{-6}		1.1	
	Total Risk	**8.7×10^{-5}**		**Total HI**	**12**
Radionuclides	**Ingestion**	1.8×10^{-5}		--	
	Immersion	1.2×10^{-13}			
	Inhalation of Volatiles	5.0×10^{-4}			
	Total Risk	**5.2×10^{-4}**			
Total Cumulative ELCR		6.1×10^{-4}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-35, K-195, K-205 is 6.1×10^{-4}. The total ELCR for nonradiological analytes is 8.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 4.2×10^{-4}, 69% contribution), chloroform (ELCR = 1.8×10^{-6}, 0.29% contribution), and TCE (ELCR = 6.7×10^{-6}, 1.1% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.8×10^{-5}, 13% contribution) where the EPC (4.0 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-35, K-195, K-205 without contribution from arsenic is 8.5×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-35, K-195, K-205 is 12, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.67, 5.5% contribution), fluoride (HQ = 0.20, 1.7% contribution), Cr(VI) (HQ = 9.0, 74% contribution), nitrate (HQ = 0.21, 1.7%

contribution), silver (HQ = 0.10, 0.79% contribution), TCE (HQ = 1.7, 14% contribution), and vanadium (HQ = 0.12, 0.99% contribution). The HI for well 199-K-35, K-195, K-205 without contribution from arsenic is 12, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Silver: argyria (dermal)
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of silver and vanadium, exposure to each of the analytes that contribute to the HI of 12 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for silver and vanadium results in a HI of 0.22, which is less than the target HI of 1. Cr(VI) and TCE report individual HQs of 9 and 1.7 respectively, which are greater than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-35, 199-K-195, and 199-K-205 are shown in Table 6-102. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.6 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-102. Summary of Well 199-K-35, 199-K-195, 199-K-205 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	301	2,000	0.15
Strontium-90	pCi/L	2.7	8	0.34
Technetium-99	pCi/L	75.6	900	0.084
Tritium	pCi/L	1,330	20,000	0.066
			Sum of Fractions	**0.64**
			Cumulative Annual Dose (mrem)	**2.6**

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.5 Extraction Wells Screened Across the Upper Unconfined Aquifer

Across the upper unconfined aquifer, nine extraction wells are screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the upper unconfined aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-146 through G-163).

Well 199-K-113A. Table 6-103 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-113A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-146 and G-147).

Table 6-103. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-113A – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	2.7×10^{-5}	Arsenic (ELCR = 2.7×10^{-5}, 21%)	**0.96**	Arsenic (HQ = 0.24, 24%) Uranium (HQ = 0.45, 45%)
	Dermal Contact	1.5×10^{-7}		**0.03**	
	Inhalation of Volatiles	--		--	
	Total Risk	**2.7×10^{-5}**		**Total HI**	1.0
Radionuclides	**Ingestion**	1.0×10^{-5}		--	
	Immersion	1.7×10^{-13}			
	Inhalation of Volatiles	9.2×10^{-5}			
	Total Risk	**1.0×10^{-4}**			
Total Cumulative ELCR		**1.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-113A is 1.3×10^{-4}. The total ELCR for nonradiological analytes is 2.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.0×10^{-4}, which is equal to the EPA upper risk threshold of 1×10^{-4}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 2.7×10^{-5}, 21% contribution) where the EPC (1.4 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-113A when contribution from arsenic is not included.

The HI for well 199-K-113A is 1.0, which is equal to the MTCA (WAC 173-340-708(5)) target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-113A are shown in Table 6-104. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 3.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-104. Summary of Well 199-K-113A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	25	2,000	0.012
Strontium-90	pCi/L	6	8	0.75
Tritium	pCi/L	840	20,000	0.042
			Sum of Fractions	0.81
			Cumulative Annual Dose (mrem)	3.2

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-114A. Table 6-105 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-114A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-148 and G-149).

Table 6-105. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-114A – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.6×10^{-5}	Arsenic ($ELCR = 1.6\times10^{-5}$, 55%)	0.32	--
	Dermal Contact	8.5×10^{-8}		0.02	
	Inhalation of Volatiles	--		--	
	Total Risk	**1.6×10^{-5}**		**Total HI**	**0.33**
Radionuclides	**Ingestion**	1.3×10^{-5}		--	
	Immersion	2.5×10^{-13}			
	Inhalation of Volatiles	--			
	Total Risk	**1.3×10^{-5}**			
Total Cumulative ELCR		**2.9×10^{-5}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-114A is 2.9×10^{-5}. The total ELCR for nonradiological analytes is 1.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.3×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 1.6×10^{-5}, 55% contribution) where the EPC (0.83 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-114A when contribution from arsenic is not included.

The HI for well 199-K-114A is 0.33, which is less than the MTCA (WAC 173-340-708(5)) target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-114A are shown in Table 6-106. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 4.6 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-106. Summary of Well 199-K-114A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	9.2	8	1.1
			Sum of Fractions	1.1
			Cumulative Annual Dose (mrem)	4.6

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-141. Table 6-107 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-141. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-150 and G-151).

The total cumulative ELCR for well 199-K-141 is 8.3×10^{-4}. The total ELCR for nonradiological analytes is 7.3×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 7.6×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.5×10^{-4}, 42% contribution) and tritium (ELCR = 3.5×10^{-4}, 42% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.3×10^{-5}, 8.8% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-141 when contribution from arsenic is not included.

The HI for well 199-K-141 is 1.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.63, 35% contribution), fluoride (HQ = 0.12, 6.9% contribution), Cr(VI) (HQ = 0.65, 36% contribution), nitrate (HQ = 0.10, 5.3% contribution), and vanadium (HQ = 0.12, 6.7% contribution). The HI for well 199-K-141 without contribution from arsenic is 1.2, which is greater than the target HI of 1.

Table 6-107. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-141 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	7.3×10^{-5}	Arsenic (ELCR = 7.3×10^{-5}, 8.8%) Carbon-14 (ELCR = 3.5×10^{-4}, 42%) Tritium (ELCR = 3.5×10^{-4}, 42%)	1.6	Arsenic (HQ = 0.63, 35%) Fluoride (HQ = 0.12, 6.9%) Hexavalent chromium (HQ = 0.65, 36%) Nitrate (HQ = 0.10, 5.3%) Vanadium (HQ = 0.12, 6.7%)
	Dermal Contact	3.9×10^{-7}		0.19	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.3×10^{-5}**		**Total HI**	**1.8**
Radionuclides	Ingestion	7.9×10^{-5}		--	
	Immersion	8.1×10^{-12}			
	Inhalation of Volatiles	6.8×10^{-4}			
	Total Risk	**7.6×10^{-4}**			
Total Cumulative ELCR		**8.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-141 are shown in Table 6-108. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 25 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-108. Summary of Well 199-K-141 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	249	2,000	0.12
Cesium-137	pCi/L	1.9	200	0.01
Strontium-90	pCi/L	45.7	8	5.7
Technetium-99	pCi/L	9.7	900	0.011
Tritium	pCi/L	4,990	20,000	0.25
			Sum of Fractions	6.1
			Cumulative Annual Dose (mrem)	24.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-144. Table 6-109 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-144. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-152 and G-153).

The total cumulative ELCR for well 199-K-144 is 2.1×10^{-3}. The total ELCR for nonradiological analytes is 7.2×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.1×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 2.0×10^{-3}, 94% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.2×10^{-5}, 3.3% contribution) where the EPC (3.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-144 when contribution from arsenic is not included.

The HI for well 199-K-144 is 1.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.62, 32% contribution), fluoride (HQ = 0.14, 7.2% contribution), Cr(VI) (HQ = 0.69, 36% contribution), nickel (HQ = 0.14, 7.1% contribution), nitrate (HQ = 0.12, 6.1% contribution), and vanadium (HQ = 0.16, 8.2% contribution). The HI for well 199-K-144 without contribution from arsenic is 1.3, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nickel: decreased body and organ weights
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Table 6-109. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-144 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.1×10^{-5}	Arsenic (ELCR = 7.2×10^{-5}, 3.3%) Tritium (ELCR = 2.0×10^{-3}, 94%)	1.7	Arsenic (HQ = 0.62, 32%) Fluoride (HQ = 0.14, 7.2%) Hexavalent chromium (HQ = 0.69, 36%) Nickel (HQ = 0.14, 7.1%) Nitrate (HQ = 0.12, 6.1%) Vanadium (HQ = 0.16, 8.2%)
	Dermal Contact	3.8×10^{-7}		0.21	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.2×10^{-5}**		**Total HI**	**1.9**
Radionuclides	**Ingestion**	3.4×10^{-5}		--	
	Immersion	9.1×10^{-14}			
	Inhalation of Volatiles	2.0×10^{-3}			
	Total Risk	**2.1×10^{-3}**			
Total Cumulative ELCR		**2.1×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Exposure to each of the analytes that contribute to the HI of 1.3 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-144 are shown in Table 6-110. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 7.55 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-110. Summary of Well 199-K-144 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	43.9	2,000	0.022
Strontium-90	pCi/L	3.2	8	0.4
Tritium	pCi/L	29,000	20,000	1.4
			Sum of Fractions	1.9
			Cumulative Annual Dose (mrem)	7.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-146. Table 6-111 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-146. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-154 and G-155).

Table 6-111. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-146 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	--	--	0.48	--
	Dermal Contact	--		0.09	
	Inhalation of Volatiles	--		--	
	Total Risk	--		Total HI	**0.57**
Radionuclides	Ingestion	--		--	
	Immersion	--			
	Inhalation of Volatiles	--			
	Total Risk	--			
Total Cumulative ELCR		--			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

There were no radiological or carcinogenic nonradiological analytes measured in well 199-K-146; therefore, cancer risks are not reported for this well.

The HI for well 199-K-146 is 0.57, which is less than the MTCA (WAC 173-340-708(5)) target HI of 1.

No beta- or photon emitters were measured in well 199-K-146, therefore a sum of fraction calculation is not applicable.

Well 199-K-147. Table 6-112 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-147. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-156 and G-157).

The total cumulative ELCR for well 199-K-147 is 1.6×10^{-4}. The total ELCR for nonradiological analytes is 4.3×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 4.3×10^{-5}, 27% contribution) where the EPC (2.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-147 when contribution from arsenic is not included.

The HI for well 199-K-147 is 1.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.37, 28% contribution), fluoride (HQ = 0.15, 12% contribution), Cr(VI) (HQ = 0.48, 36% contribution), and vanadium (HQ = 0.13, 9.7% contribution). The HI for well 199-K-147 without contribution from arsenic is 0.97, which is less than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-147 are shown in Table 6-113. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 4.6 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-112. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-147 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	4.2×10^{-5}	Arsenic (ELCR = 4.3×10^{-5}, 27%)	1.2	Arsenic (HQ = 0.37, 28%) Fluoride (HQ = 0.15, 12%) Hexavalent chromium (HQ = 0.48, 36%) Vanadium (HQ = 0.13, 9.7%)
	Dermal Contact	2.3×10^{-7}		0.15	
	Inhalation of Volatiles	--		--	
	Total Risk	**4.3×10^{-5}**		**Total HI**	**1.3**
Radionuclides	**Ingestion**	1.4×10^{-5}		--	
	Immersion	2.4×10^{-13}			
	Inhalation of Volatiles	1.0×10^{-4}			
	Total Risk	**1.2×10^{-4}**			
Total Cumulative ELCR		**1.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Table 6-113. Summary of Well 199-K-147 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	26.7	2,000	0.013
Strontium-90	pCi/L	8.8	8	1.1
Tritium	pCi/L	958	20,000	0.048
Sum of Fractions				1.2
Cumulative Annual Dose (mrem)				4.6

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-148. Table 6-114 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-148. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-158 and G-159).

The total cumulative ELCR for well 199-K-148 is 3.2×10^{-4}. The total ELCR for nonradiological analytes is 1.0×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 1.7×10^{-4}, 52% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.0×10^{-4}, 31% contribution) where the EPC (5.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-148 when contribution from arsenic is not included.

The HI for well 199-K-148 is 2.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.87, 39% contribution), fluoride (HQ = 0.24, 11% contribution), Cr(VI) (HQ = 0.76, 34% contribution), nitrate (HQ = 0.11, 4.8% contribution), and vanadium (HQ = 0.19, 8.5% contribution). The HI for well 199-K-148 without contribution from arsenic is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-148 are shown in Table 6-115. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.66 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-114. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-148 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.0×10^{-4}	Arsenic (ELCR = 1.0×10^{-4}, 31%) Tritium (ELCR = 1.7×10^{-4}, 52%)	2.0	Arsenic (HQ = 0.87, 39%) Fluoride (HQ = 0.24, 11%) Hexavalent chromium (HQ = 0.76, 34%) Nitrate (HQ = 0.11, 4.8%) Vanadium (HQ = 0.19, 8.5%)
	Dermal Contact	5.3×10^{-7}		0.23	
	Inhalation of Volatiles	--		--	
	Total Risk	**1.0×10^{-4}**		**Total HI**	**2.2**
Radionuclides	**Ingestion**	4.7×10^{-6}		--	
	Immersion	1.1×10^{-14}			
	Inhalation of Volatiles	2.1×10^{-4}			
	Total Risk	**2.2×10^{-4}**			
Total Cumulative ELCR		**3.2×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Table 6-115. Summary of Well 199-K-148 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	36	2,000	0.018
Technetium-99	pCi/L	24	900	0.027
Tritium	pCi/L	2,420	20,000	0.12
			Sum of Fractions	0.17
			Cumulative Annual Dose (mrem)	0.66

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-161. Table 6-116 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-161. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-160 and G-161).

Table 6-116. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-161 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	3.3×10^{-5}	Arsenic (ELCR = 3.3×10^{-5}, 58%)	7.8	Arsenic (HQ = 0.29, 3.6%) Hexavalent chromium (HQ = 0.17, 2.1%) Thallium (HQ = 7.0, 89%)
	Dermal Contact	1.8×10^{-7}		0.09	
	Inhalation of Volatiles	--		--	
	Total Risk	**3.3×10^{-5}**		**Total HI**	**7.9**
Radionuclides	**Ingestion**	1.5×10^{-5}		--	
	Immersion	3.5×10^{-13}			
	Inhalation of Volatiles	8.5×10^{-6}			
	Total Risk	**2.4×10^{-5}**			
Total Cumulative ELCR		**5.7×10^{-5}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-161 is 5.7×10^{-5}. The total ELCR for nonradiological analytes is 3.3×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.4×10^{-5}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 3.3×10^{-5}, 58% contribution) where the EPC (1.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-161 when contribution from arsenic is not included.

The HI for well 199-K-161 is 7.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.29, 3.6% contribution), Cr(VI) (HQ = 0.17, 2.1% contribution), and thallium (HQ = 7.0, 89% contribution). Contribution to HI is elevated for thallium (HQ = 7.0) where the EPC (1.4 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-161 without contribution from arsenic and thallium is 0.59, which is less than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-161 are shown in Table 6-117. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 5.0 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-117. Summary of Well 199-K-161 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	9.9	8	1.2
Tritium	pCi/L	124	20,000	0.0062
			Sum of Fractions	1.2
			Cumulative Annual Dose (mrem)	5.0

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-178. Table 6-118 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-178. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-162 and G-163).

The total cumulative ELCR for well 199-K-178 is 5.8×10^{-4}. There were no carcinogenic nonradiological analytes measured; therefore, nonradiological cancer risks are not reported for this well. The total ELCR for radiological analytes is 5.8×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 4.2×10^{-4}, 73% contribution) and tritium (ELCR = 1.5×10^{-4}, 26% contribution).

The HI for well 199-K-178 is 1.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are fluoride (HQ = 0.10, 7.8% contribution), Cr(VI) (HQ = 0.89, 72% contribution), and nitrate (HQ = 0.12, 9.3% contribution).

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia

Exposure to each of the analytes that contribute to the HI of 1.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-178 are shown in Table 6-119. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.3 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-118. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-178 – Extraction Well Screened Across the Upper Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	--	Carbon-14 (ELCR = 4.2×10^{-4}, 73%) Tritium (ELCR = 1.5×10^{-4}, 26%)	0.99	Fluoride (HQ = 0.10, 7.8%) Hexavalent chromium (HQ = 0.89, 72%) Nitrate (HQ = 0.12, 9.3%)
	Dermal Contact	--		0.24	
	Inhalation of Volatiles	--		--	
	Total Risk	--		Total HI	1.2
Radionuclides	Ingestion	1.5×10^{-5}		--	
	Immersion	8.4×10^{-14}			
	Inhalation of Volatiles	5.6×10^{-4}			
	Total Risk	**5.8×10^{-4}**			
Total Cumulative ELCR		**5.8×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Table 6-119. Summary of Well 199-K-178 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	302	2,000	0.15
Strontium-90	pCi/L	2.6	8	0.33
Tritium	pCi/L	2,180	20,000	0.11
			Sum of Fractions	0.59
			Cumulative Annual Dose (mrem)	2.3

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.6 Wells Screened Across Lower Unconfined Aquifer.

Across the lower unconfined aquifer, three monitoring wells are screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the lower unconfined

aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-164 through G-169).

Well 199-K-168. Table 6-120 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-168. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-164 and G-165).

The total cumulative ELCR for well 199-K-168 is 8.5×10^{-4}. The total ELCR for nonradiological analytes is 5.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.0×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 6.9×10^{-4}, 81% contribution), chloroform (ELCR = 1.9×10^{-6}, 0.22% contribution), and TCE (ELCR = 6.3×10^{-6}, 0.74% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.8×10^{-5}, 5.7% contribution) where the EPC (2.5 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-168 without contribution from arsenic is 8.2×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-168 is 3.4, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.42, 12% contribution), fluoride (HQ = 0.15, 4.4% contribution), Cr(VI) (HQ = 0.80, 23% contribution), nitrate (HQ = 0.16, 4.5% contribution), TCE (HQ = 1.6, 46% contribution), and vanadium (HQ = 0.15, 4.2% contribution). The HI for well 199-K-168 without contribution from arsenic is 3.0, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 3.0 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. TCE has an HQ of 1.6, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-168 are shown in Table 6-121. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 3.3 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-120. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-168 – Monitoring Well Screened Across Lower Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	5.1×10^{-5}	Arsenic (ELCR = 4.8×10^{-5}, 5.7%) Carbon-14 (ELCR = 6.9×10^{-4}, 81%) Chloroform (ELCR = 1.9×10^{-6}, 0.22%) Trichloroethene (ELCR = 6.3×10^{-6}, 0.74%)	2.0	Arsenic (HQ = 0.42, 12%) Fluoride (HQ = 0.15, 4.4%) Hexavalent chromium (HQ = 0.80, 23%) Nitrate (HQ = 0.16, 4.5%) Trichloroethene (HQ = 1.6, 46%) Vanadium (HQ = 0.15, 4.2%)
	Dermal Contact	7.0×10^{-7}		0.31	
	Inhalation of Volatiles	5.0×10^{-6}		1.1	
	Total Risk	**5.7×10^{-5}**		Total HI	3.4
Radionuclides	**Ingestion**	2.4×10^{-5}		--	
	Immersion	1.4×10^{-13}			
	Inhalation of Volatiles	7.7×10^{-4}			
	Total Risk	**8.0×10^{-4}**			
Total Cumulative ELCR		**8.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Table 6-121. Summary of Well 199-K-168 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	492	2,000	0.25
Strontium-90	pCi/L	3.7	8	0.46
Technetium-99	pCi/L	49.3	900	0.055
Tritium	pCi/L	1,450	20,000	0.072
			Sum of Fractions	0.84
			Cumulative Annual Dose (mrem)	3.3

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-184. Table 6-122 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-184. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-166 and G-167).

The total cumulative ELCR for well 199-K-184 is 9.9×10^{-4}. The total ELCR for nonradiological analytes is 7.1×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-122. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-184 – Monitoring Well Screened Across Lower Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	6.6×10^{-5}	Arsenic (ELCR = 6.3×10^{-5}, 6.4%) Carbon-14 (ELCR = 8.1×10^{-4}, 82%) Chloroform (ELCR = 1.7×10^{-6}, 0.17%) Trichloroethene (ELCR = 5.7×10^{-6}, 0.58%) Tritium (ELCR = 9.8×10^{-5}, 9.9%)	2.0	Arsenic (HQ = 0.55, 17%) Fluoride (HQ = 0.14, 4.4%) Hexavalent chromium (HQ = 0.34, 11%) Nitrate (HQ = 0.16, 5.0%) Nitrite (HQ = 0.17, 5.2%) Trichloroethene (HQ = 1.4, 45%) Vanadium (HQ = 0.15, 4.7%)
	Dermal Contact	7.4×10^{-7}		0.18	
	Inhalation of Volatiles	4.4×10^{-6}		1.0	
	Total Risk	**7.1×10^{-5}**		**Total HI**	**3.2**
Radionuclides	**Ingestion**	2.4×10^{-5}		--	
	Immersion	1.8×10^{-13}			
	Inhalation of Volatiles	8.9×10^{-4}			
	Total Risk	**9.2×10^{-4}**			
Total Cumulative ELCR		**9.9×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 8.1×10^{-4}, 82% contribution), chloroform (ELCR = 1.7×10^{-6}, 0.17% contribution), TCE (ELCR = 5.7×10^{-6}, 0.58% contribution), and tritium (ELCR = 9.8×10^{-5}, 9.9% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.3×10^{-5}, 6.4% contribution) where the EPC (3.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-184 without contribution from arsenic is 7.4×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-184 is 3.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.55, 17% contribution), fluoride (HQ = 0.14, 4.4% contribution), Cr(VI) (HQ = 0.34, 11% contribution), nitrate (HQ = 0.16, 5.0% contribution), nitrite (HQ = 0.17, 5.2% contribution), TCE (HQ = 1.4, 45% contribution), and vanadium (HQ = 0.15, 4.7% contribution). The HI for well 199-K-184 without contribution from arsenic is 2.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Nitrite: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of nitrite and nitrate, exposure to each of the analytes that contribute to the HI of 2.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for nitrite and nitrate results in an HI of 0.32, which is less than the target HI of 1. TCE reports an individual HQ of 1.4, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-184 are shown in Table 6-123. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.1 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-123. Summary of Well 199-K-184 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	581	2,000	0.29
Strontium-90	pCi/L	0.92	8	0.12
Technetium-99	pCi/L	39.8	900	0.044
Tritium	pCi/L	1,410	20,000	0.071
			Sum of Fractions	0.52
			Cumulative Annual Dose (mrem)	2.1

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-190. Table 6-124 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-190. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-168 and G-170).

Table 6-124. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-190 – Monitoring Well Screened Across Lower Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	9.2×10^{-5}	Arsenic (ELCR = 8.9×10^{-5}, 20%) Carbon-14 (ELCR = 2.9×10^{-4}, 66%) Chloroform (ELCR = 2.7×10^{-6}, 0.61%) Trichloroethene (ELCR = 7.6×10^{-6}, 1.7%)	3.8	Arsenic (HQ = 0.77, 14%) Cobalt (HQ = 0.11, 2.0%) Fluoride (HQ = 0.19, 3.6%) Hexavalent chromium (HQ = 0.29, 5.5%) Nitrate (HQ = 0.24, 4.4%) Thallium (HQ = 1.4, 26%) Trichloroethene (HQ = 1.9, 36%) Vanadium (HQ = 0.18, 3.4%)
	Dermal Contact	1.0×10^{-6}		0.20	
	Inhalation of Volatiles	6.4×10^{-6}		1.3	
	Total Risk	**1.0×10^{-4}**		**Total HI**	**5.3**
Radionuclides	**Ingestion**	1.0×10^{-5}		--	
	Immersion	6.0×10^{-14}			
	Inhalation of Volatiles	3.3×10^{-4}			
	Total Risk	**3.4×10^{-4}**			
Total Cumulative ELCR		**4.4×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-190 is 4.4×10^{-4}. The total ELCR for nonradiological analytes is 1.0×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.4×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 2.9×10^{-4}, 66% contribution), chloroform (ELCR = 2.7×10^{-6}, 0.61% contribution), and TCE (ELCR = 7.6×10^{-6}, 1.7% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 8.9×10^{-5}, 20% contribution) where the EPC (4.6 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-190 without contribution from arsenic is 1.0×10^{-5}, which is equal to the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-190 is 5.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.77, 14% contribution), cobalt (HQ = 0.11,

2.0% contribution), fluoride (HQ = 0.19, 3.6% contribution), Cr(VI) (HQ = 0.29, 5.5% contribution), nitrate (HQ = 0.24, 4.4% contribution), thallium (HQ = 1.4, 26% contribution), TCE (HQ = 1.9, 36% contribution), and vanadium (HQ = 0.18, 3.4% contribution). Contribution to HI is elevated for thallium (HQ = 1.4) where the EPC (0.28 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L The HI for well 199-K-190 without contribution from arsenic and thallium is 3.2, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 3.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. TCE reports an individual HQ of 1.9, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-190 are shown in Table 6-125. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.4 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-125. Summary of Well 199-K-190 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	208	2,000	0.1
Strontium-90	pCi/L	1.4	8	0.17
Technetium-99	pCi/L	32.4	900	0.036
Tritium	pCi/L	681	20,000	0.034
			Sum of Fractions	0.35
			Cumulative Annual Dose (mrem)	1.4

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.7 Well Screened Across the Upper and Lower Unconfined Aquifer

Across the upper and lower unconfined aquifer, one monitoring well is screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the upper and lower unconfined aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Table G-170 through G-171).

Well 199-K-193. Table 6-126 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-193.

Table 6-126. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-193 – Monitoring Well Screened Across Upper and Lower Unconfined Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.4×10^{-5}	Arsenic ($ELCR = 9.4\times10^{-5}$, 46%) Chloroform ($ELCR = 1.5\times10^{-6}$, 0.72%) Ethylbenzene ($ELCR = 1.7\times10^{-6}$, 0.82%)	14	Arsenic (HQ = 0.81, 5.9%) Fluoride (HQ = 0.24, 1.7%) Hexavalent chromium (HQ = 0.52, 3.8%) Thallium (HQ = 12, 84%) Vanadium (HQ = 0.15, 1.1%)
	Dermal Contact	7.1×10^{-7}		0.22	
	Inhalation of Volatiles	2.4×10^{-6}		0.02	
	Total Risk	**9.7×10^{-5}**		**Total HI**	**14**
Radionuclides	Ingestion	4.0×10^{-6}		--	
	Immersion	5.0×10^{-14}			
	Inhalation of Volatiles	1.0×10^{-4}			
	Total Risk	**1.1×10^{-4}**			
Total Cumulative ELCR		**2.0×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-193 is 2.0×10^{-4}. The total ELCR for nonradiological analytes is 9.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.1×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are chloroform ($ELCR = 1.5\times10^{-6}$, 0.72% contribution) and ethylbenzene ($ELCR = 1.7\times10^{-6}$, 0.82% contribution). Contribution to ELCR is elevated for arsenic ($ELCR = 9.4\times10^{-5}$, 46% contribution) where the EPC (4.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-193 without contribution from arsenic is 3.1×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-193 is 14, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.81, 5.9% contribution), fluoride (HQ = 0.24, 1.7% contribution), Cr(VI) (HQ = 0.52, 3.8% contribution), thallium (HQ = 12, 84% contribution), and vanadium (HQ = 0.15, 1.1% contribution). Contribution to HI is elevated for thallium (HQ = 12) where the EPC (2.3 µg/L) is greater than the range of background concentrations (minimum,

maximum, and 90th percentile) of 0.883, 1.73, and 1.67 µg/L for filtered groundwater samples. Thallium was detected in one of 21 unfiltered samples and two of 21 filtered samples (both less than background) from this well. The presence of thallium is likely naturally occurring due to the sporadic nature of the detections. The HI for well 199-K-193 without contribution from arsenic and thallium is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating the analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-193 are shown in Table 6-127. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-127. Summary of Well 199-K-193 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	1.8	8	0.23
Tritium	pCi/L	1,490	20,000	0.074
			Sum of Fractions	0.3
			Cumulative Annual Dose (mrem)	1.2

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.8 Monitoring Wells Screened Across Entire Aquifer

Across the entire aquifer, nine monitoring wells are screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the entire aquifer follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-172 through G-189).

Well 199-K-151. Table 6-128 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-151. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-172 and G-173).

The total cumulative ELCR for well 199-K-151 is 1.1×10^{-3}. The total ELCR for nonradiological analytes is 8.6×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.0×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-128. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-151 – Monitoring Wells Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.3×10^{-4}	Aldrin (ELCR = 6.0×10^{-4}, 57%) Arsenic (ELCR = 1.0×10^{-4}, 9.5%) Bis(2-ethylhexyl) phthalate (ELCR = 1.3×10^{-4}, 12%) Bromodichloromethane (ELCR = 1.2×10^{-6}, 0.11%) Chloroform (ELCR = 2.3×10^{-5}, 2.2%) Tritium (ELCR = 1.6×10^{-4}, 15%)	2.5	2-Propanol (HQ = 0.18, 2.4%) Aldrin (HQ = 3.5, 45%) Arsenic (HQ = 0.86, 11%) Bis(2-ethylhexyl) phthalate (HQ = 1.6, 21%) Fluoride (HQ = 0.27, 3.5%) Hexavalent chromium (HQ = 0.29, 3.7%) Lithium (HQ = 0.20, 2.5%) Vanadium (HQ = 0.26, 3.3%)
	Dermal Contact	6.0×10^{-4}		5.1	
	Inhalation of Volatiles	1.3×10^{-4}		0.25	
	Total Risk	**8.6×10^{-4}**		**Total HI**	**7.8**
Radionuclides	Ingestion	9.1×10^{-6}		--	
	Immersion	1.9×10^{-13}			
	Inhalation of Volatiles	1.9×10^{-4}			
	Total Risk	**2.0×10^{-4}**			
Total Cumulative ELCR		**1.1×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributors to the total cumulative ELCR are aldrin (ELCR = 6.0×10^{-4}, 57% contribution), bis(2-ethylhexyl) phthalate (ELCR = 1.3×10^{-4}, 12% contribution), bromodichloromethane (ELCR = 1.2×10^{-6}, 0.11% contribution), chloroform (ELCR = 2.3×10^{-5}, 2.2% contribution), and tritium (ELCR = 1.6×10^{-4}, 15% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.0×10^{-4}, 9.5% contribution) where the EPC (5.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-151 without contribution from arsenic is 7.6×10^{-4}, which is greater than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Aldrin was detected in one of three samples (0.12 µg/L) collected from well 199-K-151 between June 2010 and January 2011. Biological controls including pesticides and herbicides are applied on the Hanford Site to prevent the spread of contamination by biological vectors and comply with environmental, safety, health and quality principals. The presence of aldrin is likely from application of biological controls and not associated with a groundwater plume.

Bis(2-ethylhexyl) phthalate was detected in one of two samples (11 µg/L) collected from well 199-K-151 between September 2010 and January 2011; this result was qualified with a "J" flag by the laboratory indicating it is an estimated concentration. Bis(2-ethylhexy) phthalate is considered a common laboratory contaminant that is introduced in the laboratory and is not associated with a groundwater plume. As a result, bis(2-ethylhexyl) phthalate was likely introduced into this sample by the laboratory and is not associated with Hanford Site operations or a groundwater plume.

The HI for well 199-K-151 is 7.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.18, 2.4% contribution), aldrin (HQ = 3.5, 45% contribution), arsenic (HQ = 0.86, 11% contribution), bis(2-ethylhexyl) phthalate (HQ = 1.6, 21% contribution), fluoride (HQ = 0.27, 3.5% contribution), Cr(VI) (HQ = 0.29, 3.7% contribution), lithium (HQ = 0.20, 2.5% contribution), and vanadium (HQ = 0.26, 3.3% contribution). The HI for well 199-K-151 without contribution from arsenic is 6.9, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Aldrin: liver toxicity
- Bis(2-ethylhexyl) phthalate: increased relative liver weight
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Vanadium: decreased hair cysteine

With the exception of aldrin and bis(2-ethylhexyl) phthalate, exposure to each of the analytes that contribute to the HI of 6.9 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for aldrin and bis(2-ethylhexyl) phthalate results in an HI of 5.1, which is greater than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-151 are shown in Table 6-129. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.7 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-129. Summary of Well 199-K-151 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	24.3	2,000	0.012
Strontium-90	pCi/L	2.4	8	0.3
Technetium-99	pCi/L	7.7	900	0.0086
Tritium	pCi/L	2,280	20,000	0.11
			Sum of Fractions	0.43
			Cumulative Annual Dose (mrem)	1.7

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-157. Table 6-130 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-157. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-174 and G-175).

The total cumulative ELCR for well 199-K-157 is 5.2×10^{-3}. The total ELCR for nonradiological analytes is 1.8×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.1×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are chloroform (ELCR = 3.9×10^{-6}, 0.07% contribution) and tritium (ELCR = 5.0×10^{-3}, 95% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.7×10^{-4}, 3.3% contribution) where the EPC (9.0 µg/L) is greater than the range of natural background values for arsenic (0.5 µg/L to 8.8 µg/L). However, the EPC of 9 µg/L is less than the drinking water standard of 10 µg/L. The nonradiological ELCR for well 199-K-157 without contribution from arsenic is 3.9×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-157 is 5.8, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are antimony (HQ = 0.72, 12% contribution), arsenic (HQ = 1.5, 26% contribution), beryllium (HQ = 0.20, 3.4% contribution), cadmium (HQ = 0.54, 9.3% contribution), cobalt (HQ = 0.83, 14% contribution), fluoride (HQ = 0.13, 2.3% contribution), Cr(VI) (HQ = 0.77, 13% contribution), lithium (HQ = 0.50, 8.6% contribution), nitrate (HQ = 0.17, 2.9% contribution), and vanadium (HQ = 0.12, 2.0% contribution). The HI for well 199-K-157 without contribution from arsenic is 4.3, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Arsenic: hyperpigmentation, keratosis and possible vascular complications
- Antimony: longevity, blood glucose, and cholesterol
- Beryllium: small intestinal lesions
- Cadmium: significant proteinuria
- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of nitrate, antimony, beryllium, and fluoride, exposure to each of the analytes that contribute to the HI of 4.3 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for nitrate and antimony results in an HI of 0.89, which is less than the target HI of 1. Combining the HQs for beryllium and fluoride results in an HI of 0.33, which is less than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor. Arsenic reports an individual HQ of 1.5, which is greater than the target HI of 1.

Table 6-130. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-157 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.7×10^{-4}	Arsenic (ELCR = 1.7×10^{-4}, 3.3%) Chloroform (ELCR = 3.9×10^{-6}, 0.07%) Tritium (ELCR = 5.0×10^{-3}, 95%)	5.4	Antimony (HQ = 0.72, 12%) Arsenic (HQ = 1.5, 26%) Beryllium (HQ = 0.20, 3.4%) Cadmium (HQ = 0.54, 9.3%) Cobalt (HQ = 0.83, 14%) Fluoride (HQ = 0.13, 2.3%) Hexavalent chromium (HQ = 0.77, 13%) Lithium (HQ = 0.50, 8.6%) Nitrate (HQ = 0.17, 2.9%) Vanadium (HQ = 0.12, 2.0%)
	Dermal Contact	9.5×10^{-7}		0.37	
	Inhalation of Volatiles	3.5×10^{-6}		< 0.01	
	Total Risk	**1.8×10^{-4}**		**Total HI**	**5.8**
Radionuclides	Ingestion	7.7×10^{-5}		--	
	Immersion	8.0×10^{-14}			
	Inhalation of Volatiles	5.0×10^{-3}			
	Total Risk	**5.1×10^{-3}**			
Total Cumulative ELCR		**5.2×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-157 are shown in Table 6-131. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 16 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-131. Summary of Well 199-K-157 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	57.1	2,000	0.029
Strontium-90	pCi/L	2.1	8	0.26
Technetium-99	pCi/L	49.6	900	0.055
Tritium	pCi/L	71,700	20,000	3.6
			Sum of Fractions	3.9
			Cumulative Annual Dose (mrem)	15.7

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-185. Table 6-132 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-185. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-176 and G-177).

The total cumulative ELCR for well 199-K-185 is 3.2×10^{-3}. The total ELCR for nonradiological analytes is 7.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.1×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.1×10^{-3}, 96% contribution), chloroform (ELCR = 1.6×10^{-6}, 0.05% contribution), and TCE (ELCR = 1.0×10^{-5}, 0.31% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.3×10^{-5}, 2.0% contribution) where the EPC (3.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-185 without contribution from arsenic is 1.2×10^{-5}, which is greater than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-185 is 4.4, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.18, 4.1% contribution), arsenic (HQ = 0.54, 12% contribution), fluoride (HQ = 0.15, 3.4% contribution), Cr(VI) (HQ = 0.15, 3.4% contribution), manganese (HQ = 0.18, 4.1% contribution), nitrate (HQ = 0.26, 5.9% contribution), TCE (HQ = 2.5, 57% contribution), and vanadium (HQ = 0.14, 3.3% contribution). The HI for well 199-K-185 without contribution from arsenic is 3.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Table 6-132. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-185 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	6.7×10^{-5}	Arsenic (ELCR = 6.3×10^{-5}, 2.0%) Carbon-14 (ELCR = 3.1×10^{-3}, 96%) Chloroform (ELCR = 1.6×10^{-6}, 0.05%) Trichloroethene (ELCR = 1.0×10^{-5}, 0.31%)	2.3	2-Propanol (HQ = 0.18, 4.1%) Arsenic (HQ = 0.54, 12%) Fluoride (HQ = 0.15, 3.4%) Hexavalent chromium (HQ = 0.15, 3.4%) Manganese (HQ = 0.18, 4.1%) Nitrate (HQ = 0.26, 5.9%) Trichloroethene (HQ = 2.5, 57%) Vanadium (HQ = 0.14, 3.3%)
	Dermal Contact	1.0×10^{-6}		0.19	
	Inhalation of Volatiles	6.6×10^{-6}		1.9	
	Total Risk	**7.4×10^{-5}**		**Total HI**	**4.4**
Radionuclides	**Ingestion**	7.0×10^{-5}		--	
	Immersion	1.4×10^{-13}			
	Inhalation of Volatiles	3.1×10^{-3}			
	Total Risk	**3.1×10^{-3}**			
Total Cumulative ELCR		**3.2×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

With the exception of 2-propanol and TCE, exposure to each of the analytes that contribute to the HI of 3.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for 2-propanol and TCE results in a HI of 2.7, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-185 are shown in Table 6-133. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 5.3 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-133. Summary of Well 199-K-185 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	2,200	2,000	1.1
Strontium-90	pCi/L	1	8	0.12
Technetium-99	pCi/L	50.5	900	0.056
Tritium	pCi/L	742	20,000	0.037
			Sum of Fractions	1.3
			Cumulative Annual Dose (mrem)	5.3

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-189. Table 6-134 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-189. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-178 and G-179).

Table 6-134. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-189 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.0×10^{-4}	Arsenic (ELCR = 1.0×10^{-4}, 1.9%) Carbon-14 (ELCR = 2.7×10^{-3}, 51%) Chloroform (ELCR = 5.0×10^{-6}, 0.09%) Tritium (ELCR = 2.6×10^{-3}, 47%)	1.8	Arsenic (HQ = 0.87, 44%) Fluoride (HQ = 0.15, 7.5%) Hexavalent chromium (HQ = 0.55, 28%) Nitrate (HQ = 0.20, 10%) Vanadium (HQ = 0.13, 6.8%)
	Dermal Contact	5.7×10^{-7}		0.17	
	Inhalation of Volatiles	4.5×10^{-6}		< 0.01	
	Total Risk	**1.1×10^{-4}**		**Total HI**	**2.0**
Radionuclides	**Ingestion**	9.6×10^{-5}		--	
	Immersion	1.1×10^{-13}			
	Inhalation of Volatiles	5.2×10^{-3}			
	Total Risk	**5.3×10^{-3}**			
Total Cumulative ELCR		**5.4×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-189 is 5.4×10^{-3}. The total ELCR for nonradiological analytes is 1.1×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.3×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 2.7×10^{-3}, 51% contribution), chloroform (ELCR = 5.0×10^{-6}, 0.09% contribution), and tritium (ELCR = 2.6×10^{-3}, 47% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.0×10^{-4}, 1.9% contribution) where the EPC (5.2 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-189 without contribution from arsenic is 5.0×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-189 is 2.0, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.87, 44% contribution), fluoride (HQ = 0.15, 7.5% contribution), Cr(VI) (HQ = 0.55, 28% contribution), nitrate (HQ = 0.20, 10% contribution), and vanadium (HQ = 0.13, 6.8% contribution). The HI for well 199-K-189 without contribution from arsenic is 1.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-189 are shown in Table 6-135. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 12 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-135. Summary of Well 199-K-189 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	1,960	2,000	1
Strontium-90	pCi/L	1.1	8	0.14
Technetium-99	pCi/L	9.1	900	0.01
Tritium	pCi/L	37,100	20,000	1.9
			Sum of Fractions	3
			Cumulative Annual Dose (mrem)	11.9

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-202. Table 6-136 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-202. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-180 and G-181).

Table 6-136. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-202 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.5×10^{-5}	Arsenic (ELCR = 7.4×10^{-5}, 1.3%) Carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.04%) Carbon-14 (ELCR = 3.1×10^{-3}, 55%) Chloroform (ELCR = 4.1×10^{-6}, 0.07%) Tritium (ELCR = 2.4×10^{-3}, 43%)	5.2	Arsenic (HQ = 0.63, 12%) Cobalt (HQ = 0.10, 1.8%) Fluoride (HQ = 0.38, 6.9%) Hexavalent chromium (HQ = 0.20, 3.7%) Iron (HQ = 0.11, 2.1%) Nitrate (HQ = 0.20, 3.7%) Thallium (HQ = 3.2, 59%) Vanadium (HQ = 0.13, 2.4%)
	Dermal Contact	6.9×10^{-7}		0.11	
	Inhalation of Volatiles	5.1×10^{-6}		0.07	
	Total Risk	**8.0×10^{-5}**		**Total HI**	**5.4**
Radionuclides	**Ingestion**	1.2×10^{-4}		--	
	Immersion	3.4×10^{-13}			
	Inhalation of Volatiles	5.4×10^{-3}			
	Total Risk	**5.5×10^{-3}**			
Total Cumulative ELCR		**5.6×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-202 is 5.6×10^{-3}. The total ELCR for nonradiological analytes is 8.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.5×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.04% contribution), carbon-14 (ELCR = 3.1×10^{-3}, 55% contribution), chloroform (ELCR = 4.1×10^{-6}, 0.07% contribution), and tritium (ELCR = 2.4×10^{-3}, 43% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.4×10^{-5}, 1.3% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-202 without

contribution from arsenic is 6.9×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-202 is 5.4, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.63, 12% contribution), cobalt (HQ = 0.10, 1.8% contribution), fluoride (HQ = 0.38, 6.9% contribution), Cr(VI) (HQ = 0.20, 3.7% contribution), iron (HQ = 0.11, 2.1% contribution), nitrate (HQ = 0.20, 3.7% contribution), thallium (HQ = 3.2, 59% contribution), and vanadium (HQ = 0.13, 2.4% contribution). Contribution to HI is elevated for thallium (HQ = 3.2) where the EPC (0.64 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L The HI for well 199-K-202 without contribution from arsenic and thallium is 1.6, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Cobalt: thyroid, decreased iodine uptake
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Iron: GI tract; adverse gastrointestinal effects
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of iron and fluoride, exposure to each of the analytes that contribute to the HI of 1.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for iron and fluoride results in an HI of 0.49, which is less than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-202 are shown in Table 6-137. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 16 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-137. Summary of Well 199-K-202 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	2,210	2,000	1.1
Strontium-90	pCi/L	8.1	8	1
Technetium-99	pCi/L	71.9	900	0.08
Tritium	pCi/L	35,100	20,000	1.8
			Sum of Fractions	4
			Cumulative Annual Dose (mrem)	15.8

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-203. Table 6-138 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-203. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-182 and G-183).

Table 6-138. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-203 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.7×10^{-5}	Arsenic (ELCR = 7.7×10^{-5}, 9.3%) Carbon-14 (ELCR = 6.8×10^{-4}, 81%)	1.8	Arsenic (HQ = 0.67, 34%) Fluoride (HQ = 0.18, 9.0%) Hexavalent chromium (HQ = 0.58, 30%) Nitrate (HQ = 0.12, 6.0%) Vanadium (HQ = 0.15, 7.7%)
	Dermal Contact	4.1×10^{-7}		0.18	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.7×10^{-5}**		**Total HI**	**1.9**
Radionuclides	**Ingestion**	1.8×10^{-5}		--	
	Immersion	3.0×10^{-13}			
	Inhalation of Volatiles	7.4×10^{-4}			
	Total Risk	**7.6×10^{-4}**			
Total Cumulative ELCR		**8.4×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-203 is 8.4×10^{-4}. The total ELCR for nonradiological analytes is 7.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 7.6×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is carbon-14 (ELCR = 6.8×10^{-4}, 81% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.7×10^{-5}, 9.3% contribution) where the EPC (4.0 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-203 when contribution from arsenic is not included.

The HI for well 199-K-203 is 1.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.67, 34% contribution), fluoride (HQ = 0.18, 9.0% contribution), Cr(VI) (HQ = 0.58, 30% contribution), nitrate (HQ = 0.12, 6.0% contribution), and vanadium (HQ = 0.15, 7.7% contribution). The HI for well 199-K-203 without contribution from arsenic is 1.3, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.3 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-203 are shown in Table 6-139. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-139. Summary of Well 199-K-203 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	484	2,000	0.24
Tritium	pCi/L	1,150	20,000	0.058
			Sum of Fractions	0.3
			Cumulative Annual Dose (mrem)	1.2

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-207. Table 6-140 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-207. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-184 and G-185).

The total cumulative ELCR for well 199-K-207 is 5.3×10^{-2}. The total ELCR for nonradiological analytes is 9.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.3×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 5.3×10^{-2}, 100% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.0×10^{-5}, 0.17% contribution) where the EPC (4.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-207 when contribution from arsenic is not included.

The HI for well 199-K-207 is 4.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.78, 18% contribution), boron (HQ = 0.21, 4.9% contribution), fluoride (HQ = 0.24, 5.4% contribution), Cr(VI) (HQ = 2.4, 55% contribution), nitrate (HQ = 0.33, 7.6% contribution), and vanadium (HQ = 0.13, 3.1% contribution). The HI for well 199-K-207 without contribution from arsenic is 3.6, which is greater than the target HI of 1.

Table 6-140. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-207 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.0×10^{-5}	Arsenic (ELCR = 9.0×10^{-5}, 0.17%) Tritium (ELCR = 5.3×10^{-2}, 100%)	3.7	Arsenic (HQ = 0.78, 18%) Boron (HQ = 0.21, 4.9%) Fluoride (HQ = 0.24, 5.4%) Hexavalent chromium (HQ = 2.4, 55%) Nitrate (HQ = 0.33, 7.6%) Vanadium (HQ = 0.13, 3.1%)
	Dermal Contact	4.8×10^{-7}		0.65	
	Inhalation of Volatiles	--		--	
	Total Risk	**9.0×10^{-5}**		**Total HI**	**4.3**
Radionuclides	Ingestion	7.4×10^{-4}		--	
	Immersion	3.3×10^{-14}			
	Inhalation of Volatiles	5.2×10^{-2}			
	Total Risk	**5.3×10^{-2}**			
Total Cumulative ELCR		**5.3×10^{-2}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Boron: decreased fetal weight (developmental)
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 3.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cr(VI) has an HQ of 2.4, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-207 are shown in Table 6-141. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 150 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-141. Summary of Well 199-K-207 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Technetium-99	pCi/L	84.2	900	0.094
Tritium	pCi/L	761,000	20,000	38
			Sum of Fractions	38.1
			Cumulative Annual Dose (mrem)	152.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-209. Table 6-142 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-209. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-186 and G-187).

Table 6-142. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-209 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	1.2×10^{-4}	Arsenic (ELCR = 1.2×10^{-4}, 100%)	1.9	Arsenic (HQ = 1.0, 53%) Fluoride (HQ = 0.28, 15%) Vanadium (HQ = 0.23, 12%)
	Dermal Contact	6.3×10^{-7}		0.06	
	Inhalation of Volatiles	--		--	
	Total Risk	**1.2×10^{-4}**		**Total HI**	**1.9**
Radionuclides	**Ingestion**	--		--	
	Immersion	--			
	Inhalation of Volatiles	--			
	Total Risk	--			
Total Cumulative ELCR		**1.2×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-209 is 1.2×10^{-4}. The total ELCR for nonradiological analytes is 1.2×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. Radiological analytes were not measured; therefore, a total ELCR for radiological analytes is not reported.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 1.2×10^{-4}, 100% contribution) where the EPC (6.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-209 when contribution from arsenic is not included.

The HI for well 199-K-209 is 1.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 1.0, 53% contribution), fluoride (HQ = 0.28, 15% contribution), and vanadium (HQ = 0.23, 12% contribution). The HI for well 199-K-209 without contribution from arsenic is 0.90, which is less than the target HI of 1.

No beta- or photon emitters were analyzed for in well 199-K-209, therefore a sum of fraction calculation is not applicable.

Well 199-K-223. Table 6-143 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-223. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-188 and G-189).

Table 6-143. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-223 – Monitoring Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.1×10^{-6}	Carbon-14 (ELCR = 2.2×10^{-4}, 64%) Tritium (ELCR = 1.2×10^{-4}, 33%)	1.3	Fluoride (HQ = 0.17, 6.5%) Hexavalent chromium (HQ = 0.24, 9.3%) Nitrate (HQ = 0.17, 6.4%) Nitrite (HQ = 0.14, 5.2%) Trichloroethene (HQ = 1.7, 66%) Vanadium (HQ = 0.11, 4.2%)
	Dermal Contact	4.9×10^{-7}		0.16	
	Inhalation of Volatiles	5.3×10^{-6}		1.2	
	Total Risk	**8.8×10^{-6}**		**Total HI**	**2.6**
Radionuclides	Ingestion	6.3×10^{-6}		--	
	Immersion	6.4×10^{-15}			
	Inhalation of Volatiles	3.3×10^{-4}			
	Total Risk	**3.4×10^{-4}**			
Total Cumulative ELCR		**3.4×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-223 is 3.4×10^{-4}. The total ELCR for nonradiological analytes is 8.8×10^{-6}, which is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.4×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 2.2×10^{-4}, 64% contribution) and tritium (ELCR = 1.2×10^{-4}, 33% contribution). Arsenic was not reported at well 199-K-223.

The HI for well 199-K-223 is 2.6, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are fluoride (HQ = 0.17, 6.5% contribution), Cr(VI) (HQ = 0.24, 9.3% contribution), nitrate (HQ = 0.17, 6.4% contribution), nitrite (HQ = 0.14, 5.2% contribution), TCE (HQ = 1.7, 66% contribution), and vanadium (HQ = 0.11, 4.2% contribution).

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Nitrite: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of nitrite and nitrate, exposure to each of the analytes that contribute to the HI of 2.6 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for nitrite and nitrate results in an HI of 0.31, which is less than the target HI of 1. TCE reports an individual HQ of 1.7, which is greater than the target HI of 1; evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-223 are shown in Table 6-144. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.65 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-144. Summary of Well 199-K-223 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	158	2,000	0.079
Tritium	pCi/L	1,660	20,000	0.083
			Sum of Fractions	0.16
			Cumulative Annual Dose (mrem)	0.65

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.9 Extraction Wells Screened Across Entire Aquifer

Across the upper unconfined aquifer, 14 extraction wells are screened. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened across the entire aquifer follows.

Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-190 through G-217).

Well 199-K-116A. Table 6-145 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-116A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-190 and G-191).

Table 6-145. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-116A – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.4×10^{-5}	Arsenic (ELCR = 7.4×10^{-5}, 21%) Tritium (ELCR = 2.3×10^{-4}, 65%)	1.3	Arsenic (HQ = 0.64, 47%) Fluoride (HQ = 0.11, 8.4%) Hexavalent chromium (HQ = 0.16, 12%) Lithium (HQ = 0.10, 7.4%) Vanadium (HQ = 0.11, 8.4%)
	Dermal Contact	3.9×10^{-7}		0.06	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.4×10^{-5}**		**Total HI**	**1.4**
Radionuclides	**Ingestion**	9.5×10^{-6}		--	
	Immersion	1.0×10^{-13}			
	Inhalation of Volatiles	2.7×10^{-4}			
	Total Risk	**2.8×10^{-4}**			
Total Cumulative ELCR		**3.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-116A is 3.6×10^{-4}. The total ELCR for nonradiological analytes is 7.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.8×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 2.3×10^{-4}, 65% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.4×10^{-5}, 21% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-116A when contribution from arsenic is not included.

The HI for well 199-K-116A is 1.4, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.64, 47% contribution), fluoride (HQ = 0.11, 8.4% contribution), Cr(VI) (HQ = 0.16, 12% contribution), lithium (HQ = 0.10, 7.4% contribution), and vanadium (HQ = 0.11, 8.4% contribution). The HI for well 199-K-116A without contribution from arsenic is 0.72, which is less than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-116A are shown in Table 6-146. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.65 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-146. Summary of Well 199-K-116A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	33.9	2,000	0.017
Strontium-90	pCi/L	3.7	8	0.46
Tritium	pCi/L	3,330	20,000	0.17
			Sum of Fractions	0.65
			Cumulative Annual Dose (mrem)	2.6

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-120A. Table 6-147 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-120A. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-192 and G-193).

The total cumulative ELCR for well 199-K-120A is 5.5×10^{-4}. The total ELCR for nonradiological analytes is 6.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.9×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 4.6×10^{-4}, 85% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 6.0×10^{-5}, 11% contribution) where the EPC (3.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-120A when contribution from arsenic is not included.

The HI for well 199-K-120A is 4.3, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.51, 12% contribution), fluoride (HQ = 0.10, 2.2% contribution), Cr(VI) (HQ = 0.11, 2.5% contribution), nitrate (HQ = 0.10, 2.3% contribution), thallium (HQ = 3.2, 74% contribution), and vanadium (HQ = 0.11, 2.6% contribution). Contribution to HI is elevated for thallium (HQ = 3.2) where the EPC (0.64 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L The HI for well 199-K-120A without contribution from arsenic and thallium is 0.61, which is less than the target HI of 1.

Table 6-147. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-120A – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	5.9×10^{-5}	Arsenic (ELCR = 6.0×10^{-5}, 11%) Tritium (ELCR = 4.6×10^{-4}, 85%)	4.3	Arsenic (HQ = 0.51, 12%) Fluoride (HQ = 0.10, 2.2%) Hexavalent chromium (HQ = 0.11, 2.5%) Nitrate (HQ = 0.10, 2.3%) Thallium (HQ = 3.2, 74%) Vanadium (HQ = 0.11, 2.6%)
	Dermal Contact	3.2×10^{-7}		0.06	
	Inhalation of Volatiles	--		--	
	Total Risk	**6.0×10^{-5}**		**Total HI**	**4.3**
Radionuclides	Ingestion	9.3×10^{-6}		--	
	Immersion	4.8×10^{-14}			
	Inhalation of Volatiles	4.8×10^{-4}			
	Total Risk	**4.9×10^{-4}**			
Total Cumulative ELCR		**5.5×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-120A are shown in Table 6-148. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.2 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-148. Summary of Well 199-K-120A EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	15.4	2,000	0.0077
Strontium-90	pCi/L	1.7	8	0.21
Tritium	pCi/L	6,660	20,000	0.33
			Sum of Fractions	0.55
			Cumulative Annual Dose (mrem)	2.2

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-145. Table 6-149 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-145. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-194 and G-195).

Table 6-149. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-145 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	5.2×10^{-5}	Arsenic (ELCR = 5.2×10^{-5}, 1.9%) Tritium (ELCR = 2.6×10^{-3}, 96%)	1.5	Arsenic (HQ = 0.45, 27%) Fluoride (HQ = 0.14, 8.4%) Hexavalent chromium (HQ = 0.72, 43%) Nitrate (HQ = 0.12, 7.3%) Vanadium (HQ = 0.15, 9.3%)
	Dermal Contact	2.8×10^{-7}		0.21	
	Inhalation of Volatiles	--		--	
	Total Risk	**5.2×10^{-5}**		**Total HI**	**1.7**
Radionuclides	**Ingestion**	3.8×10^{-5}		--	
	Immersion	4.1×10^{-15}			
	Inhalation of Volatiles	2.6×10^{-3}			
	Total Risk	**2.7×10^{-3}**			
Total Cumulative ELCR		**2.7×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-145 is 2.7×10^{-3}. The total ELCR for nonradiological analytes is 5.2×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.7×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 2.6×10^{-3}, 96% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 5.2×10^{-5}, 1.9% contribution) where the EPC (2.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-145 when contribution from arsenic is not included.

The HI for well 199-K-145 is 1.7, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.45, 27% contribution), fluoride (HQ = 0.14,

8.4% contribution), Cr(VI) (HQ = 0.72, 43% contribution), nitrate (HQ = 0.12, 7.3% contribution), and vanadium (HQ = 0.15, 9.3% contribution). The HI for well 199-K-145 without contribution from arsenic is 1.2, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-145 are shown in Table 6-150. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 7.7 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-150. Summary of Well 199-K-145 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	31.3	2,000	0.016
Technetium-99	pCi/L	7.3	900	0.0081
Tritium	pCi/L	37,900	20,000	1.9
			Sum of Fractions	1.9
			Cumulative Annual Dose (mrem)	7.7

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-152. Table 6-151 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-152. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-196 and G-197).

The total cumulative ELCR for well 199-K-152 is 3.5×10^{-3}. The total ELCR for nonradiological analytes is 3.4×10^{-3}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.8×10^{-5}, which is equal to the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are aldrin (ELCR = 3.3×10^{-3}, 94% contribution) and chloroform (ELCR = 8.2×10^{-6}, 0.23% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.1×10^{-5}, 2.6% contribution) where the EPC (4.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-152 without contribution from arsenic is 3.3×10^{-3}, which is greater than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-151. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-152 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	2.3×10^{-4}	Aldrin (ELCR = 3.3×10^{-3}, 94%) Arsenic (ELCR = 9.1×10^{-5}, 2.6%) Chloroform (ELCR = 8.2×10^{-6}, 0.23%)	3.8	Aldrin (HQ = 19, 85%) Arsenic (HQ = 0.78, 3.5%) Bromomethane (HQ = 0.15, 0.65%) Fluoride (HQ = 0.18, 0.81%) Hexavalent chromium (HQ = 1.3, 5.9%) Lithium (HQ = 0.13, 0.56%) Molybdenum (HQ = 0.16, 0.72%) Nitrate (HQ = 0.10, 0.43%) Vanadium (HQ = 0.23, 1.0%)
	Dermal Contact	2.6×10^{-3}		18	
	Inhalation of Volatiles	5.7×10^{-4}		0.12	
	Total Risk	**3.4×10^{-3}**		**Total HI**	**22**
Radionuclides	**Ingestion**	5.9×10^{-6}		--	
	Immersion	2.6×10^{-13}			
	Inhalation of Volatiles	9.2×10^{-5}			
	Total Risk	**9.8×10^{-5}**			
Total Cumulative ELCR		**3.5×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Aldrin was detected in one of three samples (0.65 µg/L) collected from well 199-K-152 between June 2010 and January 2011. This result was flagged with a "B" laboratory qualifier indicating that aldrin was detected in the associated method blank and the sample. As a result, aldrin was introduced into this sample by the laboratory and is not associated with a groundwater plume.

The HI for well 199-K-152 is 22, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are aldrin (HQ = 19, 85% contribution), arsenic (HQ = 0.78, 3.5% contribution), bromomethane (HQ = 0.15, 0.65% contribution), fluoride (HQ = 0.18, 0.81% contribution), Cr(VI) (HQ = 1.3, 5.9% contribution), lithium (HQ = 0.13, 0.56% contribution),

molybdenum (HQ = 0.16, 0.72% contribution), nitrate (HQ = 0.10, 0.43% contribution), and vanadium (HQ = 0.23, 1.0% contribution). The HI for well 199-K-152 without contribution from arsenic is 22, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Aldrin: liver toxicity
- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Molybdenum: increased uric acid levels
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of Cr(VI), bromomethane, fluoride, molybdenum, and lithium, exposure to each of the analytes that contribute to the HI of 22 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 1.5, which is greater than the target HI of 1. Combining the HQs for bromomethane and lithium results in an HI of 0.28, which is less than the target HI of 1. Combining the HQs for bromomethane and fluoride results in a HI of 0.33, which is less than the target HI of 1. Aldrin reports an individual HQ of 19, which is greater than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-152 are shown in Table 6-152. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.42 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-152. Summary of Well 199-K-152 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	13.2	2,000	0.0066
Technetium-99	pCi/L	40	900	0.044
Tritium	pCi/L	1,080	20,000	0.054
			Sum of Fractions	0.11
			Cumulative Annual Dose (mrem)	0.42

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-153. Table 6-153 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-153. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-198 and G-199).

Table 6-153. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-153 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	4.6×10^{-5}	Arsenic (ELCR = 4.6×10^{-5}, 31%)	1.3	Arsenic (HQ = 0.40, 27%) Fluoride (HQ = 0.18, 12%) Hexavalent chromium (HQ = 0.54, 37%) Vanadium (HQ = 0.17, 11%)
	Dermal Contact	2.5×10^{-7}		0.17	
	Inhalation of Volatiles	--		--	
	Total Risk	4.6×10^{-5}		Total HI	1.5
Radionuclides	Ingestion	1.7×10^{-6}		--	
	Immersion	9.4×10^{-16}			
	Inhalation of Volatiles	1.0×10^{-4}			
	Total Risk	1.0×10^{-4}			
Total Cumulative ELCR		1.5×10^{-4}			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-153 is 1.5×10^{-4}. The total ELCR for nonradiological analytes is 4.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.0×10^{-4}, which is equal to the EPA upper risk threshold of 1×10^{-4}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 4.6×10^{-5}, 31% contribution) where the EPC (2.4 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-153 when contribution from arsenic is not included.

The HI for well 199-K-153 is 1.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.40, 27% contribution), fluoride (HQ = 0.18, 12% contribution), Cr(VI) (HQ = 0.54, 37% contribution), and vanadium (HQ = 0.17, 11% contribution). The HI for well 199-K-153 without contribution from arsenic is 1.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-153 are shown in Table 6-154. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.25 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-154. Summary of Well 199-K-153 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	23.3	2,000	0.012
Tritium	pCi/L	1,030	20,000	0.052
			Sum of Fractions	0.063
			Cumulative Annual Dose (mrem)	0.25

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-154. Table 6-155 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-154. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-200 and G-201).

The total cumulative ELCR for well 199-K-154 is 1.9×10^{-4}. The total ELCR for nonradiological analytes is 8.5×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.0×10^{-4}, which is equal to the EPA upper risk threshold of 1×10^{-4}.

Contribution to ELCR is elevated for arsenic (ELCR = 8.5×10^{-5}, 46% contribution) where the EPC (4.4 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-154 when contribution from arsenic is not included.

The HI for well 199-K-154 is 2.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.73, 25% contribution), fluoride (HQ = 0.22, 7.7% contribution), Cr(VI) (HQ = 1.6, 54% contribution), and vanadium (HQ = 0.17, 6.0% contribution). The HI for well 199-K-154 without contribution from arsenic is 2.2, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Vanadium: decreased hair cysteine

Table 6-155. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-154 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	8.5×10^{-5}	Arsenic (ELCR = 8.5×10^{-5}, 46%)	2.5	Arsenic (HQ = 0.73, 25%) Fluoride (HQ = 0.22, 7.7%) Hexavalent chromium (HQ = 1.6, 54%) Vanadium (HQ = 0.17, 6.0%)
	Dermal Contact	4.5×10^{-7}		0.44	
	Inhalation of Volatiles	--		--	
	Total Risk	**8.5×10^{-5}**		Total HI	**2.9**
Radionuclides	Ingestion	1.4×10^{-6}		--	
	Immersion	--			
	Inhalation of Volatiles	10.0×10^{-5}			
	Total Risk	**1.0×10^{-4}**			
Total Cumulative ELCR		**1.9×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Exposure to each of the analytes that contribute to the HI of 2.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Cr(VI) has an HQ of 1.6, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-154 are shown in Table 6-156. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.29 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-156. Summary of 199-K-154 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Tritium	pCi/L	1,460	20,000	0.073
			Sum of Fractions	0.073
			Cumulative Annual Dose (mrem)	0.29

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-163. Table 6-157 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-163. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-202 and G-203).

Table 6-157. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-163 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.3×10^{-5}	Arsenic (ELCR = 7.4×10^{-5}, 20%) Tritium (ELCR = 2.4×10^{-4}, 66%)	1.8	Arsenic (HQ = 0.63, 31%) Fluoride (HQ = 0.22, 11%) Hexavalent chromium (HQ = 0.85, 42%) Nitrate (HQ = 0.10, 5.0%) Vanadium (HQ = 0.17, 8.1%)
	Dermal Contact	3.9×10^{-7}		0.25	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.4×10^{-5}**		**Total HI**	**2.0**
Radionuclides	**Ingestion**	4.9×10^{-6}		--	
	Immersion	4.3×10^{-15}			
	Inhalation of Volatiles	2.9×10^{-4}			
	Total Risk	**2.9×10^{-4}**			
Total Cumulative ELCR		**3.7×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-163 is 3.7×10^{-4}. The total ELCR for nonradiological analytes is 7.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.9×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 2.4×10^{-4}, 66% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.4×10^{-5}, 20% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-163 when contribution from arsenic is not included.

The HI for well 199-K-163 is 2.0, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.63, 31% contribution), fluoride (HQ = 0.22, 11% contribution), Cr(VI) (HQ = 0.85, 42% contribution), nitrate (HQ = 0.10, 5.0% contribution), and vanadium (HQ = 0.17, 8.1% contribution). The HI for well 199-K-163 without contribution from arsenic is 1.4, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.4 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-163 are shown in Table 6-158. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.80 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-158. Summary of Well 199-K-163 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	36.8	2,000	0.018
Technetium-99	pCi/L	7.2	900	0.0080
Tritium	pCi/L	3,500	20,000	0.17
			Sum of Fractions	0.20
			Cumulative Annual Dose (mrem)	0.80

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-165. Table 6-159 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-165. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-204 and G-205).

The total cumulative ELCR for well 199-K-165 is 8.8×10^{-4}. The total ELCR for nonradiological analytes is 4.8×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.3×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 7.3×10^{-4}, 84% contribution), chloroform (ELCR = 1.8×10^{-6}, 0.20% contribution), and TCE (ELCR = 5.8×10^{-6}, 0.66% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.1×10^{-5}, 4.6% contribution) where the EPC (2.1 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-165 without contribution from arsenic is 7.6×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table 6-159. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-165 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	4.3×10^{-5}	Arsenic (ELCR = 4.1×10^{-5}, 4.6%) Carbon-14 (ELCR = 7.3×10^{-4}, 84%) Chloroform (ELCR = 1.8×10^{-6}, 0.20%) Trichloroethene (ELCR = 5.8×10^{-6}, 0.66%)	4.0	2-Propanol (HQ = 0.29, 4.7%) Arsenic (HQ = 0.35, 5.6%) Fluoride (HQ = 0.15, 2.4%) Hexavalent chromium (HQ = 3.5, 56%) Nitrate (HQ = 0.16, 2.5%) Trichloroethene (HQ = 1.4, 23%) Vanadium (HQ = 0.16, 2.6%)
	Dermal Contact	6.2×10^{-7}		1.0	
	Inhalation of Volatiles	4.6×10^{-6}		1.3	
	Total Risk	**4.8×10^{-5}**		**Total HI**	**6.2**
Radionuclides	**Ingestion**	1.9×10^{-5}		--	
	Immersion	3.5×10^{-14}			
	Inhalation of Volatiles	8.1×10^{-4}			
	Total Risk	**8.3×10^{-4}**			
Total Cumulative ELCR		**8.8×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for well 199-K-165 is 6.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are 2-propanol (HQ = 0.29, 4.7% contribution), arsenic (HQ = 0.35, 5.6% contribution), fluoride (HQ = 0.15, 2.4% contribution), Cr(VI) (HQ = 3.5, 56% contribution), nitrate (HQ = 0.16, 2.5% contribution), TCE (HQ = 1.4, 23% contribution), and vanadium (HQ = 0.16, 2.6% contribution). The HI for well 199-K-165 without contribution from arsenic is 5.9, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- 2-Propanol: decreased fetal body weight
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia

- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of 2-propanol and TCE, exposure to each of the analytes that contribute to the HI of 5.9 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for 2-propanol and TCE results in an HI of 1.7, which is greater than the target HI of 1. Cr(VI) reports an individual HQ of 3.5, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-165 are shown in Table 6-160. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.5 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-160. Summary of Well 199-K-165 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	524	2,000	0.26
Technetium-99	pCi/L	35.3	900	0.039
Tritium	pCi/L	1,340	20,000	0.067
			Sum of Fractions	0.37
			Cumulative Annual Dose (mrem)	1.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-166. Table 6-161 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-166. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-206 and G-207).

The total cumulative ELCR for well 199-K-166 is 9.9×10^{-4}. The total ELCR for nonradiological analytes is 5.6×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.4×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 8.3×10^{-4}, 83% contribution), chloroform (ELCR = 1.7×10^{-6}, 0.17% contribution), TCE (ELCR = 6.2×10^{-6}, 0.62% contribution), and tritium (ELCR = 1.1×10^{-4}, 11% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 4.8×10^{-5}, 4.9% contribution) where the EPC (2.5 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-166 without contribution from arsenic is 7.9×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-166 is 2.9, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.42, 14% contribution), fluoride (HQ = 0.15, 5.1% contribution), Cr(VI) (HQ = 0.42, 14% contribution), nitrate (HQ = 0.17, 5.7% contribution), TCE (HQ = 1.5, 52% contribution), and vanadium (HQ = 0.10, 3.5% contribution). The HI for well 199-K-166 without contribution from arsenic is 2.5, which is greater than the target HI of 1.

Table 6-161. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-166 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	5.1×10^{-5}	Arsenic (ELCR = 4.8×10^{-5}, 4.9%) Carbon-14 (ELCR = 8.3×10^{-4}, 83%) Chloroform (ELCR = 1.7×10^{-6}, 0.17%) Trichloroethene (ELCR = 6.2×10^{-6}, 0.62%) Tritium (ELCR = 1.1×10^{-4}, 11%)	1.7	Arsenic (HQ = 0.42, 14%) Fluoride (HQ = 0.15, 5.1%) Hexavalent chromium (HQ = 0.42, 14%) Nitrate (HQ = 0.17, 5.7%) Trichloroethene (HQ = 1.5, 52%) Vanadium (HQ = 0.10, 3.5%)
	Dermal Contact	6.9×10^{-7}		0.20	
	Inhalation of Volatiles	4.7×10^{-6}		1.0	
	Total Risk	**5.6×10^{-5}**		**Total HI**	**2.9**
Radionuclides	Ingestion	2.4×10^{-5}		--	
	Immersion	8.9×10^{-14}			
	Inhalation of Volatiles	9.1×10^{-4}			
	Total Risk	**9.4×10^{-4}**			
Total Cumulative ELCR		**9.9×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 2.5 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. TCE has an HQ of 1.5, which is greater than the target HI of 1; evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-166 are shown in Table 6-162. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.6 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-162. Summary of Well 199-K-166 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	591	2,000	0.3
Strontium-90	pCi/L	1.8	8	0.22
Technetium-99	pCi/L	40	900	0.044
Tritium	pCi/L	1,520	20,000	0.076
			Sum of Fractions	0.64
			Cumulative Annual Dose (mrem)	2.6

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-171. Table 6-163 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-171. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-208 and G-209).

Table 6-163. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-171 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	7.3×10^{-5}	Arsenic (ELCR = 7.4×10^{-5}, 17%) Tritium (ELCR = 3.5×10^{-4}, 81%)	2.1	Arsenic (HQ = 0.63, 27%) Fluoride (HQ = 0.23, 9.8%) Hexavalent chromium (HQ = 0.96, 40%) Nitrate (HQ = 0.10, 4.2%) Silver (HQ = 0.21, 8.9%) Vanadium (HQ = 0.17, 7.2%)
	Dermal Contact	3.9×10^{-7}		0.29	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.4×10^{-5}**		**Total HI**	**2.4**
Radionuclides	**Ingestion**	5.0×10^{-6}		--	
	Immersion	2.3×10^{-16}			
	Inhalation of Volatiles	3.5×10^{-4}			
	Total Risk	**3.5×10^{-4}**			
Total Cumulative ELCR		**4.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-171 is 4.3×10^{-4}. The total ELCR for nonradiological analytes is 7.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.5×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributor to the total cumulative ELCR is tritium (ELCR = 3.5×10^{-4}, 81% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.4×10^{-5}, 17% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-171 when contribution from arsenic is not included.

The HI for well 199-K-171 is 2.4, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.63, 27% contribution), fluoride (HQ = 0.23, 9.8% contribution), Cr(VI) (HQ = 0.96, 40% contribution), nitrate (HQ = 0.10, 4.2% contribution), silver (HQ = 0.21, 8.9% contribution), and vanadium (HQ = 0.17, 7.2% contribution). The HI for well 199-K-171 without contribution from arsenic is 1.8, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Silver: argyria (dermal)
- Vanadium: decreased hair cysteine

With the exception of silver and vanadium, exposure to each of the analytes that contribute to the HI of 1.8 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for silver and vanadium results in an HI of 0.38, which is less than the target HI of 1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-171 are shown in Table 6-164. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.0 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-164. Summary of Well 199-K-171 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	5.7	2,000	0.0028
Tritium	pCi/L	4,980	20,000	0.25
			Sum of Fractions	0.25
			Cumulative Annual Dose (mrem)	1.0

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-182. Table 6-165 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-182. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-210 and G-211).

Table 6-165. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-182 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.2×10^{-5}	Arsenic (ELCR = 9.2×10^{-5}, 31%) Chloroform (ELCR = 5.0×10^{-6}, 1.7%) Tritium (ELCR = 1.9×10^{-4}, 65%)	3.0	Arsenic (HQ = 0.79, 23%) Bromomethane (HQ = 0.12, 3.6%) Fluoride (HQ = 0.16, 4.5%) Hexavalent chromium (HQ = 1.4, 41%) Lithium (HQ = 0.40, 12%) Nitrate (HQ = 0.12, 3.5%) Vanadium (HQ = 0.22, 6.4%)
	Dermal Contact	5.3×10^{-7}		0.42	
	Inhalation of Volatiles	4.5×10^{-6}		0.10	
	Total Risk	**9.7×10^{-5}**		**Total HI**	**3.5**
Radionuclides	Ingestion	8.5×10^{-6}		--	
	Immersion	2.9×10^{-13}			
	Inhalation of Volatiles	1.9×10^{-4}			
	Total Risk	**2.0×10^{-4}**			
Total Cumulative ELCR		**3.0×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-182 is 3.0×10^{-4}. The total ELCR for nonradiological analytes is 9.7×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.0×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are chloroform (ELCR = 5.0×10^{-6}, 1.7% contribution) and tritium (ELCR = 1.9×10^{-4}, 65% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.2×10^{-5}, 31% contribution) where the EPC (4.7 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. The nonradiological ELCR for well 199-K-182 without contribution from arsenic is 5.0×10^{-6}, which is less than the MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for well 199-K-182 is 3.5, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.79, 23% contribution), bromomethane (HQ = 0.12, 3.6% contribution), fluoride (HQ = 0.16, 4.5% contribution), Cr(VI) (HQ = 1.4, 41% contribution), lithium (HQ = 0.40, 12% contribution), nitrate (HQ = 0.12, 3.5% contribution), and vanadium (HQ = 0.22, 6.4% contribution). The HI for well 199-K-182 without contribution from arsenic is 2.7, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Bromomethane: degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

With the exception of Cr(VI) and bromomethane, exposure to each of the analytes that contribute to the HI of 2.7 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for Cr(VI) and bromomethane results in an HI of 1.6, which is greater than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-182 are shown in Table 6-166. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.5 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-166. Summary of Well 199-K-182 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	1.9	8	0.24
Tritium	pCi/L	2,770	20,000	0.14
			Sum of Fractions	0.38
			Cumulative Annual Dose (mrem)	1.5

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-208. Table 6-167 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-208. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-212 and G-213).

The total cumulative ELCR for well 199-K-208 is 3.1×10^{-3}. The total ELCR for nonradiological analytes is 8.3×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.0×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

Table 6-167. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-208 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	**Ingestion**	8.3×10^{-5}	Arsenic (ELCR = 8.3×10^{-5}, 2.7%) Tritium (ELCR = 3.0×10^{-3}, 97%)	2.0	Arsenic (HQ = 0.72, 33%) Fluoride (HQ = 0.20, 9.2%) Hexavalent chromium (HQ = 0.55, 25%) Nitrate (HQ = 0.15, 6.8%) Vanadium (HQ = 0.15, 7.0%)
	Dermal Contact	4.4×10^{-7}		0.17	
	Inhalation of Volatiles	--		--	
	Total Risk	**8.3×10^{-5}**		Total HI	2.2
Radionuclides	**Ingestion**	4.3×10^{-5}		--	
	Immersion	1.7×10^{-14}			
	Inhalation of Volatiles	3.0×10^{-3}			
	Total Risk	**3.0×10^{-3}**			
Total Cumulative ELCR		**3.1×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The major contributor to the total cumulative ELCR is tritium (ELCR = 3.0×10^{-3}, 97% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 8.3×10^{-5}, 2.7% contribution) where the EPC (4.3 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-208 when contribution from arsenic is not included.

The HI for well 199-K-208 is 2.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.72, 33% contribution), fluoride (HQ = 0.20, 9.2% contribution), Cr(VI) (HQ = 0.55, 25% contribution), nitrate (HQ = 0.15, 6.8% contribution), and vanadium (HQ = 0.15, 7.0% contribution). The HI for well 199-K-208 without contribution from arsenic is 1.5, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.5 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-208 are shown in Table 6-168. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 9.1 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-168. Summary of Well 199-K-208 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	0.63	8	0.078
Tritium	pCi/L	43,800	20,000	2.2
			Sum of Fractions	2.3
			Cumulative Annual Dose (mrem)	9.1

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-210. Table 6-169 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-210. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-214 and G-215).

The total cumulative ELCR for well 199-K-210 is 6.6×10^{-4}. The total ELCR for nonradiological analytes is 7.4×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.8×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 3.3×10^{-4}, 50% contribution) and tritium (ELCR = 2.5×10^{-4}, 38% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 7.4×10^{-5}, 11% contribution) where the EPC (3.8 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-210 when contribution from arsenic is not included.

The HI for well 199-K-210 is 1.7, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.63, 37% contribution), fluoride (HQ = 0.15, 8.9% contribution), Cr(VI) (HQ = 0.56, 33% contribution), and nitrate (HQ = 0.16, 9.4% contribution). The HI for well 199-K-210 without contribution from arsenic is 1.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia

Table 6-169. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-210 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	7.3×10^{-5}	Arsenic (ELCR = 7.4×10^{-5}, 11%) Carbon-14 (ELCR = 3.3×10^{-4}, 50%) Tritium (ELCR = 2.5×10^{-4}, 38%)	1.5	Arsenic (HQ = 0.63, 37%) Fluoride (HQ = 0.15, 8.9%) Hexavalent chromium (HQ = 0.56, 33%) Nitrate (HQ = 0.16, 9.4%)
	Dermal Contact	3.9×10^{-7}		0.15	
	Inhalation of Volatiles	--		--	
	Total Risk	**7.4×10^{-5}**		**Total HI**	**1.7**
Radionuclides	Ingestion	1.2×10^{-5}		--	
	Immersion	4.5×10^{-14}			
	Inhalation of Volatiles	5.7×10^{-4}			
	Total Risk	**5.8×10^{-4}**			
Total Cumulative ELCR		**6.6×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Exposure to each of the analytes that contribute to the HI of 1.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating each of the analytes individually results in an HI <1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-210 are shown in Table 6-170. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 1.8 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-170. Summary of Well 199-K-210 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	236	2,000	0.12
Strontium-90	pCi/L	1.3	8	0.16
Tritium	pCi/L	3,630	20,000	0.18
			Sum of Fractions	0.46
			Cumulative Annual Dose (mrem)	1.8

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-224. Table 6-171 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-224. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-216 and G-217).

Table 6-171. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-224 – Extraction Well Screened Across Entire Aquifer

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.4×10^{-6}	Carbon-14 (ELCR = 6.4×10^{-4}, 88%) Chloroform (ELCR = 1.7×10^{-6}, 0.24%) Trichloroethene (ELCR = 7.8×10^{-6}, 1.1%)	3.1	Fluoride (HQ = 0.18, 3.4%) Hexavalent chromium (HQ = 2.5, 49%) Nitrate (HQ = 0.16, 3.2%) Nitrite (HQ = 0.14, 2.6%) Trichloroethene (HQ = 1.9, 37%) Vanadium (HQ = 0.15, 2.8%)
	Dermal Contact	5.4×10^{-7}		0.77	
	Inhalation of Volatiles	5.6×10^{-6}		1.3	
	Total Risk	**9.5×10^{-6}**		**Total HI**	**5.2**
Radionuclides	Ingestion	1.6×10^{-5}		--	
	Immersion	5.0×10^{-14}			
	Inhalation of Volatiles	7.0×10^{-4}			
	Total Risk	**7.2×10^{-4}**			
Total Cumulative ELCR		**7.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-224 is 7.3×10^{-4}. The total ELCR for nonradiological analytes is 9.5×10^{-6}, which is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 7.2×10^{-4}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR are carbon-14 (ELCR = 6.4×10^{-4}, 88% contribution), chloroform (ELCR = 1.7×10^{-6}, 0.24% contribution), and TCE (ELCR = 7.8×10^{-6}, 1.1% contribution). Arsenic was not reported at well 199-K-224.

The HI for well 199-K-224 is 5.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are fluoride (HQ = 0.18, 3.4% contribution), Cr(VI) (HQ = 2.5, 49% contribution), nitrate (HQ = 0.16, 3.2% contribution), nitrite (HQ = 0.14, 2.6% contribution), TCE (HQ = 1.9, 37% contribution), and vanadium (HQ = 0.15, 2.8% contribution).

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Nitrate: early clinical signs of methemoglobinemia
- Nitrite: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity
- Vanadium: decreased hair cysteine

With the exception of nitrite and nitrate, exposure to each of the analytes that contribute to the HI of 5.2 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Combining the HQs for nitrite and nitrate results in an HI of 0.30, which is less than the target HI of 1. Cr(VI) and TCE reports an individual HQ of 2.5 and 1.9, respectively, which is greater than the target HI of 1. Evaluating each of the remaining analytes individually results in an HI <1 for each contributor.

EPCs and DWSs for all beta and photon emitting radioisotopes detected in well 199-K-224 are shown in Table 6-172. The cumulative annual dose from drinking water exposure to all beta and photon emitting radioisotopes in groundwater is 1.7 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-172. Summary of Well 199-K-224 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	459	2,000	0.23
Strontium-90	pCi/L	1.2	8	0.14
Tritium	pCi/L	1,110	20,000	0.056
			Sum of Fractions	0.43
			Cumulative Annual Dose (mrem)	1.7

DWS = drinking water standard
EPC = exposure point concentration

6.3.5.4.10 Monitoring Wells Screened in the Ringold Upper Mud

Two monitoring wells are screened in the uppermost unconfined aquifer in the RUM. A summary of the cancer risks and noncancer hazards by exposure route for each individual well screened Ringold upper mud follows. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-218 through G-221).

Well 199-K-192. Table 6-173 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-192. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-218 and G-219).

Table 6-173. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-192 – Monitoring Well Screened in the Ringold Upper Mud

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.7×10^{-4}	Arsenic (ELCR = 1.7×10^{-4}, 96%)	9.0	Arsenic (HQ = 1.5, 16%) Fluoride (HQ = 0.34, 3.7%) Hexavalent chromium (HQ = 0.15, 1.6%) Thallium (HQ = 6.5, 71%) Vanadium (HQ = 0.30, 3.2%)
	Dermal Contact	9.2×10^{-7}		0.12	
	Inhalation of Volatiles	--		< 0.01	
	Total Risk	**1.7×10^{-4}**		**Total HI**	**9.1**
Radionuclides	Ingestion	6.4×10^{-6}		--	
	Immersion	1.1×10^{-13}			
	Inhalation of Volatiles	--			
	Total Risk	**6.4×10^{-6}**			
Total Cumulative ELCR		**1.8×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for well 199-K-192 is 1.8×10^{-4}. The total ELCR for nonradiological analytes is 1.7×10^{-4}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 6.4×10^{-6}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 1.7×10^{-4}, 96% contribution) where the EPC (9.0 µg/L) is greater than the range of natural background values for arsenic (0.5 µg/L to 8.8 µg/L). However, the EPC of 9 µg/L is less than the DWS of 10 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-192 when contribution from arsenic is not included.

The HI for well 199-K-192 is 9.1, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 1.5, 16% contribution), fluoride (HQ = 0.34, 3.7% contribution), Cr(VI) (HQ = 0.15, 1.6% contribution), thallium (HQ = 6.5, 71% contribution), and vanadium (HQ = 0.30, 3.2% contribution). Contribution to HI is elevated for thallium (HQ = 6.5) where the EPC (1.3 µg/L) is less than the 90th percentile Hanford Site background value of 1.67 µg/L. The HI for well 199-K-192 without contribution from arsenic and thallium is 1.1, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Arsenic: hyperpigmentation, keratosis and possible vascular complications
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 1.1 results in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Evaluating the analytes individually results in an HI <1 for each contributor. Arsenic reports an individual HQ of 1.5, which is greater than the target HI of 1.

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-192 are shown in Table 6-174. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 2.0 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-174. Summary of Well 199-K-192 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	3.8	8	0.48
Technetium-99	pCi/L	20	900	0.022
			Sum of Fractions	0.50
			Cumulative Annual Dose (mrem)	2.0

DWS = drinking water standard
EPC = exposure point concentration

Well 199-K-32B. Table 6-175 provides a summary of the cancer risks and noncancer hazards by exposure route for well 199-K-32B. Additional details, including analyte-specific risk contributions, are provided in Appendix G (Tables G-220 and G-221).

The total cumulative ELCR for well 199-K-32B is 3.1×10^{-5}. The total ELCR for nonradiological analytes is 3.0×10^{-5}, which is greater than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.7×10^{-6}, which is within the EPA risk threshold range of 1×10^{-4} to 1×10^{-6}.

There are no major risk contributors. Contribution to ELCR is elevated for arsenic (ELCR = 3.0×10^{-5}, 95% contribution) where the EPC (1.5 µg/L) is less than the 90th percentile Hanford Site background value of 7.85 µg/L. A total ELCR for nonradiological analytes is not reported for well 199-K-32B when contribution from arsenic is not included.

The HI for well 199-K-32B is 1.2, which is greater than the MTCA (WAC 173-340-708(5)) target HI of 1. Primary contributors to the noncancer HI are arsenic (HQ = 0.26, 21% contribution), cadmium (HQ = 0.14, 11% contribution), fluoride (HQ = 0.23, 18% contribution), and Cr(VI) (HQ = 0.15, 12% contribution). The HI for well 199-K-32B without contribution from arsenic is 0.99, which is less than the target HI of 1.

Table 6-175. Summary of Cancer Risks and Noncancer Hazards for Well 199-K-32B – Monitoring Well Screened in the Ringold Upper Mud

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	3.0×10^{-5}	Arsenic (ELCR = 3.0×10^{-5}, 95%)	1.2	Arsenic (HQ = 0.26, 21%) Cadmium (HQ = 0.14, 11%) Fluoride (HQ = 0.23, 18%) Hexavalent chromium (HQ = 0.15, 12%)
	Dermal Contact	1.6×10^{-7}		0.07	
	Inhalation of Volatiles	--		--	
	Total Risk	**3.0×10^{-5}**		**Total HI**	**1.2**
Radionuclides	Ingestion	1.7×10^{-6}		--	
	Immersion	3.3×10^{-14}			
	Inhalation of Volatiles	--			
	Total Risk	**1.7×10^{-6}**			
Total Cumulative ELCR		**3.1×10^{-5}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in well 199-K-32B are shown in Table 6-176. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 0.60 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-176. Summary of Well 199-K-32B EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	1.2	8	0.15
			Sum of Fractions	0.15
			Cumulative Annual Dose (mrem)	0.60

DWS = drinking water standard
EPC = exposure point concentration

6.3.6 Uncertainties in the Groundwater Risk Assessment

The purpose of this groundwater risk assessment is to determine whether a groundwater remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties relate to the selection of COPCs and the development of media concentrations to which receptors may be exposed, the assumptions about exposure and toxicity, and the characterization of health risks. Uncertainties exist regarding the quantification of health risks in terms of several assumptions about exposure and toxicity, including site-specific and general uncertainties.

6.3.6.1 Uncertainties Associated with Sampling and Analysis Data

Sampling and analysis data used in this groundwater risk assessment were collected to address the uncertainties identified in the RCBRA (DOE/RL-2007-21) and the 100-K Work Plan (DOE/RL-2008-46-ADD2). These uncertainties were generally associated with the chemical, spatial, and temporal representativeness of the data set used to evaluate baseline conditions in the RCBRA. Uncertainties with chemical representativeness were related to the use of varying analytical methods between monitoring wells within the OU. Uncertainties with spatial and temporal representativeness were associated with the varying sampling frequencies between monitoring wells because of differing monitoring programs.

The data set contains the analytical results from groundwater samples collected during the 8-year period from October 2009, through April 2017. It includes the groundwater data set collected under the 100-K Work Plan (DOE/RL-2008-46-ADD2) that were collected over an 8-month period between October 22, 2009, and June 30, 2010. Three sampling events were used to capture the effects that temporal fluctuations of river stage have on groundwater conditions. Monitoring frequencies and analytical requirements differ by well and are defined in the SAPs listed in Section 6.3.2.1.

Sampling and analysis results from each of the different sampling programs comprehensively define the suite of contaminants associated with existing source area plumes. However, differences in sampling frequencies (monthly, quarterly, annually or biennially) may create uncertainties associated with the temporal representative qualities of the data set. However, the differences in sampling frequencies are not anticipated to influence the overall concentrations of COPCs in groundwater.

6.3.6.2 Uncertainties Associated with Exposure Point Concentrations

Calculating UCL for EPCs (OSWER Directive 9285.6-10) recommends using a 95% UCL on the mean for estimating EPCs. Section 6.3.3.4 describes the methodology for calculating the EPCs for detected analytes. The EPC defaults to the maximum detected concentration when any of the following conditions are met:

- When a 95% UCL cannot be calculated due to small sample size
- When the 95% UCL is greater than the maximum detected concentration and the 97.5% Chebyshev (Mean, Sd) UCL either was not calculated by ProUCL or the calculated value was greater than the maximum detected concentration

When any of these conditions are met, the data set may be inadequate for estimating risk. The outcome may underestimate or overestimate risk.

The selection of EPCs is discussed in detail in Section 6.3.3.4, and the EPC logic was shown in Figure 6-8. The steps that are shown in Figure 6-8 are consistent with and follow ProUCL software and guidance. Table 6-177 provides a summary of the number of individual records considered in the UCL selection steps for the 100-KR-4 Groundwater OU. A limited number of instances occurred when ProUCL calculated a 95% UCL that was greater than the maximum detected concentration. As shown in Table 6-177, 152 instances occurred where a UCL was greater than the maximum detected concentration, and the maximum detected concentration was selected as the EPC. A 97.5% Chebyshev (Mean, Sd) UCL was not calculated for 78 analytes and the calculated value was greater than the maximum detected concentration for 74 analytes.

Table 6-177. Groundwater Records in EPC Selection Steps for 100-KR-4 Groundwater OU

Number of Records	100-KR-4 Groundwater OU
Total analytes input to ProUCL from 100-KR-4 Groundwater OU data set	1,976
Number of instances where highest recommended UCL was used as EPC	1,323
Number of instances that a UCL was not calculated and maximum detection was used as EPC	501
Number of instances that a UCL was greater than the maximum detection and maximum detection was used as EPC	152

EPC = exposure point concentration
OU = operable unit
UCL = upper confidence limit

6.3.6.3 Uncertainties Associated with Exposure Assumptions

The exposure assumptions used for the EPA tap water exposure scenario represent an RME. For estimating the RME, 95 percentile values (or upper-bound estimates of national averages) are generally used for exposure assumptions, and exposed populations and exposure scenarios are selected to represent upper-bound exposures. The intent of the RME, as discussed by the EPA Deputy Administrator and the Risk Assessment Council (Habicht, 1992), is to present risks as a range from central tendency to high-end risk (i.e., above the 90th percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable “high-end” segments of the subject population (Habicht, 1992). EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an upper bound of the true risk or hazard.

6.3.6.3.1 Uncertainties Associated with Inhalation of Aerosols Containing Hexavalent Chromium

According to Finley et al., 1996, “Assessment of Airborne Hexavalent Chromium in the Home Following Use of Contaminated Tapwater,” the cancer risk from exposure during showering with Cr(VI) aerosols from tap water ranged from 9.0E-07 to 5.5E-06 from water containing 2 to 10 mg/L Cr(VI). Average airborne concentrations of Cr(VI) at breathing zone height ranged from 0.087 to 0.324 μg/m^3, which was measured over 24 hours of use. The air concentrations of 0.087 to 0.324 μg/m^3 were directly correlated to water concentrations of 0.89 to 11.5 mg/L. This study concluded that exposure to indoor aerosols containing up to 10 mg/L is unlikely to create a health hazard. The study (Finley et al., 1996) also determined that ambient (outdoor) concentrations of Cr(VI) were about the same as those calculated from

indoor shower aerosols, suggesting no difference between indoor and ambient air concentrations. Cr(VI) is identified as a COPC for several wells in the 100-KR-4 Groundwater OU. However, the detected concentrations of Cr(VI) in groundwater range between 1.5 µg/L and 3,310 µg/L, which are below or in the lower concentration range of 2,000 to 10,000 µg/L evaluated in these studies.

6.3.6.4 Uncertainties Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty as defined in in the risk assessment guide (EPA/540/1-89/002) and in Superfund HHT Risk Assessment Values (Cook, 2003). These sources may include or result from the extrapolation from high to low doses and from animals to humans. This is contingent on the species, gender, age, and strain differences in the uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The human population's variability with respect to diet, environment, activity patterns, and cultural factors are also sources of uncertainty.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are nonthreshold contaminants. However, EPA has recently published revised cancer guidelines (EPA/630/P-03/001B) in which they have modified their former position of assuming nonthreshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States will be developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or where the mode of action is not known. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a nonthreshold model.

Throughout most of the world, nonthreshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (TERA, 2011). Specifically, for genotoxic contaminants, the cancer dose-response model is based on high-dose to low-dose extrapolation and assumes there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses are found in laboratory animals or are extrapolated from occupational or epidemiological studies. Cancer effects observed at low doses are commonly found in environmental exposures. These models are essentially linear at low doses, so no dose is without some risk of cancer.

6.3.6.4.1 Slope Factors for Hexavalent Chromium

For hexavalent chromium, the current assessment does not consider oral carcinogenic effects. An oral cancer slope factor has been published by NJDEP. The oral cancer slope factor derived by NJDEP is 0.5 $(mg/kg\ day)^{-1}$, as presented in NJDEP, 2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for Cr+6 Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*. Not assessing oral carcinogenic effects from hexavalent chromium has the potential to underestimate cancer risk.

6.3.6.4.2 Slope Factors for Trichloroethene

The latest revisions (September 2011) of the oral carcinogenic potency factor, the oral reference dose, and the inhalation reference concentration were used to calculate cancer risks and noncancer hazards. The oral carcinogenic potency factor of 0.046 mg/kg-day published by IRIS is used to calculate cancer risks associated with the ingestion and dermal contact exposure routes for the tap water exposure scenario. TCE is carcinogenic by mutagenic mode of action for induction of kidney tumors. According to EPA/630/R-03/003F, *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens,* those exposed to carcinogens with a mutagenic mode of action are assumed to have increased early-life susceptibility. However, data for TCE are not sufficient to develop separate risk estimates for childhood exposure; therefore, age dependent adjustment factors were not applied to the oral carcinogenic potency factor.

6.3.6.4.3 Oral Reference Dose for Total Uranium (Soluble Salts)

The RfD for uranium that is published in IRIS (0.003 mg/kg-day) was used for hazard calculations in this risk assessment. The reference dose value (0.0002 mg/kg-day) published in the memorandum dated December 21, 2016, Considering a Noncancer Oral Reference Dose for Uranium for Superfund Human Health Risk Assessments and referenced in in the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" website is not published in IRIS and an MCL using this value has not been promulgated. As such, the RfD value of 0.0002 mg/kg-day for total uranium was not used in this risk assessment. Using the IRIS value has the potential to underestimate the noncancer hazard.

6.3.6.5 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically.

6.3.6.5.1 Uncertainties Associated with the Native American Risk Assessments

As discussed in Section 6.1.3, the RCBRA (DOE/RL-2007-21) evaluated three residential scenarios that describe exposure related to rural land-use patterns that involved exposure assumptions which represented subsistence use. Of the three residential scenarios, two Native American scenarios were evaluated including the CTUIR and the Yakama Nation. Although groundwater within the 100-K OU is not anticipated to become a source of drinking water, risks from contaminants in groundwater were assessed using the two Native American scenarios (as provided by the CTUIR and the Yakama Nation) to provide estimates of human health risks that represent full-time occupancy. In addition, the risks calculated using the Native American scenarios were compared with risks estimated using the EPA standard default assumptions for residential tap water use (the tap water scenario). As described in Regional Screening Levels (EPA, 2018), the residential tap water scenario reflects an RME scenario.

The groundwater risk assessment provided in this RI provides an update to address the uncertainties associated with the assessment of groundwater risks presented in the RCBRA (DOE/RL-2007-21, Section 6.3.1). The uncertainties in the RCBRA (DOE/RL-2007-21) were associated with the ability of the groundwater data set collected from 1998 to 2008 to represent current baseline conditions and potential exposure within each groundwater OU. The following paragraphs discuss the uncertainties with risks associated with groundwater contaminants based on current baseline conditions.

The Native American and tap water scenarios addressed direct exposure to contaminants in groundwater associated with household uses of groundwater, such as drinking and cooking (ingestion) and bathing (dermal absorption). If VOCs were measured in groundwater and identified as COPCs, indirect exposure by inhalation of VOCs in air while bathing or when using groundwater in the home for other purposes was also addressed. In addition to household use of groundwater, the CTUIR and Yakama Nation scenarios also incorporated inhalation and dermal exposures to COPCs in groundwater used in a sweat lodge. The results from the Native American groundwater risk assessment are presented in Table 6-178. The pathway-specific risks and hazards were summed to obtain a cumulative estimate of risk and hazard for all groundwater exposure pathways included in each of the CTUIR and Yakama Nation exposure scenarios (drinking water and sweat lodge).

Exposure parameters for drinking water ingestion, VOC inhalation and dermal absorption differ between the Native American drinking water exposure scenarios and the EPA tap water scenario. Examples of these differences include the following:

- Exposure frequency: Native American, 365 d/yr; EPA tap water, 350 d/yr
- Exposure duration: Native American, 70 years; EPA tap water, 26 years
- Drinking water ingestion rate: Native American, 4 L/day; EPA tap water, 2.5 L/day
- Inhalation rate: CTUIR, 25 m^3/day, Yakama Nation, 26 m^3/day; EPA tap water, 20 m^3/day

As a result, the Native American exposure scenarios both produce higher total ELCR and HI than the EPA tap water scenario. Depending on the contaminants and pathways involved, (as described in the following discussion), the ELCR and HI for the Native American scenarios may be 4- to 5-fold greater than for the tap water scenario including drinking water ingestion, VOC inhalation, and dermal absorption exposure pathways. COPCs are the same for each of the three exposure scenarios; the percent contribution for each COPC is higher for the Native American scenarios than the EPA tap water scenario.

The largest uncertainties associated with the Native American scenarios are regarding the use of groundwater in a sweat lodge.

EPCs for air in a sweat lodge were calculated for the CTUIR Resident and Yakama Resident scenarios. Appendix 4 of Harris and Harper, 2004, provides equations for estimating vapor-phase contaminant concentrations for volatile and semivolatile COPCs in the water used to create steam in the lodge, as well as separate equations for estimating air-phase contaminant concentrations for aerosolized nonvolatile COPCs. Inhalation exposure to nonvolatile COPCs in the sweat lodge was evaluated in the CTUIR and Yakama Nation resident scenarios in spite of concerns with the model for calculating these air-phase EPCs. The CTUIR exposure scenario equation for calculating air-phase EPCs for nonvolatile analytes (Equation 3-2 in Harris and Harper, 2004) calculates the concentration of a nonvolatile COPC in air as a function of the concentration of water vapor produced by the volatilization of water poured over hot rocks in a sweat lodge. Because nonvolatile contaminants have no vapor pressure, Equation 3-2 does not have a common physical basis with volatile chemicals.

It is possible that inhalation of nonvolatile COPCs might occur by an alternative physical model (e.g., respiration of respirable-size aerosols, if such aerosols were formed when water is poured over the hot rocks in a sweat lodge). However, a model of resuspension of nonvolatile impurities in aerosol form is inconsistent with other mechanical processes involving steam. For example, EPA does not address this pathway in shower volatilization models (EPA 600/R-00/096, *Volatilization Rates from Water to Indoor Air Phase II*). It is also inconsistent with the widespread use of steam distillation for commercial water purification.

Groundwater within the 100-KR-4 Groundwater OU is currently contaminated, and withdrawal is prohibited as a result of institutional controls put in place by DOE (DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*). Under current site use conditions, no complete human exposure pathways to groundwater are assumed to exist. Groundwater within the OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use.

Table 6-178. Summary of Cancer Risks and Noncancer Hazards for Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios for the 100-KR-4 Groundwater Operable Unit

Environmental Medium/ Exposure Pathway	CTUIR Total Cumulative ELCR	CTUIR Risk Drivers [e]	CTUIR HI	CTUIR Hazard Drivers [f]	Yakama Nation Total ELCR	Yakama Nation Risk Drivers [e]	Yakama Nation HI	Yakama Nation Hazard Drivers[f]
Remediated Waste Sites (Direct Contact and Food Chain Pathways) [a]	9×10^{-3} to 8×10^{-4}	Cesium-137 Cobalt-60 Europium-152 Europium-154 Strontium-90	0.0017 to 1,100	Ethylene glycol Mercury	9×10^{-3} to 9×10^{-4}	Cesium-137 Cobalt-60 Europium-152 Europium-154 Strontium-90	0.0046 to 1,400	Ethylene glycol Mercury
Groundwater as a potential drinking water source [b]	2.0×10^{-2}	1,2,4-Trichlorobenzene Aldrin Bis(2-ethylhexyl) phthalate Bromodichloromethane Carbon tetrachloride Carbon-14 Chloroform Ethylbenzene TCE Tritium	20	Aldrin Bis(2-ethylhexyl) phthalate Cyanide Cr(VI) TCE	2.1×10^{-2}	1,2,4-Trichlorobenzene Aldrin Bis(2-ethylhexyl) phthalate Bromodichloromethane Carbon tetrachloride Carbon-14 Chloroform Ethylbenzene TCE Tritium	25	Aldrin Bis(2-ethylhexyl) phthalate Cyanide Cr(VI) Manganese TCE
Groundwater as a potential source of steam from sweat lodge use (includes aerosolized nonvolatiles) [c]	3.9×10^{-2}	Aldrin Beryllium Bis(2-ethylhexyl) phthalate Cadmium Carbon-14 Cobalt Cr(VI) Nickel Tritium Uranium-233/234	51	Cr(VI) Manganese	2.6×10^{-1}	Aldrin Beryllium Bis(2-ethylhexyl) phthalate Bromodichloromethane Cadmium Carbon tetrachloride Carbon-14 Chloroform Cobalt Ethylbenzene Cr(VI) Nickel Strontium-90 TCE Tritium Uranium-233/234 Uranium-235 Uranium-238	374	Barium Cobalt Cr(VI) Cobalt Manganese Nickel Uranium Vanadium

Table 6-178. Summary of Cancer Risks and Noncancer Hazards for Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios for the 100-KR-4 Groundwater Operable Unit

Environmental Medium/ Exposure Pathway	CTUIR Total Cumulative ELCR	CTUIR Risk Drivers [e]	CTUIR HI	CTUIR Hazard Drivers [f]	Yakama Nation Total ELCR	Yakama Nation Risk Drivers [e]	Yakama Nation HI	Yakama Nation Hazard Drivers[f]
Groundwater as a potential source of steam from sweat lodge use (excludes aerosolized nonvolatiles) [d]	--	--	--	--	9.3×10^{-3}	Aldrin Bis(2-ethylhexyl) phthalate Bromodichloromethane Carbon tetrachloride Carbon-14 Chloroform Ethylbenzene TCE Tritium	6.3	Hexavalent chromium

References: ECF-100KR4-17-0083, Rev. 0, *Native American Risk Assessment for the 100-KR-4 Groundwater Operable Unit*.

DOE/RL-2007-21, Rev. 0, *River Corridor Baseline Risk Assessment Volume II, Part 1 and Part 2: Human Health Risk Assessment.*

Notes:

a. DOE/RL-2007-21, CTUIR Resident Scenario ECLR, HI, and drivers: Section 5.4.4.1 and Table 5-75 and Section 5.4.4.3 and Table 5-77; Yakama Nation Resident Scenario ELCR, HI, and drivers: Section 5.4.4.1 and Table 5-78 and Section 5.4.4.3 and Table 5-80.

b. ECF-100KR4-17-0083, CTUIR drinking water ECLR, HI, and drivers: Table 18, Yakama Nation drinking water ELCR, HI, and drivers: Table 20.

c. ECF-100KR4-17-0083, CTUIR sweat lodge ECLR, HI, and drivers: Table 19, Yakama Nation sweat lodge with aerosolized nonvolatiles ELCR, HI, and drivers: Table 21.

d. ECF-100KR4-17-0083, Yakama Nation sweat lodge without aerosolized nonvolatiles ELCR, HI, and drivers: Table 22.

e. For remediated waste sites, contributes ≥ 10% of total risk. For groundwater, individual ELCR $>1\times10^{-6}$ (chemicals) or individual ELCR $> 1\times10^{-4}$ (radionuclides).

f. For remediated waste sites, contributes ≥ 10% of HI. For groundwater, HQ >1 for groundwater.

Cr(VI) = hexavalent chromium
TCE = trichloroethene
CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index

6.4 Risk Assessment Conclusions of the Riparian and Near-Shore Environment from RCBRA and the Columbia River Component

Human health risks were assessed in areas outside the footprints of waste sites as part of the RCBRA (DOE/RL-2007-21, Volume II) and the CRC HHRA (DOE/RL-2010-117, Volume II). The following sections summarize the conclusions obtained from these two risk assessments. Table 6-179 presents a summary of the total risks and noncancer hazards associated with the riparian and near-shore area and the Columbia River. Several investigations conducted on effluent pipelines that discharged to the Columbia River are also summarized in the following sections.

6.4.1 Risk Assessment Conclusions from the River Corridor Baseline Risk Assessment

The assessment of human health risks was based on "broad-area" environmental data that characterized concentrations of COPCs in upland and riparian surface soil, river water and sediment in near-shore areas, and fish tissue.

The exposure scenarios considered for riparian and near-shore areas were an Avid Angler, Casual User and Tribal scenarios, including a Nonresident Tribal scenario, and ingestion of fish in the CTUIR and Yakama Resident scenarios. The casual user scenario addresses occasional recreational use and is focused on activities such as walking and picnicking in riparian areas near the river. The Avid Angler is focused on individuals who are not engaged in a subsistence lifestyle. The Avid Angler application is associated with exposure in the nearshore region of the River Corridor, and takes into consideration potential exposures to sediments and fish. The nonresident Tribal scenario is focused on individuals engaged in a subsistence lifestyle who reside offsite but use the River Corridor for various activities such as hunting, gathering plants, and fishing.

EPCs in soil in the riparian environment were calculated using MULTI-INCREMENT® sampling from riparian locations in the 100-K Area (RCBRA SAP [DOE/RL-2005-42]). Discrete sediment samples used to calculate EPCs were obtained from sites in the River Corridor selected from locations of known groundwater plumes, areas of groundwater discharge to the river, results of past biota sampling locations, or areas of fine-grained sediment deposits. Data from sculpin, clams, and benthic macroinvertebrates (primarily crayfish) were used to estimate fish ingestion risks to avid angler and nonresident Tribal receptors.

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Table 6-179. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore Areas Along the 100-K Shoreline

Environment/ Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Casual User Scenario						
Riparian Soil	2×10^{-6}	None	0.019	None	--	RCBRA - DOE/RL-2007-21, Tables 4-14 and 4-16
Avid Angler Scenario						
Near-Shore – sediment, river water, dust	2×10^{-6}	None	0.0055	None	--	RCBRA - DOE/RL-2007-21, Tables 4-17 and 4-19
Fish ingestion - Sculpin	4×10^{-5}	Carbon-14*	2.2	Metals	Screening-level result employing near-shore COPC concentrations in sculpin, a small fish with a limited home range.	
Nonresident Tribal Scenario						
Soil, sediment, water	6×10^{-5}	None	0.71	None	--	RCBRA - DOE/RL-2007-21, Tables 4-24 and 4-26
Plants and game	2×10^{-2}	Arsenic, Carbon-14	83	Arsenic, Cadmium	Ingestion of contaminants in plants and game were modeled using bio-transfer factors which overstated concentrations accumulated from soil.	
Fish Ingestion - Sculpin	3×10^{-4}	Carbon-14	13	Metals	Screening-level result employing near-shore COPC concentrations in sculpin, a small fish with a limited home range.	

Table 6-179. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore Areas Along the 100-K Shoreline

Environment/ Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Casual User Scenario (Child- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.005	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC - DOE/RL-2010-117, Tables 6-1 and 6-2.
100-A Study Area COPCs in Sediment	5×10^{-7}	None	0.02	None		
100-B Study Area COPCs in Surface Water	0	None	0.003	None		
100-B Study Area COPCs in Sediment	4×10^{-7}	None	0.02	None		
100-B Study Area COPCs in Island Soil	8×10^{-7}	None	0.02	None		
Casual User Scenario (Adult- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.001	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC - DOE/RL-2010-117, Tables 6-13 and 6-14.
100-A Study Area COPCs in Sediment	3×10^{-6}	None	0.003	None		
100-B Study Area COPCs in Surface Water	0	None	0.0009	None		
100-B Study Area COPCs in Sediment	2×10^{-6}	None	0.002	None		
100-B Study Area COPCs in Island Soil	5×10^{-7}	None	0.003	None		

Table 6-179. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore Areas Along the 100-K Shoreline

Environment/ Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
Avid Angler Scenario (Child- Columbia River)						
100 Area, Fish Ingestion	1×10^{-6}	None	7	PCBs (dioxin and nondioxin-like)	--	CRC - DOE/RL-2010-117, Table 6-25
Avid Angler Scenario (Youth- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.001	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC - DOE/RL-2010-117, Tables 6-28 and 6-29.
100-A Study Area COPCs in Sediment	7×10^{-7}	None	0.005	None		
100-A Study Area COPCs in Fish	$4\times10^{-6*}$	None	7	PCBs (dioxin and nondioxin-like)		
100-B Study Area COPCs in Surface Water	0	None	0.0008	None		
100-B Study Area COPCs in Sediment	5×10^{-7}	None	0.003	None		
100-B Study Area COPCs in Island Soil	3×10^{-7}	None	0.006	None		
100-B Study Area COPCs in Fish	$4\times10^{-6*}$	None	7	PCBs (dioxin and nondioxin-like)		
Avid Angler Scenario (Adult- Columbia River)						
100-A Study Area COPCs in Surface Water	0	None	0.0007	None	Risks in each media summed across chemical carcinogens and radionuclides.	CRC - DOE/RL-2010-117, Tables 6-34 and 6-35.
100-A Study Area COPCs in Sediment	3×10^{-6}	None	0.003	None		

Table 6-179. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore Areas Along the 100-K Shoreline

Environment/ Exposure Media	Excess Lifetime Cancer Risk	Primary Risk Drivers	Noncancer Hazard Index	Primary Noncancer Hazards	Comment	Source
100-A Study Area COPCs in Fish	$3\times10^{-5*}$	None	7	PCBs (dioxin and nondioxin-like)		
100-B Study Area COPCs in Surface Water	0	None	0.0005	None		
100-B Study Area COPCs in Sediment	2×10^{-6}	None	0.002	None		
100-B Study Area COPCs in Island Soil	5×10^{-7}	None	0.003	None		
100-B Study Area COPCs in Fish	$3\times10^{-5*}$	None	7	PCBs (dioxin and nondioxin-like)		

Notes: Zero values indicate that there were no COPCs for that medium, therefore no risks or noncancer hazards were calculated.

Risks presented in this table are for COPCs identified in the study area (i.e. along the River Corridor sites). COPCs for reference areas are presented in the DOE/RL-2010-117, *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment*. t. (Note that risks associated with reference area COPCs typically are greater than risks associated with study area COPCs).

Risk estimates for the CTUIR and Yakama Nation scenarios are provided in DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, and DOE/RL-2010-117.

* Carbon-14 was detected in one sucker fillet at a concentration slightly higher than the minimum detectable activity of the instrument and is likely a false positive result. Risk contributions of carbon-14 were low relative to the contribution of risk from PCBs and chlorinated pesticides. Carbon-14 was not detected in nearshore groundwater, seeps, or sediment but was detected in one soil sample collected from the riparian area.

The results of the broad-area risk assessment in the 100-K Area for the casual user and avid angler scenarios showed that lifetime cancer risk was 2×10^{-6} and below a noncancer HI of 1 for direct exposures to soil, sediment, and surface water. The cancer risk from fish ingestion for the avid angler was 4×10^{-5} based on the presence of carbon-14 in sculpin tissue. The HI for the avid angler scenario was 2.2, the primary hazard drivers were metals.

Risks for riparian soil were higher than 1×10^{-4} cancer risk and above a noncancer HI of 1 for the nonresident Tribal scenario. Modeled concentrations of arsenic and carbon-14 from riparian soil into native vegetation provided the largest contribution to cancer risks and noncancer HIs. However, as discussed in the RCBRA (DOE/RL-2007-21), uncertainties in the food chain modeling methods considerably overstate risks from plant ingestion exposure pathways, particularly for arsenic. Cancer risks and noncancer HI from fish ingestion, based on sculpin data, were higher than 1×10^{-4} and greater than the target HI of 1 for the Tribal scenarios.

Carbon-14 was the primary risk driver for fish ingestion. Carbon 14 was detected in one sucker fillet at a concentration slightly higher than the minimum detectable activity of the instrument and is likely a false positive result. Risk contributions of carbon 14 were low relative to the contribution of risk from polychlorinated biphenyl (PCBs) and chlorinated pesticides. Carbon 14 was not detected in near shore groundwater, seeps, or sediment but was detected in one soil sample collected from the riparian area.

The noncancer HIs for fish ingestion were higher than one for the avid angler and nonresident Tribal scenario. The COPC providing the major contribution to the noncancer hazard was copper detected in clams and crayfish. As discussed in the RCBRA (DOE/RL-2007-21), it is likely that the calculated HI values for copper overstate the risks from ingestion of this metal. Copper is present in hemocyanin for carrying oxygen in the blood, both in crayfish and clams. HI values for ingestion of crayfish from reference areas are similar to the 100-K Area. Human health risks from copper are associated with GI irritation by free copper ions in drinking water, which is an effect that may not be relevant to ingestion of copper in food.

6.4.2 Risk Assessment Conclusions from the Columbia River Component

The CRC HHRA (DOE/RL-2010-117, Volume II) provides a comprehensive assessment of human health risks for the Hanford Reach. The intent of the CRC HHRA was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA (DOE/RL-2007-21). Human exposure scenarios addressed in the CRC HHRA were an avid angler, casual user, hypothetical future resident, and a Native American (Yakama Nation) subsistence fisher. As discussed in the CRC HHRA, fish ingestion exposure provided the largest contribution to overall human health risks. A fish sampling program was specifically created to support the CRC HHRA and provided a consistent sampling and analysis approach among species, tissue types, and analytes (Columbia River RI Work Plan [DOE/RL-2008-11]). The fish species targeted in the sampling program were intended to be the most representative of the exposure scenarios identified in the CRC HHRA and included the following:

- Common carp (*Cyprinus carpio*)
- Mountain whitefish (*Prosopium williamsoni*)
- Walleye (*Stizostedion vitreum*)
- Smallmouth bass (*Micropterus dolomieui*)
- Bridgelip sucker (*Catostomus columbianus*)
- White sturgeon (*Acipenser transmontanus)*

Separate fillets, carcasses (including the head and skeleton), and combined livers and kidneys were analyzed. Fillet samples for all species except sturgeon were prepared with the skin on, as skin for these types of fish is often left on during preparation and consumption.

The fish consumption pathway provided the largest contribution (99% contribution) to human health risks evaluated for the avid angler and Native American scenarios. The fish consumption pathway was evaluated using two separate approaches. In the first approach, risk was quantified assuming a receptor consumed a varied diet consisting of all six species evaluated. In a second approach, risk was quantified for each individual fish species. Although the concentrations of COPCs, and hence, estimated hazard/risk, varied among the different species, the relative magnitude of risk remained similar among all six fish species. Relative magnitude of risk for the avid angler scenario was generally in the range of 2×10^{-3} to 8×10^{-3}, with bass and carp having the overall lowest and highest associated cancer risk, respectively. PCBs, chlorinated pesticides (notable dieldrin and beta-hexachlorocyclohexane), cobalt, lithium, and mercury were the primary risk drivers through fish ingestion. Throughout the 100 Area sub-area (where the 100-K OU is located), all of the risk drivers in fish also were identified in upstream reference areas. Carbon-14 was the only radionuclide consistently detected among fish tissue samples, although at a very low (1%) frequency of detection. Carbon-14 was also only sporadically detected in abiotic media. Several radionuclides were detected in some fish tissue samples at a very low (1%) frequency of detection. With the exception of carbon-14, these radionuclides were eliminated as COPCs because it was concluded the concentrations were erroneous data quality or data consistency issues.

PCBs, mercury, and chlorinated pesticides in fish tissue, which are primary risk drivers, are prevalent in fish tissue in many water bodies, due to their widespread historical use, atmospheric deposition and, consequently, high prevalence in abiotic media. The results from Chapter 4 and Riparian and Near-Shore CSM in Appendix L show that there are unlikely to be sources or transport pathways from 100-K OU sites or groundwater, coupled with comparable risks associated with fish caught in reference areas, it is unlikely that Hanford Site activities in the 100-K OUs are associated with the fish ingestion risks projected in the CRC HHRA (DOE/RL-2010-117, Volume II).

Results from the risk characterization indicate that the risks related to exposure to surface water, sediment, and island soil are very small relative to that from the fish ingestion pathway. Cumulative risks for the casual user scenario (which included direct contact exposure pathways to sediment, surface water, and island soil) were 3×10^{-6} or lower in the 100-A Study Area and 2×10^{-6} or lower in the 100-B Study Area. Noncancer HIs were well below 1 for all scenarios for surface water, sediment and island soil. Arsenic in sediment within most of the exposure points accounted for over half of the cumulative risk. Of the radionuclides, cobalt-60, europium-152, and cesium-137 constitute the majority of radiation cancer risk. Radionuclide risks from abiotic media (surface water, island soil, and sediments) are within the target cancer risk range. Cesium-137 is a known constituent of worldwide atmospheric fallout and was found in reference areas. Risks from island soil exposures were relatively minor compared to risks from other abiotic media.

6.4.3 Risk Assessment Conclusions for River Pipelines

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, the two inactive 100-K effluent pipelines, extending from the 1908K outfall structure, remain in their original locations in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines. The RCBRA (DOE/RL-2007-21, Volume II)

provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

In 1984, *River Discharge Lines Characterization Report* (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F Reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The HHRA determined that elevated human radiological exposure could occur if portions of the river pipelines became dislodged and washed ashore (DOE/RL-2007-21, Section 8.2.2).

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent “worst case” conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the B and D/DR Reactors.

The analytical results from the 1984 and 1995 effluent pipeline characterization studies at the 105-B, 105-C, 105-D/DR, and 105-F Reactors may reasonably be applied to effluent pipelines in 100-K, because operations among these reactors were similar. Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (BHI-01141) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk, because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks and, therefore, no remediation requirements under CERCLA. This is supported by the following facts:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations due to decay
- Inaccessible location
- Unavailability of significant contaminants to affect human health and the environment

Based on available information, no elevated risk levels are expected to be associated with these pipelines.

6.5 Summary and Conclusions

The soil and groundwater human health risk assessment for the 100-K Source OUs and 100-KR-4 Groundwater OUs accomplish the following objectives:

- Propose direct contact PRGs in soil.
- Evaluate the effectiveness of source interim actions for the 100-K Source OUs.
- Qualitatively evaluate soil data from RI and LFI soil borings and wells to determine if results could be useful for risk management decisions.
- Confirm that wastes sites are remediated to the RAOs and RAGs published in the 100 Area RDR/RAWP (DOE/RL-96-17) in accordance with 1996 MTCA.
- Confirm that previously remediated waste sites achieve the MTCA direct contact PRGs proposed for the FS. In other words, confirm which sites cleaned up under interim action do not need to be revisited in the FS to demonstrate protection of human health.
- Propose soil SSLs and PRGs protective of groundwater and surface water for use in the FS in accordance with EPA guidance and the MTCA (WAC 173-340-747(5)) procedure as described in Section 2.2 of DOE/RL-2011-50, *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*. Proposed soil SSLs and PRGs protective of groundwater and surface water are presented in Section 5.3.3 of this report.
- Evaluate previously remediated waste sites to determine if residual soil concentrations are predicted to affect groundwater at concentrations greater than DWSs or risk-based concentrations calculated in accordance with MTCA (WAC 173-340-747(5)) procedures (as reported in Section 5.3.3). The results of this comparison are provided in Section 5.4 of this report.
- Identifies the waste sites and COPCs in the vadose zone that require further evaluation in the FS.
- Identifies the COCs in groundwater that require further evaluation in the FS.
- Propose PRGs in groundwater (see Chapter 8, Table 8-3) that include DWSs and risk-based concentrations calculated in accordance with 2013 MTCA (WAC 173-340-720).

The methodology used to assess risks for the RI uses PRGs following DOE and EPA guidance updated through November 2017 (Table 6-5 provides more detail). COPCs in the vadose zone and groundwater were identified in a conservative manner, as described in EPA guidance. The methods for developing EPCs are based on ProUCL guidance manual (EPA/600/R-07/041). PRGs for the vadose zone were developed to reflect a range of exposure scenarios and include those that represent the RAOs (residential scenario) and reasonably anticipated future land use (casual recreational user).

Contaminant concentrations in groundwater were compared with a range of groundwater and surface water standards for protection of human health and aquatic organisms. In addition, risks from contaminants in groundwater were assessed using Tribal scenarios based on assumptions provided by the CTUIR and Yakama Nation. The EPA tap water scenario is also evaluated to provide a similar scenario using exposure assumptions that represent RME.

Cumulative risks were calculated for multiple contaminants and multiple exposure pathways by exposure media (i.e., soil or groundwater). Cumulative risks summed across soil and groundwater were not

calculated for the residential scenario because the RME for this scenario does not include combined exposures to both media; therefore, they are presented separately.

RI and LFI data were compared to PRGs developed in the RI/FS soil BRA. Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs from each individual well, soil boring, or test pit were combined and compared to PRGs including those that represent the RAOs (residential scenario) and reasonably anticipate future land use (casual-recreational user). Soil samples collected from depth intervals greater than 4.6 m (15 ft) bgs from each individual soil boring or test pit were combined and compared to residential PRGs for radionuclides.

The protection of groundwater and surface water from contaminants currently in the vadose zone was discussed in Chapter 5. The ERA that evaluates the protection of terrestrial receptors is discussed in Chapter 7.

6.5.1 Conclusions for the Soil Risk Assessment

The primary contaminants that are the largest contributors to calculated risks and HIs in the vadose zone are radionuclides. The radionuclides can be categorized as being related to waste disposal, including carbon-14, cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90.

6.5.1.1 Shallow Zone Results for Closeout Verification Data

Cancer risks associated with radionuclides at remediated waste sites within the top 4.6 m (15 ft) of soil are $>1\times10^{-4}$ at four waste sites based on the residential scenario. Cancer risks for a casual-recreational user scenario are approximately 1,000 times lower than the residential scenarios.

Four remediated waste site groups represented by the following five decision units are reported with concentrations of one or more radioisotopes in the shallow zone (Table 6-11). The following bullets indicate the year that radioisotopes in shallow decision units will decay to a total cumulative ELCR that is $<1\times10^{-4}$.

- 100-K-56:1 (shallow focused decision unit) contains europium-152 at a concentration of 3.1 pCi/g and strontium-90 at a concentration of 0.5 pCi/g, resulting in a risk of 1.2×10^{-4}, when sampled in 2005. Activities of all radionuclides have decayed to a total cumulative ELCR $<1.0\times10^{-4}$ at 2007.

- 116-K-1 (shallow decision unit) contains cesium-137 at a concentration of 1.2 pCi/g, and strontium-90 at a concentration of 1.7 pCi/g, resulting in a risk of 1.1×10^{-4}, when sampled in 2003. Activities of all radionuclides have decayed to a total cumulative ELCR $<1.0\times10^{-4}$ at 2007.

- The 100-K-6, 100-K-46, 100-K-62, 132-KE-1 (shallow 1 decision unit) remediated waste site contains carbon-14 at a concentration of 66 pCi/g, cesium-137 at a concentration of 1.7 pCi/g, and strontium-90 at a concentration of 0.79 pCi/g, resulting in a risk of 1.1×10^{-4}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2066. This contamination is associated with the collocated 116-KE-1 gas condensate crib and will, therefore, subsequently be considered as part of the 116-KE-1 site.

- The 118-K-1 (P1 shallow 4 decision unit) remediated waste site contains strontium-90 at a concentration of 5.6 pCi/g, resulting in a risk of 2.4×10^{-4}, when sampled in 2008. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2045.

- The 118-K-1 (P1 shallow focused 1 decision unit) remediated waste site contains cesium-137 at a concentration of 3.7 pCi/g, and strontium-90 at a concentration of 2.0 pCi/g, resulting in a risk

of 1.7×10^{-4}, when sampled in 2008. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2032.

For nonradiological contaminants at remediated waste sites, all of the remediated waste sites are less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5} or the target HI of 1.

6.5.1.1 Shallow Zone Results for RI and LFI Data

Four soil borings and 13 monitoring wells were drilled for the RI; 21 wells were drilled for remedial process optimization (e.g. adequate plume delineation). In general, the comparison of soil concentrations from RI data to RBSLs are consistent with the conclusions of the soil risk assessment. Only LFI sample locations (100-KR-1-TP1, 100-KR-1-TP-3, 199-K-39, and 199-K-40) report soil concentrations greater than residential RBSLs. In all cases, these waste sites have been remediated under the interim action ROD.

6.5.1.2 Deep Zone Results for Closeout Verification Data

Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. The RBSLs (developed for the residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

A total of 10 remediated waste site groups represented by the following 15 decision units are reported with concentrations of one or more radioisotope in the deep zone. The following bullets indicate the year that radioisotopes in deep decision units will decay to a total cumulative ELCR that is $<1\times10^{-4}$.

- 100-K-6, 100-K-46, 100-K-62, 132-KE-1 (shallow 2 decision unit) contains carbon-14 at a concentration of 139 pCi/g, cesium-137 at a concentration of 15.5 pCi/g, and strontium-90 at a concentration of 11 pCi/g, resulting in a risk of 1.0×10^{-3}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 6357. Although the samples from this decision unit were assigned to the shallow zone, DOE/RL-2012-38 indicates that these samples were collected from both the shallow and deep zones. Vadose zone material collected from the deep zone report concentrations greater than the RBSLs. Radioisotopes in the 100-K-6, 100-K-46, 100-K-62, and 132-KE-1 site group decision unit are associated with the collocated 116-KE-1 gas condensate crib and will subsequently be considered as part of the 116-KE-1 site.

- 100-K-46 (deep decision unit) contains cesium-137 at a concentration of 6.2 pCi/g and strontium-90 at a concentration of 0.99 pCi/g, resulting in a risk of 1.9×10^{-4}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2038. Radioisotopes in 100-K-46 waste site decision unit is associated with the collocated 116-KE-1 gas condensate crib and will subsequently be considered as part of the 116-KE-1 site.

- 116-K-2 (deep 1 decision unit) contains cesium-137 at a concentration of 140 pCi/g, cobalt-60 at a concentration of 2.8 pCi/g, europium-152 at a concentration of 69 pCi/g, europium-154 at a concentration of 6.2 pCi/g, nickel-63 at a concentration of 995 pCi/g, and strontium-90 at a concentration of 7.7 pCi/g, resulting in a risk of 5.8×10^{-3}, when sampled in 2005. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2185.

- 116-K-2 (deep 2 decision unit) contains cesium-137 at a concentration of 144 pCi/g, cobalt-60 at a concentration of 4.4 pCi/g, europium-152 at a concentration of 82 pCi/g, europium-154 at a concentration of 12 pCi/g, nickel-63 at a concentration of 660 pCi/g, and strontium-90 at a

concentration of 6.7 pCi/g, resulting in a risk of 6.4×10^{-3}, when sampled in 2005. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2176.

- 118-K-1 (P2 deep focused 1 decision unit) contains cesium-137 at a concentration of 11 pCi/g and strontium-90 at a concentration of 29 pCi/g, resulting in a risk of 1.6×10^{-3}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2126.
- 118-K-1 (P2 deep focused 7 decision unit) contains cesium-137 at a concentration of 36 pCi/g and strontium-90 at a concentration of 12 pCi/g, resulting in a risk of 1.4×10^{-3}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2123.
- 118-K-1 (P2 deep focused 2 decision unit) contains cesium-137 at a concentration of 4.4 pCi/g, europium-152 at a concentration of 37 pCi/g, and strontium-90 at a concentration of 15 pCi/g, resulting in a risk of 1.9×10^{-3}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2102.
- 118-K-1 (P2 deep 7 decision unit) contains cesium-137 at a concentration of 10 pCi/g and strontium-90 at a concentration of 7.3 pCi/g, resulting in a risk of 5.6×10^{-4}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2084.
- 116-K-1 (deep decision unit) contains cesium-137 at a concentration of 1.5 pCi/g, cobalt-60 at a concentration of 2.5 pCi/g, europium-152 at a concentration of 5.5 pCi/g, and strontium-90 at a concentration of 8.6 pCi/g, resulting in a risk of 9.7×10^{-4}, when sampled in 2003. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2088.
- 100-K-56:1 (deep decision unit) contains cesium-137 at a concentration of 26 pCi/g, cobalt-60 at a concentration of 1.1 pCi/g, europium-152 at a concentration of 31 pCi/g, and europium-154 at a concentration of 2.0 pCi/g, resulting in a risk of 1.5×10^{-3}, when sampled in 2005. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2087.
- 100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71 (deep focused 1 decision unit) contains cesium-137 at a concentration of 48 pCi/g and strontium-90 at a concentration of 16 pCi/g, resulting in a risk of 1.8×10^{-3}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2135.
- 100-K-3, 100-K-36, 100-K-79:7 (deep focused 1 decision unit) contains strontium-90 at a concentration of 6.2 pCi/g, resulting in a risk of 2.7×10^{-4}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2054.
- 100-K-3, 100-K-36, 100-K-79:7 (deep P4P5 decision unit) contains strontium-90 at a concentration of 5.4 pCi/g, resulting in a risk of 2.4×10^{-4}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2048.
- 100-K-47, 100-K-69, 100-K-70, 100-K-71 (deep decision unit) contains europium-152 at a concentration of 0.68 pCi/g, and strontium-90 at a concentration of 2.8 pCi/g, resulting in a risk of 1.4×10^{-4}, when sampled in 2012. Activities of all radionuclides will decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2025.
- 100-K-55:1 (deep decision unit) contains cesium-137 at a concentration of 3.9 pCi/g, cobalt-60 at a concentration of 0.59 pCi/g, europium-152 at a concentration of 0.78 pCi/g, and europium-154 at a concentration of 0.29 pCi/g, resulting in a risk of 1.4×10^{-4}, when sampled in 2005. Activities of all radionuclides have decayed to a total cumulative ELCR of $<1.0\times10^{-4}$ in 2011.

6.5.1.3 Deep Zone Results for RI and LFI Data

Soil samples were collected from depths greater than 4.6 m (15 ft) bgs from 4 RI soil borings, 20 RI wells, 3 LFI soil borings, 4 LFI test pit samples, and 6 LFI wells. In general, the comparison of soil concentrations from RI data to RBSLs are consistent with the conclusions of the soil risk assessment.

At 199-K-200, strontium-90 concentrations are greater than the residential RBSL of 2.2 pCi/g at depths ranging between 8.6 and 11 m (28.2 and 35.5 ft) bgs. Concentrations of strontium-90 decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2033.

At 199-K-201, cesium-137, europium-152, and strontium concentrations are greater than the residential RBSLs at depths ranging between 5.9 and 8.5 m (19.3 and 27.8 ft) bgs. Concentrations of cesium-137, europium-152, and strontium decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2171.

The 116-K-2 waste site was remediated under the interim action ROD and is included in the soil risk assessment. The results for the 116-K-2 waste site report similar risk contributors when compared to soil borings 199-K-200 and 199-K-201. Activity levels of cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 decay to levels less than residential RBSLs by year 2148.

At 199-K-222 (a monitoring well to characterize the UPR-100-K-1 waste site), americium-241, plutonium-239/240, and strontium-90 are greater than the residential RBSLs at depths ranging between 7.3 and 8.4 m (24.1 and 27.7 ft) bgs. Concentrations of americium-241, plutonium-239/240, and strontium-90 decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 36922.

6.5.1.4 Summary of Remediated Waste Sites that Warrant Evaluation of Remedial Alternatives

Thirty remediated waste sites (including grouped sites) have cumulative cancer risks greater than 1×10^{-4}. Table 6-180 identifies the remediated waste sites that warrant evaluation of remedial alternatives in the FS, their COPCs, their human health direct contact cumulative cancer risks, and the year their cumulative cancer risk decays to $<1\times10^{-4}$.

Table 6-180. Summary of 100-K Operable Units Remediated Waste Sites that Warrant Evaluation of Remedial Alternatives in the FS

Reason Waste Site Warrants Evaluation of Remedial Alternatives	COPC	Cumulative Cancer Risk (Year Risk Decays $< 1\times10^{-4}$)	Waste Site Name
Sites with deep zone human health direct contact cumulative risk currently $>1\times10^{-4}$	Strontium-90	2.7×10^{-4} (2054)	100-K-3, 100-K-36, 100-K-79:7*
	Strontium-90	2.4×10^{-4} (2048)	100-K-3, 100-K-36, 100-K-79:7*
	Cesium-137, strontium-90	1.8×10^{-3} (2135)	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71
	Cesium-137, strontium-90	1.9×10^{-4} (2038)	100-K-46
	Europium-152, strontium-90	1.4×10^{-4} (2025)	100-K-47*, 100-K-69, 100-K-70, 100-K-71
	--	1.4×10^{-4} (2011)	100-K-55:1
	Cesium-137, cobalt-60, europium-152, europium-154	1.5×10^{-3} (2087)	100-K-56:1
	Cesium-137, europium-152, strontium-90	9.7×10^{-4} (2088)	116-K-1

Table 6-180. Summary of 100-K Operable Units Remediated Waste Sites that Warrant Evaluation of Remedial Alternatives in the FS

Reason Waste Site Warrants Evaluation of Remedial Alternatives	COPC	Cumulative Cancer Risk (Year Risk Decays < 1×10^{-4})	Waste Site Name
	Cesium-137, europium-152, europium-154, nickel-63, strontium-90	5.8×10^{-3} (2185)	116-K-2
	Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, strontium-90	6.4×10^{-3} (2176)	116-K-2
Sites with shallow zone and deep zone human health direct contact cumulative risks >1 $\times10^{-4}$	Strontium-90	2.5×10^{-4} (2045)	118-K-1 P1_Shallow_4
	Cesium-137, strontium-90	1.7×10^{-4} (2032)	118-K-1 P1_Shallow_Focused_1
	Cesium-137, strontium-90	5.6×10^{-4} (2084)	118-K-1 P2_Deep_7
	Cesium-137, strontium-90	1.6×10^{-3} (2126)	118-K-1 P2_Deep Focused_1
	Cesium-137, europium-152, strontium-90	1.9×10^{-3} (2102)	118-K-1 P2_Deep_Focused_2
	Cesium-137, strontium-90	1.4×10^{-3} (2123)	118-K-1 P2_Deep_Focused_7
Sites with only shallow zone human health direct contact cumulative risks >1 $\times10^{-4}$	--	--	--
Sites with shallow zone and deep zone human health direct contact cumulative risks >1 $\times10^{-4}$ and exceed the soil screening level for groundwater protection	Carbon-14, cesium-137, strontium-90	1.7×10^{-4} (2066)	100-K-6, 100-K-46, 100-K-62, 132-KE-1 Shallow_1
	Carbon-14, cesium-137, strontium-90	1.0×10^{-3} (6357)	100-K-6, 100-K-46, 100-K-62, 132-KE-1 Shallow_2

*Although this site or subsite is listed, it has not undergone remediation and is not classified as interim closed out.

COPC = contaminant of potential concern

FS = feasibility study

6.5.2 Conclusions for the Groundwater Risk Assessment

The primary objective of the groundwater risk assessment is to identify the COPCs in groundwater that require further evaluation in the FS. Groundwater COPCs for the human health risk assessment were identified using several different analyses, including the following:

- Individual groundwater measurements were compared to risk-based concentrations to identify concentrations greater than cleanup levels based on a target HQ of 1 (see Chapter 4, Appendix D for the results of the comparison).
- Individual groundwater measurements were compared to risk-based concentrations to identify concentrations greater than cleanup levels based on a target risk level of 1 in 1,000,000 (1×10^{-6}) (see Chapter 4, Appendix D for the results of the comparison).

- Individual groundwater measurements were compared to DWSs to identify concentrations greater than these standards (see Chapter 4, Appendix D for the results of this comparison).
- Cumulative cancer risks and noncancer hazards for chemicals based on the results of the EPA tap water (residential) scenario are compared to the MTCA HHRA Procedures (WAC 173-340-708(5)(a)) cumulative cancer risk threshold of 1×10^{-5} and the noncancer hazard threshold of 1 (see Section 6.3.5 for the risk characterization results).
- Cumulative cancer risks for radiological analytes based on the results of the EPA tap water (residential) scenario are compared to the upper end of the NCP (40 CFR 300) risk range (1×10^{-4} to 1×10^{-6}) for cumulative carcinogenic site risk to an individual based on RME (see Section 6.3.5 for the risk characterization results).
- SOFs and 4 mrem/yr dose equivalent were calculated for beta particle and photon emitters. Current MCLs for beta particle and photon emitters are based on an annual dose equivalent of 4 mrem to the total body or any internal organ (see Section 6.3.5 for the results of this evaluation).

In addition to the analyses described above, the CTUIR and Yakama Nation exposure scenarios evaluated groundwater as a source of drinking water and as a source of steam for sweat lodge use (see Appendix G [Section G5] for a discussion of these results).

The groundwater data set used for this RI consists of sampling and analysis data from 82 groundwater wells within the 100-KR-4 groundwater OU. Monitoring wells are evaluated and discussed based on the location of the screen placement. In total, 20 monitoring wells and 1 extraction well are screened at the top of the unconfined aquifer, 20 monitoring wells, three monitoring wells that are combined for evaluation purposes, and nine extraction wells are screened across the upper unconfined aquifer, three monitoring wells are screened across the lower unconfined aquifer, one monitoring well is screened in the upper and lower unconfined aquifer, nine monitoring wells and fourteen extraction wells are screened across the entire aquifer, and two monitoring wells are screened in the Ringold Upper Mud (RUM).

The contaminants in groundwater that are the largest contributors to calculated risks, dose, and hazards are summarized in Table 6-181. A summary of the results is provided in the following subsections.

Table 6-181. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards		Cumulative Annual Dose (4 mrem/yr)
Monitoring Wells Screened Across Top of the Unconfined Aquifer				
199-K-106A	Carbon-14, Nitrate, TCE, Tritium	Carbon-14 (3.2×10^{-2}) Tritium (3.3×10^{-3})	TCE & 2-propanol (HI = 2.1)	Carbon-14, Tritium
199-K-107A	Strontium-90, TCE	Carbon-14 (9.6×10^{-4})	TCE & 2-propanol (HI = 1.6)	Strontium-90
199-K-108A	TCE, Nitrate [a]	Carbon-14 (1.2×10^{-3})	TCE (HQ = 1.2)	None
199-K-110A	Total chromium[c]	None		None

Table 6-181. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards		Cumulative Annual Dose (4 mrem/yr)
199-K-111A	Tritium, Cr(VI) [b], Total Chromium [c], Dissolved Total Chromium [e]	Carbon-14 (3.2×10^{-4}) Tritium (9.1×10^{-3})	Cr(VI) (HQ = 6.9)	Tritium
199-K-132	Carbon-14, Cr(VI) [d], Nitrate, TCE	Carbon-14 (6.0×10^{-3}) Tritium (3.4×10^{-4})	Cyanide (HQ = 2.9) TCE & 2-propanol (HI = 1.8)	Carbon-14
199-K-139	Strontium-90, Cr(VI) [d], TCE	Carbon-14 (1.8×10^{-3}) Tritium (1.8×10^{-4})	Cr(VI) (HQ = 1.2)[g] TCE (HQ = 1.8)	Strontium-90
199-K-140	Cr(VI) [d], TCE	Carbon-14 (8.7×10^{-4}) Tritium (1.2×10^{-4})	TCE & 2-propanol (HI = 1.8)	None
199-K-18	None	Tritium (1.1×10^{-2})	Cr(VI) & bromomethane (HI = 2.7)	Tritium
199-K-19	Strontium-90	Tritium (2.8×10^{-4})	None	Strontium-90
199-K-200	Strontium-90	Strontium-90 (2.8×10^{-4}) Tritium (2.0×10^{-4})	None	Strontium-90
199-K-201	Strontium-90, Cr(VI) [d]	None	Cr(VI) (HQ = 2.1)[h]	Strontium-90
199-K-22	Cr(VI) [d]	Tritium (1.1×10^{-4})	Cr(VI) & bromomethane (HI = 1.9)	Strontium-90
199-K-23	Cr(VI) [b], Total Chromium [c], Dissolved Total Chromium [e], Nitrate [a]	Carbon-14 (1.1×10^{-4})	Cr(VI) (HQ = 1.3)	None
199-K-29*	Carbon-14 [f], Nitrate [f]	Carbon-14 (4.4×10^{-3}) Tritium (9.0×10^{-3})	None	Carbon-14, Tritium
199-K-30*	Carbon-14 [f]	Carbon-14 (5.7×10^{-3}) Tritium (1.9×10^{-3})	None	Carbon-14, Tritium
199-K-32A	Cr(VI) [d], Nitrate [a]	Carbon-14 (3.8×10^{-4}) Tritium (6.2×10^{-4})	None	None
199-K-34	Strontium-90	Carbon-14 (5.5×10^{-3}) Tritium (1.6×10^{-4})	2-Propanol & TCE (HI = 1.2)	Carbon-14, Strontium-90

Table 6-181. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards		Cumulative Annual Dose (4 mrem/yr)
199-K-36	Cr(VI) [b]	Carbon-14 (1.7×10^{-4})	Cr(VI) & bromomethane (HI = 4.7)	None
699-73-61	None	None		None
Extraction Well 199-K-137 Screened Across Top of the Unconfined Aquifer				
199-K-137	Cr(VI) [b], TCE	Carbon-14 (1.4×10^{-3})	Cr(VI) (HQ = 1.3) TCE (HQ = 1.6)	None
Monitoring Wells Screened Across Upper Unconfined Aquifer				
199-K-11	TCE	Carbon-14 (1.8×10^{-3})	TCE (HQ = 1.7)	None
199-K-117A	None	None		None
199-K-125A	None	Tritium (4.1×10^{-4})	None	None
199-K-138	TCE	Carbon-14 (7.6×10^{-4}) Tritium (9.6×10^{-5})	Propanol & TCE (HI = 1.8)	None
199-K-142	Cr(VI) [d]	Carbon-14 (3.1×10^{-4})	None	None
199-K-173	Cr(VI) [b], Dissolved Total Chromium [e], TCE	Carbon-14 (6.7×10^{-4}) Tritium (9.5×10^{-5})	Cr(VI) (HQ = 9) TCE (HQ = 1.4)	None
199-K-183	TCE	Carbon-14 (6.5×10^{-4}) Tritium (1.1×10^{-5})	TCE (HQ = 1.5)	None
199-K-186	Cr(VI) [d]	Carbon-14 (1.4×10^{-4})	None	None
199-K-187	None	None		None
199-K-188	Cr(VI) [d]	Carbon-14 (1.2×10^{-4})	None	None
199-K-191	None	Tritium (4.2×10^{-4})	None	None
199-K-194	None	None		None
199-K-20	Strontium-90	Tritium (6.5×10^{-4})	None	Strontium-90
199-K-204	Carbon-14, TCE	Carbon-14 (2.5×10^{-2}) Tritium (4.2×10^{-4})	Cyanide (HQ = 4.4) TCE (HQ = 1.2)	Carbon-14
199-K-21	Strontium-90, Cr(VI)	None		Strontium-90
199-K-221	Strontium-90, Tritium, Cr(VI) [d]	Carbon-14 (2.6×10^{-3}) Tritium (1.9×10^{-3})	None	Tritium

Table 6-181. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards		Cumulative Annual Dose (4 mrem/yr)
199-K-222	Strontium-90, Cr(VI) [d]	Carbon-14 (3.0×10^{-4}) Strontium-90 (1.6×10^{-3})	None	Strontium-90
199-K-31	TCE	Carbon-14 (5.1×10^{-4}) Tritium (1.2×10^{-4})	TCE (HQ = 1.3)	None
199-K-37	Cr(VI) [d]	None		None
699-72-73	None	Tritium (8.0×10^{-4})	None	Tritium
Combined Wells Screened Across Upper Unconfined Aquifer (199-K-205 is an operating KW extraction well)				
199-K-35*, K-195*, K-205	Cr(VI) [b], Total Chromium [c], Dissolved Total Chromium [e], TCE	Carbon-14 (4.2×10^{-4})	Cr(VI) (HQ = 9) TCE (HQ = 1.7)	None
Extraction Wells Screened Across Upper Unconfined Aquifer				
199-K-113A	None	None		None
199-K-114A	None	None		Strontium-90
199-K-141	Strontium-90, Cr(VI)	Carbon-14 (3.5×10^{-4}) Tritium (3.5×10^{-4})	None	Strontium-90
199-K-144	Cr(VI) [d]	Tritium (2.0×10^{-3})	None	Tritium
199-K-146	None	None		None
199-K-147	Cr(VI) [d]	None		Strontium-90
199-K-148	None	Tritium (1.7×10^{-4})	None	None
199-K-161	Strontium-90	None		Strontium-90
199-K-178	Cr(VI) [d]	Carbon-14 (4.2×10^{-4}) Tritium (1.5×10^{-4})	None	None
Monitoring Wells Screened Across Lower Unconfined Aquifer				
199-K-168	TCE	Carbon-14 (6.9×10^{-4})	TCE (HQ = 1.6)	None
199-K-184	TCE	Carbon-14 (8.1×10^{-4}) Tritium (9.8×10^{-5})	TCE (HQ = 1.4)	None
199-K-190	TCE	Carbon-14 (2.9×10^{-4})	TCE (HQ = 1.9)	None
Monitoring Well Screened Across Upper and Lower Unconfined Aquifer				
199-K-193	Cr(VI) [d]	None		None

Table 6-181. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards		Cumulative Annual Dose (4 mrem/yr)
Monitoring Wells Screened Across Entire Aquifer				
199-K-151	None	Chloroform (2.3×10^{-5}) Tritium (1.6×10^{-4})	None	None
199-K-157	None	Tritium (5.0×10^{-3})	None	Tritium
199-K-185	Carbon-14, Nitrate, TCE	Carbon-14 (3.1×10^{-3}) TCE (1.0×10^{-5}),	2-Propanol & TCE (HI = 2.7)	Tritium
199-K-189	Carbon-14, Tritium, Cr(VI) [d]	Carbon-14 (2.7×10^{-3}) Tritium (2.6×10^{-3})	None	Carbon-14, Tritium
199-K-202	Carbon-14, Tritium, Cr(VI) [d]	Carbon-14 (3.1×10^{-3}) Tritium (2.4×10^{-3})	None	Carbon-14, Strontium-90, Tritium
199-K-203	Cr(VI) [d]	Carbon-14 (6.8×10^{-4})	None	None
199-K-207	Tritium, Cr(VI) [b], Dissolved Total Chromium [e], Nitrate	Tritium (5.3×10^{-2})	Cr(VI) (HQ = 2.4)	Tritium
199-K-209	None	None		None
199-K-223	Cr(VI) [d], TCE	Carbon-14 (2.2×10^{-4}) Tritium (1.2×10^{-4})	TCE (HQ = 1.7)	None
Extraction Wells Screened Across Entire Aquifer				
199-K-116A	None	Tritium (2.3×10^{-4})	None	None
199-K-120A	None	Tritium (4.6×10^{-4})	None	None
199-K-145	None	Tritium (2.6×10^{-3})	None	Tritium
199-K-152	Cr(VI) [d]	None	Cr(VI)[i] and bromomethane (HI = 1.5)	None
199-K-153	Cr(VI) [d]	None		None
199-K-154	Cr(VI) [d]	None	Cr(VI)[j] (HQ = 1.6)	None
199-K-163	None	Tritium (2.4×10^{-4})	None	None
199-K-165	Cr(VI) [d], TCE	Carbon-14 (7.3×10^{-4})	2-propanol and TCE (HI = 1.7) Cr(VI)[k] (HQ = 3.5)	None

Table 6-181. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards		Cumulative Annual Dose (4 mrem/yr)
199-K-166	Cr(VI) [d], TCE	Carbon-14 (8.3×10^{-4}) Tritium (1.1×10^{-4})	TCE (HQ = 1.5)	None
199-K-171	Cr(VI) [d]	Tritium (3.5×10^{-4})	None	None
199-K-182	Cr(VI) [d]	Tritium (1.9×10^{-4})	Cr(VI)[l] and bromomethane (HI = 1.6)	None
199-K-208	None	Tritium (3.0×10^{-3})	None	Tritium
199-K-210	Cr(VI) [d]	Carbon-14 (3.3×10^{-4}) Tritium (2.5×10^{-4})	None	None
199-K-224	Cr(VI)[b], Total Chromium [c], Dissolved Total Chromium [e], TCE	Carbon-14 (6.4×10^{-4})	Cr(VI) (HQ = 2.5) TCE (HQ = 1.9)	None
Monitoring Wells Screened Across Ringold Upper Mud				
199-K-192	None	None		None
199-K-32B	None	None		None

*Well is currently decommissioned.

a. Concentrations have recently increased above the DWS in 2017.

b. Cr(VI) concentrations are greater than WAC 173-201A standard of 10 µg/L and the MTCA (WAC 173-340-720) groundwater cleanup level of 48 µg/L.

c. Total chromium concentrations are greater than the DWS of 100 µg/L.

d. Cr(VI) concentrations are greater than WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," of 10 µg/L.

e. Dissolved total chromium concentrations are greater than the AWQC of 65 µg/L.

f. Exceeded DWS prior to decommissioning.

g. Cr(VI) concentrations have been less than MTCA (WAC 173-340-720) groundwater cleanup level of 48 µg/L since August 2010.

AWQC = ambient water quality criteria
COPC = contaminant of potential concern
Cr(VI) = Cr(VI)
DWS = drinking water standard
MTCA = "Model Toxics Control Act—Cleanup"
OU = operable unit
TCE = TCE

6.5.2.1 Monitoring and Extraction Wells Screened Across the Top of the Unconfined Aquifer

Based on the comparison of individual groundwater concentrations to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: Carbon-14, Cr(VI), nitrate, strontium-90, total chromium, trichloroethene, and tritium. Based on the comparison of individual groundwater concentrations to federal AWQC or WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," Cr(VI) and total chromium are retained as COPCs. Results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS.

The combination of carbon-14, strontium-90, and tritium result in an annual dose equivalent greater than 4 mrem to the total body or any internal organ. The results of this evaluation support the need for evaluation in the FS.

Based on results of the EPA tap water (residential) scenario risk assessment, carbon-14, bromomethane, cyanide, 2-propanol, trichloroethene, tritium and Cr(VI) are the primary contributors to cancer risks and noncancer hazards. Therefore, they are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.3.5 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.5.2.2 Monitoring and Extraction Wells Screened Across the Upper Unconfined Aquifer (including the combined wells)

Based on the comparison of individual groundwater concentrations to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: Carbon-14, Cr(VI), strontium-90, trichloroethene, and tritium. Based on the comparison of individual groundwater concentrations to federal AWQC or WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," Cr(VI) is retained as a COPC. Results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS.

The combination of carbon-14, strontium-90, and tritium result in an annual dose equivalent >4 mrem to the total body or any internal organ. The results of this evaluation support the need for evaluation in the FS.

Based on results of the EPA tap water (residential) scenario risk assessment, carbon-14, cyanide, trichloroethene, strontium-90, tritium, 2-propanol, and Cr(VI) are the primary contributors to cancer risks and noncancer hazards. Therefore, they are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.3.5 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.5.2.3 Monitoring Wells Screened Across the Lower Unconfined Aquifer

Based on the comparison of individual groundwater concentrations to DWSs or state groundwater cleanup levels, trichloroethene is retained as a COPC. No COPCs were retained, based on the comparison of individual groundwater concentrations to federal AWQC or WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington." Results of this evaluation indicate the need to evaluate trichloroethene for potential remedial technologies in the FS.

Concentrations of radionuclides in groundwater result in an annual dose equivalent of <4 mrem to the total body or any internal organ.

Based on results of the EPA tap water (residential) scenario risk assessment, carbon-14, trichloroethene, and tritium, are the primary contributors to cancer risks and noncancer hazards. Therefore, they are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.3.5 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.5.2.4 Monitoring Wells Screened Across the Upper and Lower Unconfined Aquifer

Based on the comparison of individual groundwater concentrations to DWSs or state groundwater cleanup levels no COPCs are retained. Based on the comparison of individual groundwater concentrations to federal AWQC or WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," Cr(VI) is retained as a COPC. Results of this evaluation indicate the need to evaluate this analyte for potential remedial technologies in the FS.

Concentrations of radionuclides in groundwater result in an annual dose equivalent of <4 mrem to the total body or any internal organ.

Based on results of the EPA tap water (residential) scenario risk assessment, there are no contributors to cancer risks and noncancer hazards.

6.5.2.5 Monitoring and Extraction Wells Screened Across the Entire Unconfined Aquifer

Based on the comparison of individual groundwater concentrations to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: carbon-14, Cr(VI), nitrate, total chromium, trichloroethene, and tritium. Based on the comparison of individual groundwater concentrations to federal AWQC or WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," Cr(VI) is retained as a COPC. Results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS.

The combination of carbon-14, strontium-90, and tritium result in an annual dose equivalent >4 mrem to the total body or any internal organ. The results of this evaluation support the need for evaluation in the FS.

Based on results of the EPA tap water (residential) scenario risk assessment, carbon-14, tritium, chloroform, bromomethane, 2-propanol, trichloroethene, and Cr(VI) are the primary contributors to cancer risks and noncancer hazards. Therefore, they are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.3.5 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.5.2.6 Monitoring Wells Screened Across Ringold Upper Mud

No COPCs were retained based on the comparison of individual groundwater concentrations to DWSs or state groundwater cleanup levels. Similarly, no COPCs were retained, based on the comparison of individual groundwater concentrations to federal AWQC or WAC 173 201A. Concentrations of groundwater were less than the annual dose equivalent of 4 mrem to the total body or any internal organ.

Based on the results of the EPA tap water (residential) scenario risk assessment, there are no contributors to cancer risks and noncancer hazard.

7 Ecological Risk Assessment

This chapter presents the ERA completed to provide information for decision making about additional remediation of the 100-K OUs. This ERA integrated recently collected RI data (described in Chapter 4), results from past ERAs, and operational process information with the remediation performed under the interim action RODs to identify the need for further remedial action and development of ecological PRGs.

Previous remedial actions completed in the River Corridor were implemented under interim action RODs. The RAOs in the 100 Area interim action RODs were developed to achieve protection of human health. Protection of ecological receptors from direct contact with contaminated shallow vadose zone material (<4.6 m [15 ft]) was not addressed directly in the interim action RODs but indirectly with the assumption that attainment of standards for protection of human health or that reduced contaminant leaching would also be protective of ecological receptors. Protection of ecological receptors from groundwater discharges into the river was considered in the interim action RODs through consideration of state water quality standards and federal AWQC. Interim action RODs were written for River Corridor sites to allow cleanup activities to move forward as potential risks were identified. However, final remedy selection (development of final action RODs) must be completed for the NPL (40 CFR 300, Appendix B) CERCLA sites in the River Corridor to reach final closeout. Thus, per CERCLA requirements, this ERA was performed to determine if interim actions were sufficiently protective of ecological receptors and for completion of the final action ROD. This ERA incorporates information from many past investigations (described throughout this ERA) in the 100-K Area and the River Corridor to assemble a holistic ERA that provides answers to questions about risk from waste sites in the 100-K OUs to the environment. This ERA does rely heavily on two past risk assessments for the aquatic component of the assessment: the RCBRA (DOE/RL-2007-21, Volume I)[1] and the CRC (DOE/RL-2010-117, Volume I)[2]. This ERA provides an evaluation of ecological receptor exposure (and risk) to contaminated soil in the shallow vadose zone of the 100-K upland waste sites (100-KR-1 and 100-KR-2 OUs), contaminated soil in the riparian zone and islands adjacent to the 100-K Area, and pore water, sediment, and surface water in the Columbia River adjacent to the 100-K Area.

The RCBRA was a comprehensive examination of current and potential risks in areas potentially affected by Hanford Site processes within the combined 100 and 300 Area OUs. The RCBRA used multiple measures of exposure, ecological effect, and ecosystem/receptor characteristics to evaluate risk at 20 upland study sites across the River Corridor associated with remediated waste sites (10 excavated/ backfilled sites and 10 surface removal/native soil sites) and 10 reference areas, as described in the RCBRA SAP (DOE/RL-2005-42). The sites studied were selected from high-priority waste sites that had been remediated when the study was developed. The sites represent the types of waste sites and remedial actions addressed by the interim action RODs. Based on this set of study sites, the results from the RCBRA identified some contaminants in soil as COECs, which were principally metals and pesticides. Multiple measures of exposure and effects were also used to evaluate risk to aquatic organisms and wildlife in the riparian area and nearshore (aquatic environment between low and high tide areas) environment of the Columbia River. The potential for COECs in the nearshore environment to have originated from the 100-K OUs was evaluated in detail in this ERA and is discussed later in this chapter (Section 7.7).

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[1] All citations to the RCBRA (DOE/RL-2007-21) in this chapter are referring to *Volume I: Ecological Risk Assessment*.

[2] All citations to the CRC (DOE/RL-2010-117) in this chapter are referring to *Volume I: Screening-Level Ecological Risk Assessment*.

The CRC used analytical chemistry data collected from surface water, sediment, pore water, and island soil to evaluate the potential for risk to ecological receptors, including aquatic life living within the Columbia River and wildlife frequenting or inhabiting the islands within the river. Based on a screening-level ERA (SLERA), the CRC identified some contaminants in island soil and Columbia River sediments and pore water as COPECs, which were principally metals. The potential for these contaminants to have originated from 100-K was evaluated in this ERA and is discussed later in this chapter.

This ERA builds on the work performed in the previous two broad area-wide ERAs to inform decisions specifically about 100-K. The study designs of the RCBRA and CRC, coupled with results that identified COECs across the River Corridor, required development of an ERA approach for the 100-K RI and FS that allowed assessment of risk on a site-by-site basis, as well as supported development of PRGs. Therefore, the initial conclusions that applied across the entire River Corridor were examined further and a more detailed risk assessment was developed. The detailed ERA approach incorporates the use of ecological soil screening levels (EcoSSLs)[3] and ecological PRGs, which have been developed using the tiered process outlined in CHPRC-00784, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*, hereinafter referred to as Tier 1 Ecological SSLs (included in Appendix H), and CHPRC-01311, *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*, hereinafter referred to as Tier 2 Wildlife PRGs (included in Appendix H). This tiered process allows the incorporation of more sophisticated ERA methods and increasing levels of ecological site-specific information, to provide SSLs and PRGs that are more representative of Hanford Site conditions. Development of the risk-based concentration values (SSLs and PRGs) incorporates the problem formulation, the conceptual ecological exposure models, and selected bioaccumulation datasets originally developed in the RCBRA. These values were used in this ERA to evaluate ecological risk in 100-K waste sites with verification sampling and analytical information, to provide site-specific ecological risk information for each site.

The following approaches have been used in this ERA to evaluate ecological risk in the upland environment potentially associated with 100-K waste sites:

- **Updating the identification of COPCs (Section 7.1)**. The RCBRA went through a process to identify COPCs for ecological receptors, based on a sitewide review of River Corridor data. This identification process has been updated to account for verification sampling data specifically in individual 100-K waste sites.

- **Presenting the problem formulation (Section 7.2)**. This section summarizes the problem formulation used to develop the risk-based concentration values used in this assessment as ecological SSLs. This problem formulation reflects conditions in upland environments across the Hanford Site and incorporates information developed from the RCBRA.

[3] SSLs were used for initial screening to eliminate chemicals for which there is little likelihood of risk, while PRGs were used to provide both a more refined risk screen and characterization, as well as to aid risk management decisions (Section 7.6).

- **Presenting screening-level effects and exposure assessments (Section 7.3)**. This section summarizes the quantitative assessments used in developing the risk-based concentration values, including the wildlife exposure factors, biotransfer factors, and wildlife toxicity reference values (TRVs) (Appendix H, Tables H-1 to H-4). The data and methods used to develop risk-based concentrations protective of plants and soil invertebrates are discussed in this section. More detailed descriptions of the data and methods used to calculate all of the ecological risk-based concentrations in soil are presented in CHPRC-00784. These values are also incorporated into the ERA of the RCBRA.

- **Updating the screening-level ecological risk characterization for 100-K waste sites (Section 7.4)**. Verification sampling and analysis data for the 100-K waste sites were used to calculate EPCs, which were then compared with the ecological SSLs. The results from these comparisons were used to identify receptors of interest and COPECs for identifying the need for further action at the 100-K waste sites. The results of this risk characterization were used to determine which of the risk-based concentration values should be recommended for baseline assessment.

- **Presenting baseline assessments of risk for upland habitats (Section 7.5)**. This section summarizes the quantitative assessments used to develop the biotransfer factors (Appendix H, Table H-5). The data and methods used to develop PRGs protective of plants and soil invertebrates are discussed in this section. More detailed descriptions of the data and methods used to calculate the PRGs for soil are presented in ECF-HANFORD-11-0158, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site*, hereinafter referred to as the *Tier 2 Plant/Invertebrate PRGs* document, and Tier 2 Wildlife PRGs (CHPRC-01311). These values are also incorporated into the ERA of the RCBRA (DOE/RL-2007-21). Verification sampling and analysis data for the 100-K waste sites were used to calculate EPCs, which were then compared with the ecological SSLs and, as appropriate, PRGs. The results from these comparisons were used to identify receptors of interest and COPECs for identifying the need for further action at 100-K waste sites. The results of this risk characterization were used to determine which of the risk-based concentration values should be recommended for use as PRGs.

- **Scientific management decision point (SMDP) for upland habitats (Section 7.6)**. Potential risks identified through the direct comparison of verification sampling soil data to SSLs and PRGs were considered in the context of a number of additional factors. Uncertainties in the risk characterization, spatial information, data quality, magnitude and aerial extent of risk, and confidence in risk-based values were included with other factors to provide conclusions regarding which, if any, risks should be addressed further in the FS. A discussion of the process for developing final remediation goals was also included, along with conclusions for the SMDP for evaluating waste sites:

  - Size of the waste site relative to home range (Appendix H, Table H-6) of wildlife receptors (e.g., developing and applying an area use factor [AUF] in the comparison of an exposure point concentration to the PRGs)
  - Estimation of exposure using a central tendency estimate such as the 95% UCL
  - Size of the waste site relative to area of adjacent uncontaminated habitat
  - Nature and extent of residual contamination following remediation
  - Potential presence of exposure pathways following remediation
  - Number and frequency of exceedances of the risk thresholds (PRGs)

  - Location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances
  - Depth at which exceedances of the risk thresholds (PRGs) occur

- **Analyzing risk in the riparian, nearshore areas, and the Columbia River (Section 7.7)**. This section summarizes the evaluation of risk to aquatic organisms and wildlife in the stretch of the Columbia River adjacent to 100-K. A problem formulation outlined the ecological resources that were evaluated, incorporating information developed in the RCBRA and CRC. COPECs[4] identified in riparian and island soil, and the surface water and sediments of the Columbia River as identified in the RCBRA and CRC, were evaluated as to the potential for attribution to 100-K sources. This section presents an evaluation of data from nearshore groundwater wells[5], aquifer tubes, and seeps to capture these and any other COPECs in the aquatic environment that might have originated from the 100-K Area.

- **Scientific Management Decision Point (SMDP) for riparian, nearshore areas, and the Columbia River (Section 7.8)**. This section evaluates ecological risks identified within the Columbia River and the relationship between potential 100-K sources to the Columbia River, transport pathways, and ecological receptors. The RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) evaluated risks to an array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics at representative study sites. RCBRA study sites were specifically selected to represent locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, and sediment). The multiple lines of evidence from these two investigations are examined to reach conclusions regarding the relationships between 100-K sources and riparian and nearshore media (soil, sediment, pore water, and surface water).

7.1 Identification of Contaminants of Potential Concern for Upland Habitats

The upland environment is the generally arid area above the river high water mark extending inland from the Columbia River. This section describes the sources of data used in the ERA for the uplands, the DQA and data validation process, and the identification process for COPCs in soil. CVP and RSVP data collected within waste sites in the 100-KR-1 and 100-KR-2 OUs were used to identify COPCs. This section presents the risk assessment for individual waste sites using CVP/RSVP data. During the course of this ERA, COPCs were examined to identify a refined list of COPECs estimated to pose site-related ecological risks to receptor populations.

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[4] The CRC was a SLERA that identified COPECs primarily by abiotic media concentrations exceeding ecological risk-based thresholds. The RCBRA was a BERA that identified what were called COECs for the Columbia River through multiple lines of evidence but there was not a complete analysis of linkage to Hanford Site operations. Thus, for this BERA, the RCBRA COECs are referred to as COPECs, and are evaluated specifically with respect to Hanford Site operations associated with the 100-K Area.

[5] Section 6.3 evaluates the protection of aquatic receptors from groundwater that have the potential to discharge to the Columbia River. The approach used to identify COCs that warrant further evaluation in the FS is presented in Section 6.3. The approach is based on comparison of groundwater concentrations to the lowest available chemical-specific ARARs published for the protection of human health and aquatic receptors. Thus, risks to aquatic receptors have been considered in the context of evaluating the risks groundwater may contribute to surface water at the groundwater-surface water interface. Combining the assessment of human health provides a streamlined approach that addresses the restoration of groundwater and protection of aquatic receptors.

7.1.1 Data Summary

The risk assessment is divided into two parts: investigation of upland or terrestrial areas and investigation of riparian and nearshore aquatic areas. The upland risk assessment is presented in Sections 7.1 through 7.6 and discussion of the data for the riparian, nearshore, and riverine areas (e.g., surface water, sediment, pore water and nearshore groundwater wells) is presented in Section 7.7, while supporting data tables are provided in Appendix J. The upland/terrestrial and riparian/nearshore/riverine risk assessment in this chapter focuses on examining potential residual risk at 100-K waste sites, including those that were not included in the RCBRA.

Remediation of 100-K waste sites began in 2002. Waste site CVP, RSVP, and RI data residing in the HEIS database were used in the soil risk assessment. Table G-1 (Appendix G) summarizes the remediated waste sites with CVP/RSVP soil data, associated decision unit(s)[6], and reclassification status. The waste sites listed in Table G-1 are a subset of the waste sites that were listed in Appendix C, Table C-1, of the 100-K RI/FS Work Plan (DOE/RL-2008-46-ADD2). A summary of the remediated waste sites and consolidated waste sites for the 100-K Area was provided in Chapter 6. Two waste sites contained deep decision units only (the 100-K-46 waste site and the 100-K-47, 100-K-69, 100-K-70, and 100-K-71 waste site) and 100% of the analytes within another waste site were non-detect (132-KE-1) and were therefore excluded from further consideration or assessment of ecological risk. Four shoreline waste sites were included in the evaluation (100-K-111, 100-K-57, 100-K-64, 100-K-83). Of the waste sites included in this ERA, 13 were also evaluated in the RCBRA (DOE/RL-2007-21). The closeout verification data used in risk assessment are included in Appendix D.

7.1.2 Data Quality Assessment

A DQA is performed and reported in each closeout documentation report. The DQA compares the verification sampling approach and resulting analytical data with the sampling and data quality requirements specified by the project objectives and performance specifications. The DQA determines if the data are of the right type, quality, and quantity to support site cleanup verification decisions within specified error tolerances. The DQA also determines if the analytical data are found acceptable for decision-making purposes and if the sample design was sufficient for the purpose of clean site verification. The cleanup verification sample analytical data and detailed DQA are summarized in the appendices associated with the CVPs. Results of each DQA are incorporated, by reference, and no further DQA was performed as part of this risk assessment.

All analytical data are evaluated, and a portion is validated for compliance with QA project plan requirements as documented in the 100 Area RDR/RAWP (DOE/RL-96-17). Data evaluation is performed to determine whether the laboratory carried out all steps required by the 100-K SAP (DOE/RL-2009-41) and the laboratory contract governing the conduct of analysis and reporting of the data. This evaluation also examines the available laboratory data to determine whether an analyte is present or absent in a sample and the degree of overall uncertainty associated with that determination.

7.1.3 Identification of COPCs

All analytes detected at least once in a waste site decision unit for the 100-K waste sites included in the ERA are identified as COPCs except those exclusions described in this section. Verification sampling and analysis data are collected according to sample design requirements for the type of decision unit. For this

[6] As described in Section 6.2.2.2, the floor and sidewalls of an excavated waste site are divided into one or more decision units (e.g., shallow zone and overburden). A sampling design was developed for each decision unit.

ERA, an exposure area and a decision unit are operationally defined as being the same. Verification sampling and analysis data are subsequently grouped to calculate EPCs.

The contribution from naturally occurring metals and anthropogenic radioisotopes is discussed in the risk characterization section in accordance with EPA 540-R-01-003. The risk characterization discusses both elevated background concentrations and their contribution to site risks and naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants but exceed RBSLs.

The RCBRA identifies a subset of analytes that are excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. The following exclusion lists employed in the RCBRA were also applied to the waste site verification data during the data reduction steps described in Section 6.2.

- **Radionuclides with a half-life of less than 3 years**: Radionuclides with half-lives less than 3 years would not be present as a result of historical Hanford Site operations because radioactive decay would have occurred since operations ceased.

- **Essential nutrients**: Essential nutrients that are present at relatively low concentrations and toxic only at high concentrations were not considered in the QRA.

- **Water quality or soil physical property measurements**: These analytes were measured only to obtain information on water quality or soil properties to understand potential confounding factors for bioassays conducted for soil, sediment, or water or to interpret their influence on the toxicity of COPCs (e.g., grain size for soil and water hardness for metal effects).

- **Background radionuclides (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232)**: As identified and implemented in the RCBRA (DOE/RL-2007-21), these background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford Site operations or processes.

- A list of the analytes that meet the exclusion criteria for the soil risk assessment is described in Section 6.2.2.2 and presented in Appendix G (Table G-4). The RCBRA included the evaluation of remaining analytes as candidate COPCs, based on comparisons to Hanford Site background, reference areas, and an analyte-specific assessment to identify COPCs; however, that was not applied as part of this soil risk assessment. Because one of the last steps used in the RCBRA to identify COPCs was not applied, more analytes are identified as COPCs in this risk assessment than were identified in the RCBRA. Identifying all detected analytes (except those on the exclusion list) as COPCs is a more streamlined approach that is consistent with EPA 540-R-01-003.

In addition to the analytes identified for exclusion by the steps previously described, aluminum and iron were excluded as COPCs for all decision units within the 100-K OUs. EcoSSLs for aluminum and iron are based on soil pH (OSWER Directive 9285.7-60, *Ecological Soil Screening Level for Aluminum Interim Final*; OSWER Directive 9285.7-69, *Ecological Soil Screening Level for Iron Interim Final*). The potential for aluminum toxicity is only identified in soil when the pH is 5.5 or less. While iron is essential for plant growth and is generally considered to be a micronutrient (Thompson and Troeh, 1973, *Soil and Soil Fertility*), the potential for iron bioavailability is only identified when the pH is less than 5 or greater than 8 (OSWER Directive 9285.7-69). Oxidized environments (upland or well-aerated soil, such as those at the Hanford Site) promote the precipitation of ferric-oxide compounds, which are not available to plants for uptake. The main concern from an ecological risk perspective for iron is not direct chemical toxicity per se, but the effect of iron as a mediator in the geochemistry of other (potentially

toxic) metals[7] and the potential physical hazard of depositing flocculent (OSWER Directive 9285.7-69). Manganese and these other COPCs are being evaluated with the screening levels identified in Section 7.3. Data collected during the 2011 Hanford Sitewide field study indicated that soil pH ranges between 5.8 and 8.7 (ECF-HANFORD-11-0158, presented in Appendix H). The range of soil pH in the River Corridor indicates that aluminum would not be bioavailable. While most measurements of soil pH also suggest that iron would not be bioavailable, iron may be bioavailable at the limited number of locations where the soil pH exceeds 8. While aluminum concentrations are not bioavailable and do not pose a risk to terrestrial ecological receptors, iron may be bioavailable and has the potential to mediate the geochemistry of other potentially toxic metals in limited areas. However, both are excluded from further consideration for the 100-K Area given the limited occurrence of surface soil with pH measures in the range that would be bioavailable.

The COPC list for the 100-K Area was evaluated to develop a COPEC list in this risk assessment. A COPEC is defined as a COPC with concentrations exceeding both the background concentration and ecological effect level. The process for identifying COPECs is discussed in Section 7.4.

7.2 Problem Formulation for Upland Habitats

The problem formulation includes the physical layout of the site, its history and ecology, and the development of an ecological CSM that evaluates potential exposure pathways and identifies the representative species that were used to assess ecological risk to those and other similar species. The problem formulation includes identification of the important aspects of the 100-K Area waste site decision units to be protected (referred to as "assessment endpoints") and the means by which the assessment endpoints are evaluated (measures of exposure and effects).

7.2.1 Site Setting

The 100-K Area is situated between 100-BC and 100-N (Figure 1-1) and collectively covers an area of approximately 9 km^2 (3.5 mi^2). The Columbia River along 100-K is a portion of the Hanford Reach, an important ecological, cultural, historical, and recreational feature. The upland environment is described in this section, and the riparian and nearshore habitats are described in Subsection 7.7.2.1, which focuses on evaluating the potential for exposures in the riparian and nearshore environments to be of concern and to have originated from Hanford Site operations (i.e., from waste sites in 100-K).

The predominant plant community in the 100 Areas is sagebrush/Sandberg's bluegrass/cheatgrass. Currently, two plant species on the Hanford Site are federally listed as threatened or endangered under the *Endangered Species Act of 1973*. Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Physaria douglasii* ssp. *tuplashensis*) were listed as threatened species under the federal *Endangered Species Act of 1973* (78 FR 23984) in April 2013. Neither of these two plant species or the associated critical habitats are present within the 100-K Area or riparian areas and both species have specific physical requirements not found within the 100-KR-1 or 100-KR-2 OUs (CH2M HILL, 2018). A more detailed evaluation conducted in *Potential for the Presence of Two Federal Threatened Species (White Bluffs Bladderpod and Umtanum Desert Buckwheat) within Hanford Site, 100-K Source Operable Units* concluded there is no effect to either of these two species or on the designated critical habitat due to 100-K activities (CH2M HILL, 2018, presented in Appendix H).

[7] Manganese oxides also mediate soil bioavailability in addition to iron oxides (EPA 120/R-07/001, *Framework for Metals Risk Assessment*). However, this discussion is strictly presenting the case of why it is acceptable to eliminate iron as a COPC. Manganese will remain a COPC.

Plant species listed as threatened or endangered by the State of Washington include the awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and Columbia yellowcress (*Rorippa columbiae*). These plant species are restricted to wetlands in the riparian zone of the Columbia River (NEPA Characterization Report [PNNL-6415]). It is possible that Columbia yellowcress (*Rorippa columbiae*) is present along the river shoreline near 100-K. Table 3-9 (Chapter 3) presents the complete list of state-listed flora. However, previous rare plant surveys have identified only rare riparian plants in 100-K (DOE/RL-96-32).

Shrub and grassland habitats dominate the Hanford Site, including the uplands of the River Corridor, and support a diverse and abundant variety of wildlife species. Most of the 100 Area has not been significantly disturbed since farming ceased in the 1940s and these habitats are now mostly undisturbed or fully recovered, thus supporting diverse and abundant wildlife communities. Wildlife use of the remaining disturbed and developed areas (e.g., reactor facilities, P&T facilities) is expected to be reduced because these areas are less attractive and provide less of the needs of wildlife than do natural habitats. However, even these areas can be frequented by wildlife. Birds, small mammals, and invertebrates are common inhabitants of facilities and associated infrastructure on the Hanford Site (Appendix H, Table H-18). Common species that could use or inhabit the upland habitats near 100-K include large animals like Rocky Mountain elk (*Cervu elaphus*) and mule deer (*Odocoileus hemionus*); predators such as coyote (*Canis latrans*), bobcat (*Lynx rufus*), and badger (*Taxidea taxus*); and herbivores including deer mice (*Peromyscus maniculatus*), harvest mice (*Riethrodontonomys megalotis*), ground squirrels (*Spermophilus* spp.), voles (*Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus*). The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus*). Other animals, including cottontails (*Sylvilagus nutalli*), jackrabbits, snakes, and burrowing owls (*Athene cunicularia*) may use abandoned burrows of other animals.

No species of fauna that regularly frequent the Hanford Site are currently listed as threatened or endangered under the *Endangered Species Act of 1973* (DOE/RL-96-32).

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. DOE will continue to protect nest and roost sites on the Hanford Site under the Bald Eagle Management Plan (DOE/RL-94-150). Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (2,625 to 1,312 ft). Bald eagles have generally been observed at the Hanford Site from November to March (Fitzner and Hanson, 1979, “A Congregation of Wintering Bald Eagles”). During daylight hours, bald eagles perch along the Hanford Reach of the Columbia River and a few kilometers inland (DOE/RL-94-150). The primary perching areas occur in trees from the Hanford town site to the Vernita Bridge. Bald eagles predominantly forage on the banks of the river and the island where waterfowl roost and salmon carcasses can be found. Six primary night roosts were identified along the Hanford Reach in the original Bald Eagle Management Plan (DOE/RL-94-150, Rev. 0), and two more (downstream of the Hanford town site and Wooded Island) were added in Revision 1 of the plan. Eight protected roosting sites are located along the Columbia River (DOE/RL-94-150). These protected roosting sites are primarily located between 100-D and the 300 Area, not near the 100-K Area. The 100-K Area is outside of the nesting buffer zones and important foraging areas. Additional consideration of this species is not required for this risk assessment.

Species listed as threatened or endangered by Washington State include the Ferruginous hawk (*Buteo regalis*), Greater sage grouse (*Centroercus urophasianus*), American white pelican (*Pelecanus erythrorhynchos*), and Sandhill crane (*Grus canadensis*). Table 3-43 of this report presents the complete list of state-listed fauna. The Ferruginous hawk, Greater sage grouse, and American white pelican are not known to occur within or on the 100-K upland waste sites and are monitored as part of the Hanford Site

Biological Resources Management Plan (DOE/RL-96-32). The American white pelican has been observed within the Columbia River along the Hanford Reach; however, it does not regularly frequent away from the open water of the river, including the upland areas of the 100-KR-1 and 100-KR-2 OUs. Sandhill cranes migrate through the bottomlands on the Yakima River area and Moses Lake for a couple of weeks twice a year (Stinson, 2017, *Periodic Status Review for the Sandhill Crane*) and have been observed during migration on islands within the Hanford Reach. However, annual breeding bird surveys on the Hanford Site have only counted a Sandhill Crane twice since 1988, and no nesting or foraging has been recorded onsite, indicating that cranes may stop on annual migrations, but do not stay for extended periods of time (Stinson, 2017). Further, the 100-K Area lacks a large body of marshy standing water that is preferred by cranes. Given the current lack of exposure and ongoing monitoring, additional consideration of these species is not required for this risk assessment.

Although upland environments remain the focus of this discussion, it should be noted that the section of the Columbia River adjacent to the Hanford Site is within the Hanford Reach, which extends from Priest Rapids Dam downstream to the slack waters of Lake Wallula, created by the McNary Dam. The Hanford Reach contains three species listed as threatened or endangered under the *Endangered Species Act of 1973*, including Upper Columbia River spring-run Chinook salmon (*Oncorhynchus tshawytscha*), Upper Columbia River steelhead trout (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*). The occurrence of these species within the Hanford Reach is discussed in detail in Appendix H.

7.2.2 Simplified Ecological Exposure Model

Development of the ecological CSM for this ERA involved characterizing the exposure pathways and ecological receptors that might be associated with the habitat types in the upland environment of the 100-K waste sites. Appropriate exposure pathways and representative endpoint species for the 100-K upland environment were developed based on information from the RCBRA (DOE/RL-2007-21) and are discussed in this subsection. As mentioned, full risk evaluations of the riparian area or the islands within the Columbia River are not presented because they were already completed for the RCBRA and CRC (DOE/RL-2010-117); however, the same models and receptors were employed here as in those documents. The aquatic exposure models are described in Subsection 7.7.2.2 with the evaluation of the aquatic exposure pathways. Results of those exposure and effects assessments (i.e., the risk characterization conclusions) are discussed in Chapter 4, as well as Sections 7.6 and 7.8 of this chapter with respect to the potential for 100-K to contribute to the final identified risks.

With consideration of the ecological setting, land use, and COPC release mechanisms and transport pathways at 100-K upland environments, the ecological exposure pathways considered most plausible are graphically displayed in Figure 7-1 and included the following:

- Direct contact of vegetation with analytes in surface soil.
- Direct contact with, and ingestion of, surface soil by terrestrial invertebrates (e.g., beetles and ants).
- Direct contact with, and ingestion of, surface soil by terrestrial avian and mammalian wildlife; dietary exposure of terrestrial avian and mammalian wildlife to COPCs bioaccumulated in food items (e.g., plants or prey).
- Dietary exposure to emissions from radionuclides bioaccumulated and retained within the tissues of plants, terrestrial invertebrates, and terrestrial wildlife.
- External exposure of plants, terrestrial invertebrates, and terrestrial wildlife to emissions from radionuclides in soil.

- Ecological receptors are not likely to have complete exposure pathways to soil below the biologically active zone (0 to 1.8 m [0 to 6 ft], MTCA [WAC 173-340]). The biologically active zone for Hanford is 3 m (10 ft) as described in Sample et al., 2015, "Depth of the Biologically Active Zone in Upland Habitats at the Hanford Site, Washington: Implications for Remediation and Ecological Risk Management." However, a standard depth of compliance of 4.6 m (15 ft) was used within the initial screening risk characterization and decision units with only deep soil (greater than 4.6 m [15 ft] bgs) not evaluated in this ERA.

A food web model for the upland environment of the Hanford Site (Figure 7-2) was developed based on an understanding of the ecology of the area and documented in the previous ERAs. The arrows in Figure 7-2 illustrate the caloric energy flow from the base of the terrestrial Hanford food web through to apex species.

Some endpoint entities are evaluated at the population level and others at the community level. A population is a group of conspecific organisms, whereas a community is a multispecies group of organisms occupying an area that has been defined as relevant to an ERA. As reported in EPA/100/R-09/006, *Summary Report: Risk Assessment Forum Technical Workshop on Population-Level Ecological Risk Assessment*: "Define ecological risk assessment…as estimating the likelihood or probability of adverse effects (e.g., mortality to single species of organisms, reduction in populations of nontarget organisms due to acute, chronic, a reproductive effect, or disruption in community and ecosystem level functions)."

The following entities (represented by trophic guilds) and their associated organizational level have been identified as endpoints for evaluation:

- Terrestrial plants—community level
- Terrestrial invertebrates—community level
- Soil microorganisms and microbial processes—community level
- Herbivorous birds—population level
- Herbivorous mammals—population level
- Insectivorous birds—population level
- Insectivorous mammals—population level
- Omnivorous birds—population level
- Omnivorous mammals—population level
- Carnivorous birds—population level
- Carnivorous mammals—population level
- Carnivorous and insectivorous reptiles and amphibians[8]

[8] Although part of the food web for the upland environment, effects data for reptiles and amphibians are limited. Therefore, SSLs were not developed for this trophic guild.

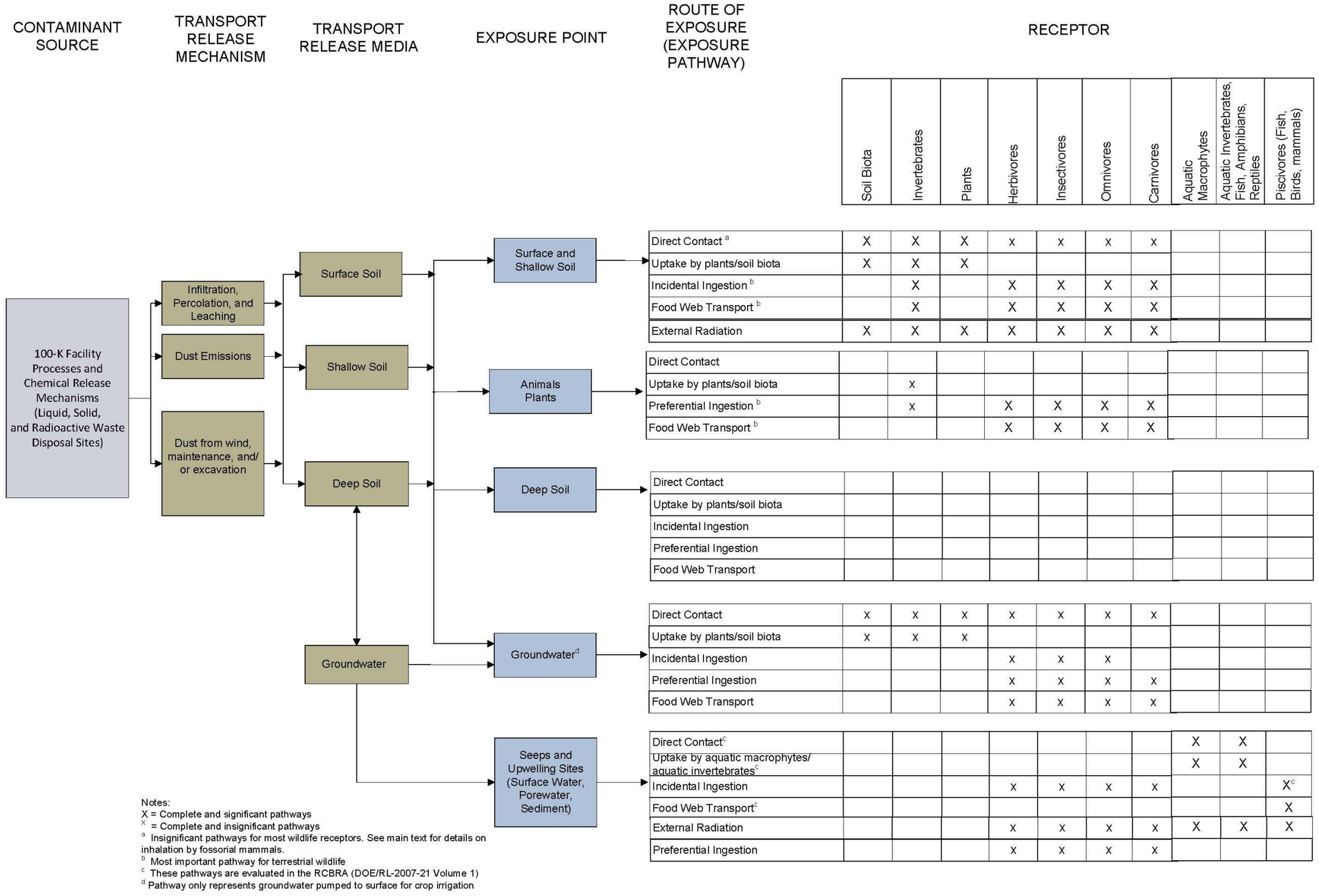


Figure 7-1. Ecological Conceptual Site Model for Terrestrial Habitats in Hanford Site Upland Environment

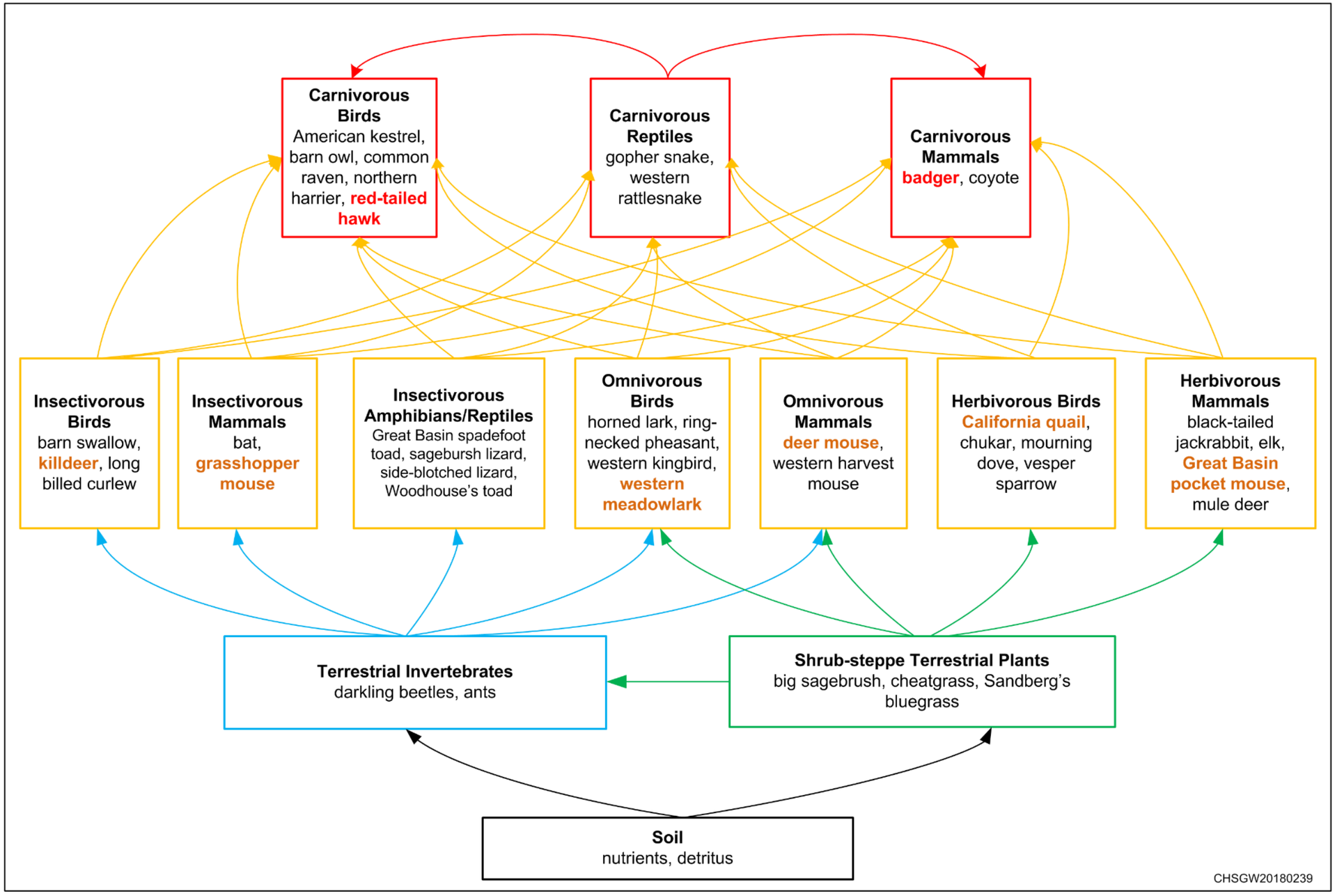


Figure 7-2. Hanford Site Upland Environment Terrestrial Food Web

EPA has developed guidance (EPA/630/R-92/001, *Framework for Ecological Risk Assessment*; EPA/540/F-95/037, *Ecological Significance and Selection of Candidate Assessment Endpoints*; and EPA/630/P-02/004F, *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment*) that can aid in distinguishing the assessment level. These guidelines intentionally do not specify a target level of organization to protect for an entity, allowing flexibility in setting the target organizational level that works for the individual project. The organizational levels described in this subsection align with the management goals originally defined in BHI-01757, which focuses on protecting individuals for special status species, preventing adverse effects on Hanford Site biota from contaminants, protecting rare habitats, and minimizing contaminant loading into biota. With the ecosystem present at the Hanford Site, maintaining the health of wildlife populations and the function of a plant community is appropriate as opposed to focusing on populations of particular plant species within that community.

As noted in Appendix A to EPA/630/P-02/004F, EPA principles for ERA and risk management at Superfund sites state, "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota." Should a special status species of plant (such as an endangered species of native grass or forb) be present at a given Hanford waste site, then protecting that population would be acceptable. However, the assessment endpoints described in Section 7.2.3 that align with the entities described in this section were selected appropriately to protect populations and communities. Although the endpoints identified may be expressed as single species toxicity tests, as these guidance documents state, interpretation of the results relative to lowest observed effect concentration (LOEC) or lowest observed adverse-effect level (LOAEL) endpoints for the protection of populations and communities is appropriate.

Section III of OSWER Directive 9285.7-28 P, *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites*, states: "Levels that are expected to protect local populations and communities can be estimated by extrapolating from effects on individuals and groups of individuals using a lines-of-evidence approach. The performance of multi-year field studies at Superfund sites to try to quantify or predict long-term changes in local populations is not necessary for appropriate risk management decisions to be made. Data from discrete field and laboratory studies, if properly planned and appropriately interpreted can be used to estimate local population or community-level effects." The directive further states that "Superfund ERAs gather effects data on individuals in order to predict or postulate potential effects on local wildlife, fish, invertebrates, and plant populations and communities that occur in specific habitats at sites." Finally, as noted in EPA, 2004, *Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs, U.S. Environmental Protection Agency—Endangered and Threatened Species Effects Determinations*: "If effects on the survival and reproduction of individuals are limited, it is assumed that risks at the population level from such effects will be of minor consequence."

To calculate ecological SSLs, endpoint representative species were selected for each entity identified above (trophic guilds/functional groups) that could use the site. For example, a red-tailed hawk may be considered representative of raptors visiting the site. Consistent with EPA 540-R-97-006, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments Interim Final* (hereinafter called Ecological Risk Assessment Guidance for Superfund [ERAGS]); EPA/630/R-95/002F, *Guidelines for Ecological Risk Assessment*; and MTCA (WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures"), endpoint species should preferably be ones that have ecological relevance, are of societal value, are susceptible to chemical stressors at the site, or allow risk managers to meet policy goals. These factors were used to select representative receptor species common to the Hanford Site upland environment that are within the trophic guilds identified above. Selected receptors are conservative indicators of the potential for risk to the trophic guilds

identified for assessment. The following are representative receptor species selected for each of the trophic guilds (Figure 7-3):

- Herbivorous birds—California quail (*Callipepla californica*)
- Herbivorous mammals—Great Basin pocket mouse (*Perognathus parvus*)
- Insectivorous birds—killdeer (*Charadrius vociferus*)
- Insectivorous mammals—northern grasshopper mouse (*Onychomys leucogaster*)
- Omnivorous birds—western meadowlark (*Sturnella neglecta*)
- Omnivorous mammals—deer mouse (*Peromyscus maniculatus*)
- Carnivorous birds (raptors)—red-tailed hawk (*Buteo jamaicensis*)
- Carnivorous mammals—badger (*Taxidea taxus*)

Unlike birds and mammals, methods to differentiate exposure and effects among different plant species or among different invertebrate species are unavailable. Therefore, individual species for terrestrial vegetation and invertebrates were not selected to represent the plant or invertebrate populations and communities for evaluation.

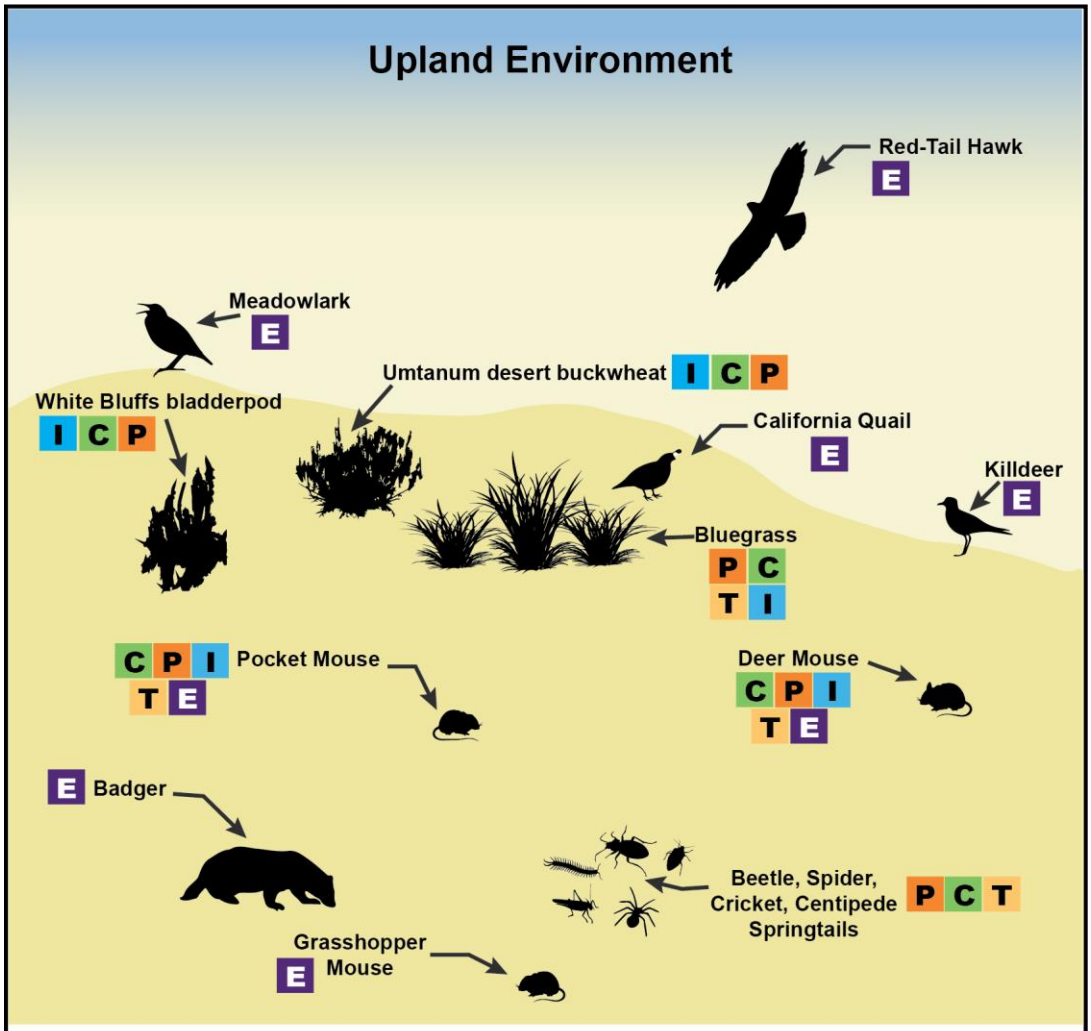
7.2.3 Assessment Endpoints

Assessment endpoints are an expression of the important ecological values that are to be protected at a site (Suter, 1993, *Ecological Risk Assessment*; EPA/630/R-95/002F; Suter et al., 2000, *Ecological Risk Assessment for Contaminated Sites*). Assessment endpoints are based on known information concerning the analytes present, the study area, the ecological CSM, and risk hypotheses. There are three components to each assessment endpoint: entity (e.g., migratory birds), attribute of that entity (e.g., individual survival), and measure (e.g., a measurable value, such as an effect level). Measures are described following the general description of assessment endpoints (EPA/630/R-95/002F; Suter et al., 2000).

The assessment endpoint entities for the 100-K Area were selected based on the following principal criteria:

- Ecological relevance
- Societal relevance
- Susceptibility (or high exposure) to known or potential stressors at the Hanford Site

The attribute selected for each entity was based on the organizational level of the entity and the primary criteria that were used to select it. Entities and attributes were selected for community and population levels of assessment.



Assessment of Conditions

Community level - receptors with a **C** were assessed as a multispecies group of organisms occupying an area and measures were collected to be reflective of exposure and effects to the multi species group.

Population level – receptors with a **P** were assessed as a group of conspecific organisms and measures were collected to be reflective of exposure and effects to the conspecific group.

Individual level – receptors with an **I** were either assessed as individual organisms because they were rare, threatened, or endangered, or measures of exposure to individual organisms were collected as described in more detail in the RCBRA.

Wildlife exposure analysis – receptors with an **E** were assessed through the use of a food chain model that reflective of contaminant uptake and diets specific to the representative species.

Measurments of tissue COPEC concentrations - receptors with a **T** were collected for tissue residue analysis (e.g., eggs, whole body, fillets or targeted organs)

COPEC: Contaminants of Potential Ecological Concern

BCRIFS451

Figure 7-3. Summary of Measures of Exposure and Effects Evaluated in the Upland Environment

7.2.4 Measures of Exposure and Effects

Measures (formerly referred to as measurement endpoints) are measurable attributes used to evaluate the risk hypotheses and are predictive of effects on the assessment endpoints (EPA/630/R-95/002F). The categories of measures include the following:

- Measures of exposure are used to evaluate intake of a contaminant from contact with environmental media (e.g., soil). Measures of exposure can be an EPC of a COPC in an environmental medium or food item. A measure of exposure also can be a dose occurring through ingestion, inhalation, or dermal contact with a contaminant in an environmental medium. SSLs were estimated by back-calculating from a target dose associated with the selected assessment endpoint to a corresponding concentration in soil (see Section 7.3.1 for further discussion).
- The measure of exposure represents the exposure appropriate for the assessment endpoint (e.g., a wildlife population) throughout its exposure area (e.g., the entire home range of the target species). Thus, the average exposure to multiple individuals (e.g., the population of wildlife or the plant community) in a species is the basis for population or community level effects.
- Measures of effect are used to evaluate the response of an organism that is exposed to a stressor. Measures of effects included TRVs for wildlife and the LOECs in soil for plants and soil invertebrates (Section 7.3.1). The maximum acceptable adverse effect levels generally selected for population and community level assessment endpoints are LOECs or LOAELs, when available.
- Measures of ecosystem and receptor characteristics are used to evaluate the ecosystem characteristics that influence the assessment endpoints, the distribution of stressors, and the characteristics of the assessment endpoints that may affect exposure or response to the stressor. Measures of ecosystem and receptor characteristics are used to characterize ecological risks as part of a baseline ERA. These kinds of ecological information were not used directly in calculating SSLs. However, measures of ecosystem and receptor characteristics may represent additional lines of evidence that can be used along with SSLs in evaluating remedial alternatives in the RI/FS.

7.3 Screening-Level Effects and Exposure Assessment for Upland Habitats

Effects and exposure assessments were conducted and then integrated to develop thresholds for evaluating the 100-K data, as described in ERAGS (EPA 540-R-97-006). The initial evaluation of soil concentrations used conservative thresholds (SSLs), which helped to eliminate from further consideration those contaminants that pose negligible risk but also ensured that COPECs were not eliminated prematurely.

For wildlife, the effects assessment presents TRVs that have been derived from available literature-based toxicity information on COPCs and that can be used in determining the potential for adverse effects to ecological receptors. The effects-based values presented in the screening assessment were initial, conservative values from the published literature (e.g., Tri-Parties' guidance or compendiums). These values were then used within food chain exposure dose models from the exposure assessment to establish media benchmarks (thresholds). For plants and invertebrates, the effects data are incorporated more simply because the effects are measured relative to direct exposure. Thus, the concentration associated with an observed effect in the exposure medium (soil, water, and sediment) becomes the benchmark (threshold).

The exposure assessment identifies exposure pathways associated with the representative receptor species listed in Section 7.2.2, and describes the models used to estimate exposure and calculate SSLs.

TRVs were combined with the exposure information to calculate SSLs. This section presents the salient features of the effects and exposure assessments as they were used to calculate the SSLs. An overview of the development of the nonradionuclide and radionuclide SSLs is described in the exposure assessment for each receptor group (i.e., plants, soil invertebrates, and wildlife). The methodology used to develop the SSLs is detailed in CHPRC-00784, which is presented in Appendix H.

7.3.1 Screening Effects Assessment

The ecological screening-level effects assessment consists of an evaluation of available toxicity or other effects information that can be used to conservatively interpret the significance of the exposures to COPCs relative to potential adverse effects to ecological receptors. The effects data used in this screening level assessment are represented by single chemical toxicity data from literature sources and are summarized below for radionuclides and nonradionuclides. The screening level effects data presented below are used either directly (for plants and invertebrates) or within exposure dose models (for wildlife) to establish concentrations in the exposure media (e.g., soil) that are protective of plant and invertebrate communities and wildlife populations.

7.3.1.1 Effects Assessment for Radionuclides

Radionuclide toxicity data for plants and wildlife are discussed within DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, hereinafter called the Graded Approach for Radiation Doses to Biota (provided in Appendix H). Two radionuclide effect thresholds, as determined by consensus of international radiation regulatory agencies, form the basis for effect thresholds used to develop screening effects levels of radionuclides in soil for the protection of plants and animals. General guidance from ICRP Publication 60, *1990 Recommendations of the International Commission on Radiological Protection*; IAEA STR-332, *Proliferation Resistance Fundamentals for Future Nuclear Energy Systems*; and UNSCEAR, 2000, "Sources and Effects of Ionizing Radiation," concluded that radiological doses to terrestrial plants and terrestrial vertebrates should not exceed 1.0 and 0.1 rad/day, respectively. If radiation exposure does not exceed these biota dose levels, the consensus opinion of the international radiological organizations is that ecological populations will be protected. DOE has adopted these effect thresholds and integrated them into DOE-STD-1153-2002.

7.3.1.2 Effects Assessment for Nonradionuclides

Effects data for the nonradionuclide COPCs are presented for plants and invertebrates and for wildlife. A description of the sources of information employed and an explanation of the selection of effects data are included. The overarching theme was to employ the most recent of relevant toxicological information available as described within ERAGS (EPA 540-R-97-006) and MTCA (WAC 173-340-7493).

Plants and Invertebrates. Single chemical, screening-level toxicity values for terrestrial plants and soil invertebrates were available from the following sources:

- EPA Ecological Soil Screening Levels (http://www.epa.gov/ecotox/ecossl/)
- Screening benchmark concentrations in soil developed by the Oak Ridge National Laboratory (ORNL); many ecological indicator soil concentrations published by Ecology were drawn from ORNL screening benchmark concentrations
- Ecological indicator soil concentrations found in MTCA (WAC 173-340-7493(2)(a)(i), Table 749-3)
- The lowest available plant or invertebrate value from these sources that was selected as the SSL for each analyte because it represents direct exposure of the receptors to the media (these SSLs are presented in Table 7-1, and a brief discussion of each source is provided in this subsection)

EPA EcoSSLs for plants and soil invertebrates were derived using data from tests performed within soil conditions favoring relatively high bioavailability for upland soil. The soil chemistry conditions of data considered for the EcoSSLs included relatively high bioavailability conditions defined by low organic matter content and low soil pH. From the studies reviewed, the measures of toxic effects to either plants or soil invertebrates were grouped into one of four ecologically relevant endpoints: reproduction, population characteristics, growth, or physiological changes. Toxicity parameters used in deriving EcoSSLs were EC20 (effective concentration affecting 20% of a test population), maximum acceptable toxicant concentration (MATC), and EC10 (effect concentration affecting 10% of a test population). MATC was calculated by EPA from studies that reported a no observed adverse effect concentration (NOAEC) and a lowest observed adverse effect concentration (LOAEC). MATC was calculated as the geometric mean of the LOAEC and NOAEC. Studies that reported only a LOAEC or only a NOAEC were not considered to provide a reliable assessment of the dose response and were not used for EcoSSL development.
The EcoSSL for plants and soil invertebrates was calculated as the geometric mean of all the toxicity parameters from studies conducted under conditions of high bioavailability. The use of the EC20, MATC, and EC10 as toxicity parameters means that EcoSSLs for plants and soil invertebrates are not based directly on NOAECs. EcoSSLs for plants and soil invertebrates instead represent a level where effects have been observed but to a percent of individuals that is considered acceptable within the ERA practice and to be protective of populations or communities, as demonstrated by its use within the EcoSSL approach documents (OSWER Directive 9285.7-55, *Guidance for Developing Ecological Soil Screening Levels*).

The ORNL benchmarks for toxicity to plants from chemical analytes in soil were based on thresholds for effects on growth and reproduction derived from published toxicity studies conducted in soil or solution. The benchmarks are concentrations of chemicals that correspond to the LOEC for the 10th percentile of plant species tested. The ORNL benchmarks for toxicity to soil invertebrates and heterotrophic processes from analytes in soil represent thresholds (LOECs) for statistically significant effects on growth, reproduction, or activity. The toxicity benchmarks were derived by rank ordering the LOEC values and then selecting a value that approximated the 10th percentile.

If 10 or fewer values were available for a chemical, the lowest LOEC was used. If the 10th percentile fell between LOEC values, a value was chosen by interpolation. If a chemical concentration in soil represented a 50% or higher reduction in survivorship of plants, the concentration was divided by five to approximate the more sensitive endpoints of growth or production. Plant toxicity benchmarks for metals are usually lower than soil invertebrates or microbial processes, and they are lower than most risk-based values calculated for wildlife.

Ecological indicator soil concentrations presented in Table 749-3 of MTCA (WAC 173-340) represent soil concentrations that are expected to be protective at any MTCA site and are provided for use in eliminating hazardous substances from further consideration under MTCA (WAC 173-340-7493(2)(a)(i)). The ecological indicator soil concentrations for plants are based on benchmarks published in ES/ER/TM-85/R3, *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*. The ecological indicator soil concentrations for soil biota are based on benchmarks published in ES/ER/TM-126/R2, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*.

Table 7-1. Tier 1 SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs	MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type		
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark
Radionuclides	Americium-241	pCi/g	---	---	---	---	---	21,500	---	---	21,500	---	21,500
	Carbon-14	pCi/g	---	---	---	---	---	60,700	---	---	60,700	---	60,700
	Cesium-134	pCi/g	---	---	---	---	---	1,090	---	---	1,090	---	1,090
	Cesium 137	pCi/g	---	---	---	---	---	2,210	---	---	2,210	---	2,210
	Cobalt-60	pCi/g	---	---	---	---	---	6,130	---	---	6,130	---	6,130
	Curium-244	pCi/g	---	---	---	---	---	153,000	---	---	153,000	---	153,000
	Europium-152	pCi/g	---	---	---	---	---	14,700	---	---	14,700	---	14,700
	Europium-154	pCi/g	---	---	---	---	---	12,500	---	---	12,500	---	12,500
	Europium-155	pCi/g	---	---	---	---	---	153,000	---	---	153,000	---	153,000
	Hydrogen-3 (Tritium)	pCi/g	---	---	---	---	---	1,680,000	---	---	1,680,000	---	1,680,000
	Neptunium-237	pCi/g	---	---	---	---	---	8,150	---	---	8,150	---	8,150
	Plutonium-238	pCi/g	---	---	---	---	---	17,500	---	---	17,500	---	17,500
	Plutonium-239/240	pCi/g	---	---	---	---	---	12,700	---	---	12,700	---	12,700
	Radium-226	pCi/g	---	---	---	---	---	288	---	---	288	---	288
	Radium-228	pCi/g	---	---	---	---	---	245	---	---	245	---	245
	Strontium 90	pCi/g	---	---	---	---	---	3,580	---	---	3,580	---	3,580
	Technetium-99	pCi/g	---	---	---	---	---	21,900	---	---	2,1900	---	21,900
	Thorium-232	pCi/g	---	---	---	---	---	23,500	---	---	23,500	---	23,500
	Uranium-234	pCi/g	---	---	---	---	---	51,600	---	---	51,600	---	51,600
	Uranium-235	pCi/g	---	---	---	---	---	27,400	---	---	27,400	---	27,400
	Uranium-238	pCi/g	---	---	---	---	---	15,700	---	---	15,700	---	15,700
Metals	Aluminum	mg/kg	Narrative Statement		OSWER Dir. 9285.7-60	50	---	---	50	---	50	---	50
	Antimony	mg/kg	---	78	OSWER Dir. 9285.7-61	5	---	---	5	---	5	78	5
	Arsenic (Total All Valence States)	mg/kg	18	---	OSWER Dir. 9285.7-62	10	60	---	---	---	10	60	10
	Arsenic (V)	mg/kg	---	---	---	---	---	---	10	60	10	60	10
	Barium	mg/kg	---	330	OSWER Dir. 9285.7-63	500	---	---	500	---	500	330	330
	Beryllium	mg/kg	---	40	OSWER Dir. 9285.7-64	10	---	---	10	---	10	40	10
	Boron	mg/kg	---	---	---	0.5	---	---	0.5	---	0.5	---	0.5
	Cadmium	mg/kg	32	140	OSWER Dir. 9285.7-65	4	20	---	4	20	4	20	4
	Chromium (Total) [a,b]	mg/kg	---	---	OSWER Dir. 9285.7-66	1	0.4	---	42	42	1	0.4	0.4

Table 7-1. Tier 1 SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs	MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type		
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark
Metals (con't)	Chromium (+3)	mg/kg	---	---	OSWER Dir. 9285.7-66	1	0.4	---	42	42	1	0.4	0.4
	Cobalt	mg/kg	13	---	OSWER Dir. 9285.7-67	20	---	---	20	---	13	---	13
	Copper	mg/kg	70	80	OSWER Dir. 9285.7-68	100	50	---	100	50	70	50	50
	Lead	mg/kg	120	1,700	OSWER Dir. 9285.7-70	50	500	---	50	500	50	500	50
	Lithium[b]	mg/kg	---	---	---	2	---	---	35	---	2	---	2
	Manganese[b]	mg/kg	220	450	OSWER Dir. 9285.7-71	500	---	---	1,100	---	220	450	220
	Mercury	mg/kg	---	---	---	0.3	0.1	---	0.3	0.1	0.3	0.1	0.1
	Molybdenum	mg/kg	---	---	---	2	---	---	2	---	2	---	2
	Nickel	mg/kg	38	280	OSWER Dir. 9285.7-76	30	200	---	30	200	30	200	30
	Selenium	mg/kg	0.52	4.1	OSWER Dir. 9285.7-72	1	70	---	1	70	0.52	4.1	0.52
	Silver	mg/kg	560	---	OSWER Dir. 9285.7-77	2	---	---	2	---	2	---	2
	Thallium	mg/kg	---	---	---	1	---	---	1	---	1	---	1
	Tin	mg/kg	---	---	---	50	---	---	50	---	50	---	50
	Uranium	mg/kg	---	---	---	5	---	---	5	---	5	---	5
	Vanadium	mg/kg	---	---	OSWER Dir. 9285.7-75	2	---	---	2	---	2	---	2
	Zinc[b]	mg/kg	160	120	OSWER Dir. 9285.7-73	50	200	---	86	200	50	120	50
Inorganics	Iodine	mg/kg	---	---	---	4	---	---	4	---	4	---	4
Volatile Organics	Chlorobenzene	mg/kg	---	---	---	---	40	---	---	40	---	40	40
	Toluene	mg/kg	---	---	---	200	---	---	200	---	200	---	200
Polycyclic Aromatic Hydrocarbons	Acenaphthene	mg/kg	---	29	OSWER Dir. 9285.7-75	20	---	---	20	---	20	29	20
	Acenaphthylene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	29	29
	Anthracene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	29	29
	Benzo(a)pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Benzo(a)anthracene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18

Table 7-1. Tier 1 SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs	MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type		
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark
Polycyclic Aromatic Hydrocarbons (con't)	Benzo(b)fluoranthene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Benzo(ghi)perylene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Benzo[k]fluoranthene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Chrysene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Dibenz(ah)anthracene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Fluoranthene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Fluorene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	30	---	---	30	---	29	29
	Indeno[1,2,3-cd]pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	2-Methylnaphthalene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	29	29
	Naphthalene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	29	29
	Phenanthrene	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	29	29
	Pyrene	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
	Low MW PAHs [c]	mg/kg	---	29	OSWER Dir. 9285.7-75	---	---	---	---	---	---	29	29
	High MW PAHs [d]	mg/kg	---	18	OSWER Dir. 9285.7-75	---	---	---	---	---	---	18	18
Petroleum	Gasoline Range Organics	mg/kg	---	---	---	---	---	---	---	100	---	100	100
	TPH-Diesel	mg/kg	---	---	---	---	---	---	---	200	---	200	200
Semivolatile Organics	Phenol	mg/kg	---	---	---	70	30	---	70	30	70	30	30
	Bis[2-ethylhexyl] phthalate [e]	mg/kg	---	---	---	100	---	---	100	---	100	---	100
Aroclors	Polychlorinated Biphenyls (PCB) [f,g]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1016 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1221 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1232 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1242 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1248 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1254	mg/kg	---	---	---	40	---	---	40	---	40	---	40

Table 7-1. Tier 1 SSLs in Upland Soil for Plants and Soil Invertebrates

Group	Soil Constituent	Units	EPA EcoSSLs			ORNL ES/ER/TM-85/R3, ES/ER/TM-126/R2		DOE BCGs	MTCA (WAC 173-340, Table 749-3)		Lowest Screening Benchmark by Receptor Type		
			Plants	Invertebrate	Reference	Plants	Invertebrate	Terrestrial Plant	Plant	Soil Biota	Plant	Inverts	Overall Lowest Screening Benchmark
Aroclors (con't)	Aroclor-1260 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
	Aroclor-1262 [f]	mg/kg	---	---	---	40	---	---	40	---	40	---	40
Pesticides	alpha-Chlordane [h]	mg/kg	---	---	---	---	---	---	---	1	---	1	1
	gamma-Chlordane [h]	mg/kg	---	---	---	---	---	---	---	1	---	1	1

Sources: ES/ER/TM-85/R3, *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*.
ES/ER/TM-126/R2, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*.
2007 MTCA (WAC 173-340, "Model Toxics Control Act—Cleanup").
Note: Complete reference citations are in Chapter 8.
a. When chromium (total) is not available, the lower of either Cr(III) or Cr(IV) as available was used as a surrogate.
b. MTCA plant and soil biota benchmarks were replaced by Washington state natural background concentrations.
c. The low MW PAHs screening values from EPA (OSWER Directive 9285.7-78, *Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Final*) represents the sum of the low MW PAHs. For the purposes of this assessment, the benchmark was also applied to the individual low MW PAHs.
d. High MW PAHs screening values from EPA (OSWER Directive 9285.7-78) represent the sum of the high MW PAHs. For the purposes of this assessment, the benchmark was also applied to the individual high MW PAHs.
e. Values for diethyl phthalate were used as a surrogate for bis(2-ethylhexyl) phthalate.
f. Aroclor 1254 value was used as surrogate.
g. MTCA values represent screening values for PCB mixtures.
h. MTCA values are based on chlordane.

--- = value not available
BCG = biota concentration guide
DOE = U.S. Department of Energy
EcoSSL = ecological soil screening level
EPA = U.S. Environmental Protection Agency
MTCA = Model Toxics Control Act
MW = molecular weight
ORNL = Oak Ridge National Laboratory
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SSL = soil screening level

Wildlife (Birds and Mammals). Bird and mammal TRVs for both no observed adverse-effect levels (NOAELs) and LOAELs were used in the SSL development. TRVs were employed within models relating the ingested dose of the chemicals (Section 7.3.2) with the TRVs to establish SSLs that represent screening level adverse effects thresholds. The TRVs were obtained from various sources, and focus was given to the most recent sources and those derived or endorsed by EPA and Ecology (as evidenced by their use in either EcoSSLs or in MTCA [WAC 173-340]). The primary literature sources used were EcoSSLs. The toxicity studies used were selected initially from the following sources, which have been listed in order of preference:

- OSWER Directives

  9285.7-56, *Ecological Soil Screening Levels for Dieldrin Interim Final*

  9285.7-57, *Ecological Soil Screening Levels for DDT and Metabolites Interim Final*

  9285.7-60, *Ecological Soil Screening Level for Aluminum Interim Final*

  9285.7-61, *Ecological Soil Screening Levels for Antimony Interim Final*

  9285.7-62, *Ecological Soil Screening Levels for Arsenic Interim Final*

  9285.7-63, *Ecological Soil Screening Levels for Barium Interim Final*

  9285.7-64, *Ecological Soil Screening Levels for Beryllium Interim Final*

  9285.7-65, *Ecological Soil Screening Levels for Cadmium Interim Final*

  9285.7-66, *Ecological Soil Screening Levels for Chromium Interim Final*

  9285.7-67, *Ecological Soil Screening Levels for Cobalt Interim Final*

  9285.7-68, *Ecological Soil Screening Levels for Copper Interim Final*

  9285.7-69, *Ecological Soil Screening Level for Iron Interim Final*

  9285.7-70, *Ecological Soil Screening Levels for Lead Interim Final*

  9285.7-71, *Ecological Soil Screening Levels for Manganese Interim Final*

  9285.7-72, *Ecological Soil Screening Levels for Selenium Interim Final*

  9285.7-73, *Ecological Soil Screening Levels for Zinc Interim Final*

  9285.7-75, *Ecological Soil Screening Levels for Vanadium Interim Final*

  9285.7-76, *Ecological Soil Screening Levels for Nickel Interim Final*

  9285.7-77, *Ecological Soil Screening Levels for Silver Interim Final*

  9285.7-78, *Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Final*

- MTCA (WAC 173-340, Table 749-5)

- Other available literature—primarily ES/ER/TM-86/R3, *Toxicological Benchmarks for Wildlife: 1996 Revision*

- NOAEL and LOAEL values selected for chemicals and reported in the integrated risk information system (IRIS)

- NOAEL and LOAEL values presented in wildlife toxicity assessments developed by the United States Army Center for Health Promotion and Preventive Medicine

An EPA panel of experts developed a process for reviewing and selecting TRVs for EcoSSL development for wildlife, presented in OSWER Directive 9285.7-55. The process was to select NOAELs to develop EcoSSLs for wildlife. Selected TRVs were either the highest NOAEL for population level effects (e.g., survival, growth, and reproduction endpoints) below the lowest LOAEL for population level effects or the geometric mean of NOAELs, depending on the number and quality of data available. Selection of the TRVs for development of Hanford SSLs attempted to draw on the work of this expert panel. Thus, for analytes for which EPA has developed EcoSSLs for birds and mammals, those same NOAELs were used for wildlife SSL development for Hanford (see CHPRC-00784 in Appendix H for a full detailed description). In some cases, the NOAEL-based TRV for the EcoSSL was the highest NOAEL below the lowest LOAEL identified for studies evaluating survival, growth, and reproduction endpoints. In these cases, the paired LOAEL from the study was selected as the LOAEL for Hanford SSL development. In other cases, the geometric mean of the NOAELs for growth and reproduction endpoints was selected to derive the EcoSSL. In these cases, the LOAEL for Hanford SSL development was selected as the lowest LOAEL from the EcoSSL dataset above the geometric mean NOAEL.

The only exception to this TRV selection process was for the arsenic TRV for avian receptors, in which case the selected study was not identified and reviewed by the EPA panel. The selected study (Stanley et al., 1994, “Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival”) was conducted by the U.S. Fish and Wildlife Service (USFWS) at Patuxent Wildlife Research Center over a period of 92 to 173 days that resulted in both a NOAEL and LOAEL for reproductive effects. The EcoSSL document considered nine studies on the effects of arsenic to have sufficient quality to consider in developing the avian SSL. Holcman and Stibilj, 1997, “Arsenic Residues in Eggs from Laying Hens Fed with a Diet Containing Arsenic (III) Oxide,” presented an unbound NOAEL that was selected because it was the lowest value. The Stanley study was conducted by a reliable research group over a much longer time frame, and produced bounded results (i.e., the NOAEL was bound by a LOAEL). The intent of the EcoSSLs is to provide a value that can be used to provide a reliable conservative screen. The intent of this ERA was not to perform a conservative screen but rather to develop Hanford-specific species thresholds for use with evaluations on post remediation verification data. Therefore, for arsenic, expanding the use of TRV data beyond that within the EcoSSL document was considered appropriate and the NOAEL and LOAEL from Stanley et al., 1994, were selected for arsenic over the arsenic EcoSSL recommendation.

For analytes lacking EcoSSLs, other primary and secondary sources of studies were used. Whenever possible, the primary literature sources were obtained and evaluated. Appropriate toxicity studies were selected from these sources based on several criteria:

- Studies were of chronic exposures or exposures during a critical stage of life (e.g., reproduction).
- Exposure was oral through food ingestion to ensure data were representative of oral exposures expected for wildlife in the field.
- Emphasis was placed on studies of reproductive impacts to achieve relevancy to population level effects.
- Studies presented adequate information to evaluate and determine the magnitude of exposure and effects (or no effects concentrations).

Specifically, toxicity studies were selected to serve as the TRV if exposure was chronic or was measured during a critical life stage, the dosing regime was sufficient to identify both a NOAEL and a LOAEL, and the study considered ecologically relevant effects (e.g., growth, reproduction, or survival). If multiple studies for a given COPC meet these criteria, the study generating the lowest reliable toxicity value was selected to be the TRV.

Full explanations of the TRVs selected, the method of calculating SSLs and PRGs, and resulting SSLs and PRGs are found in Appendix H (CHPRC-00784 for SSLs and CHPRC-01311 for PRGs).

7.3.2 Screening Exposure Assessment

A summary of the screening-level exposure assessment for plants and invertebrates, wildlife, and radionuclide exposures is provided in the following subsections. Additionally, a brief description of SSL development as a relationship between the effects assessment described in Section 7.3.1 and the exposure assessment (this section) is provided. For wildlife, this description is provided with distinct sections for nonradionuclide SSLs, radionuclide SSLs, and nonradionuclide PRGs, which all included unique details in the estimation of exposure.

7.3.2.1 Radiological Exposure Assessment for Plants and Wildlife (Birds and Mammals)

Exposure to radionuclides differs from chemical exposure. Terrestrial biota receive exposure to radionuclides through a combination of both internal and external pathways. Internal exposure is a function of radiation emitted from radionuclides that are retained in tissues. At a terrestrial site such as the 100-K Source OUs, external exposure is caused by radiation from radionuclides in soil with which biota come into contact (or come near). For the purposes of developing SSLs, radionuclide exposure was estimated based on the internal and external radiation exposure models described in the Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002).

For screening effects to plants, DOE presented biota concentration guides (BCGs) for radionuclides in DOE-STD-1153-2002. These BCG values for evaluating direct exposure of plants to contaminated soil are presented in Table 7-1.

The Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) includes the screening method used for plants and three more detailed levels of analysis for demonstrating compliance with applicable dose limits for protection of biota:

- A general screening that involves comparing maximum radionuclide concentrations in environmental media (i.e., soil) with a set of BCGs to evaluate compliance with the biota dose limits.
- Site-specific screening using more realistic site representative parameters (e.g., bioaccumulation factors [BAFs]) in place of conservative default parameters, using mean radionuclide concentrations in place of maximum values, and taking into account time dependence and spatial extent of contamination.
- Site-specific analysis employing a kinetic-allometric modeling methodology. Multiple parameters, which represent contribution to an organism's internal dose, can be modified to represent site-and organism-specific characteristics. These parameters include body mass, consumption rates of food or soil, inhalation rate, lifespan, and biological elimination rates. Development of the organism-specific characteristics involves using allometric equations that relate these parameters to body mass.
- Site-specific biota dose assessment involving the collection and analysis of biota samples.

Wildlife SSLs can be calculated using the dose models, equations, and default parameters presented in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002). The values in soil calculated using these *default* methods (wildlife BCGs) are found in Table 6.4 of DOE-STD-1153-2002. However, these default methods were not used in this screening. These dose models, equations, and default parameters are also incorporated into the ANL, 2009b, RESRAD-BIOTA for Windows®, Version 1.5 model (DOE/EH-0676, *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1*) to establish values protective of wildlife populations. RESRAD-BIOTA presents three levels of analysis, which correspond to the following levels in the graded approach:

- Level 1—general screening approach
- Level 2—site-specific screening with representative parameters
- Level 3—site-specific analysis using the kinetic/allometric modeling methodology

BCGs for plants in this ERA were calculated using the Level 1 analysis in RESRAD-BIOTA. For wildlife (animals), more site-specific SSLs were developed using RESRAD-BIOTA for Windows, Version 1.5 (ANL, 2009b) with a Level 3 analysis. As listed above, there are numerous refinements to the conservative default parameters that can be made within RESRAD BIOTA. Many of these refinements were not made for this screening assessment, in particular the assumptions about the site-specific uptake of radionuclides. SSL values were established for eight different species representing feeding guilds found at the Hanford Site. However, modeling parameters such as body mass, ingestion rates, and diets were not Hanford-specific. Also, Hanford Site-specific tissue residue data for radionuclides was insufficient for developing models, so bioaccumulation values from relevant published literature were instead used (Beresford et al., 2008, "Derivation of Transfer Parameters for Use Within the ERICA Tool and the Default Concentration Ratios for Terrestrial Biota"). Because much of the receptors-specific modeling was not site-specific (i.e., based on studies conducted at Hanford), and significant refinement could still be incorporated, the resulting model output (i.e., soil thresholds) were not considered equivalent to what is used in baseline risk assessment. For this, and additional reasons described below, the resulting values were considered SSLs.

The SSLs for radionuclides use conservative assumptions for internal and external exposure. Although existing effects data support the application of these dose limits to representative individuals within populations of animals, the assumptions and parameters applied in the derivation of the SSLs are based on a maximally exposed individual, representing a conservative approach for screening purposes. Thus, the output from RESRAD BIOTA included some aspects of a Level 1 analysis and was considered a screening assessment. Radionuclide SSLs for wildlife are shown in Table 7-2.

The following assumptions are used for estimating doses from external exposure for the purposes of developing radiological SSLs for wildlife:

- The source medium is infinite in extent and contains uniform concentrations of radionuclides (i.e., there are no "hot spots").
- One hundred percent of the radionuclide energies are absorbed (despite the small size of some of the receptors).
- Organisms exposed to soil are uniformly surrounded by the source medium.

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Table 7-2. Summary of Tier 1 Wildlife SSLs for Radionuclides

Radionuclide	California Quail	Western Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	Lowest
Americium-241	28,900	25,000	11,900	17,800	72,100	48,700	41,400	4,840	4,840
Carbon-14	54	60.10	56.30	49.50	61.40	59.70	135	31.60	31.60
Curium-244	389,000	252,000	105,000	207,000	2,300,000	722,000	499,000	50,800	50,800
Cobalt-60	805	805	805	863	805	805	806	1,000	805
Cesium-134	1,140	1,190	1,200	854	1,160	1,180	1,270	562	562
Cesium 137	2,390	2,700	2,800	1,430	2,510	2,630	3,280	924	924
Europium-152	1,740	1,740	1,740	1,880	1,740	1,740	1,740	2,220	1,740
Europium-154	1,610	1,610	1,610	1,740	1,610	1,610	1,610	2,060	1,610
Europium-155	33,400	33,400	33,400	37,300	33,400	33,400	33,400	48,600	33,400
Hydrogen-3 (tritium)	1,430	1,280	936	1,130	3,270	2,290	2,830	420	420
Neptunium-237	8,190	8,140	7,880	9,150	8,250	8,170	8,180	11,200	7,880
Plutonium-238	36,300	56,200	20,900	26,800	291,000	161,000	161,000	5,980	5,980
Plutonium-239/240	38,800	60,300	22,300	28,400	324,000	175,000	176,000	6,270	6,270
Radium-226	168	142	58.30	377	285	165	199	193	58.30
Radium-228	169	140	55.20	418	306	165	203	193	55.20
Antimony-125	4,580	4,580	4,580	5040	4,580	4,580	4,580	6,130	4,580
Strontium 90	521	302	151	112	706	519	413	91.10	91.10
Technetium-99	5,360	11,500	137,000	280,000	8,670	12,100	412,000	128,000	5,360
Thorium-232	5,070	12,900	5,340	12,400	34,400	32,500	86,200	4,560	4,560
Uranium-234	12,700	21,800	6,370	40,900	30,300	24,800	51,600	14,200	6,370
Uranium-235	6,340	7,810	4,360	10,200	8,600	8,130	9,630	8,060	4,360
Uranium-238	8,020	10,400	5,150	22,100	11,900	11,000	13,900	13,400	5,150

Notes: All values are in units of picocuries per gram of soil.
Highlighted cells represent limiting (lowest) value.
— = not available

The following assumptions are used in estimating doses from internal exposure for the purposes of developing wildlife SSLs:

- All radionuclide decay energies are retained in tissue (100% of energies absorbed).
- Exposure for a given radionuclide includes all decay chain progeny.
- All radionuclides are uniformly distributed such that all target tissues may be affected.

Because the dose from radionuclides is additive (Jones et al., 2003, "Principles and Issues in Radiological Ecological Risk Assessment"), the total contribution of radionuclides known to be associated with Hanford Site processes was also calculated. A total radionuclide exposure estimate was calculated using the SOF method. With the SOF method, the contributions of various radionuclides were reviewed to determine their contribution to dose. Contributions were considered significant if the radionuclide EPC was greater than the SSL and was detected frequently.

7.3.2.2 Nonradiological Exposure Assessment for Terrestrial Plants and Soil Invertebrates

Terrestrial plants and soil invertebrates experience exposure primarily through the soil in which they live. This exposure occurs as a consequence of living in a contaminated medium (i.e., receptors are directly exposed to COPCs). Although other exposure pathways (e.g., dietary exposure for invertebrates or foliar uptake for plants) may contribute to total exposure for these receptors, exposure through the soil predominates. Consequently, estimates of exposure for terrestrial plants and soil invertebrates are represented by the concentration of COPCs in the soil (mg/kg).

7.3.2.3 Nonradiological Exposure Assessment for Wildlife (Birds and Mammals)

In contrast to plants and soil invertebrates, birds and mammals experience chemical exposure through multiple pathways, including the ingestion of drinking water (seeps), sediment/soil, and biotic media (food), inhalation, and dermal contact. Modeling is often employed to assess exposure via these multiple exposure pathways. The end product, or exposure estimate, for birds and mammals is a dose estimate that quantifies the amount of chemical in milligrams per kilogram receptor body weight per day (mg/kg/day).

The following general form of the model is used to estimate exposure of birds and mammals to chemicals in environmental media (Suter et al., 2000):

$$Et = Eo + Ed + Ei$$

where:

Et = total chemical exposure experienced by wildlife

Eo = oral exposure

Ed = dermal exposure

Ei = inhalation exposure

Oral exposure occurs through the consumption of contaminated food, water, or sediment/soil; dermal exposure occurs when contaminants are absorbed directly through the skin; and inhalation exposure occurs when volatile compounds or fine particulates are inhaled into the lungs. Although methods are available for assessing dermal exposure to humans (EPA/600/8-91/011B, *Dermal Exposure Assessment: Principles and Applications*), data necessary to estimate dermal exposure generally are not available for wildlife (EPA/600/8-91/011B, *Dermal Exposure Assessment: Principles and Applications*, Volumes I and II). Similarly, methods and data necessary to estimate wildlife inhalation exposures are poorly developed (EPA/600/R-93/187b, *Wildlife Exposure Factors Handbook*) or limited. Recent publications have suggested the inclusion of inhalation and dermal pathways for developing TRVs for VOCs in fossorial

mammals (Gallegos et al., 2007, "Wildlife Ecological Screening Levels for Inhalation of Volatile Organic Chemicals") and pesticides in birds (Mineau, 2012, "A Comprehensive Re-Analysis of Pesticide Dermal Toxicity in Birds and Comparison with the Rat"). However, VOCs and pesticides were not the primary COPECs identified for the 100-K Area in past investigations. Moreover, a wildlife receptor's exposure to contaminants by inhalation and dermal contact usually contributes little to its overall exposure (OSWER Directive 9285.7-55). Dermal exposure is low, even to burrow-dwelling animals, because of the presence of protective dermal layers (e.g., feathers, fur, or scales). Therefore, for the purposes of developing the SSL values, both dermal and inhalation exposure were assumed to be negligible.[9] Therefore, only oral exposures via ingestion of soil and food were included in the development of risk-based concentrations for birds and mammals.

Large mammalian wildlife using the upland 100-K Area waste site areas can and do move down to the Columbia River riparian area and drink from the freshwater seeps and the more abundant Columbia River. Bats and birds frequenting or residing in these areas also can use the seeps along the Columbia River to meet their daily needs. A semi-quantitative evaluation of the ingestion of seep water was performed and is discussed in Section 7.5.4.12.

Total chemical exposure experienced by wildlife (E_t) is assumed equal to oral exposure (E_o). By replacing E_o with a generalized exposure model modified from Suter et al., 2000, to include only soil and food ingestion, the previous equation was rewritten as follows:

$$E_t = \left[\left[\sum_{i=1}^{n} B_{ij} \times P_i \times FIR\right] + \left[Soil_j \times P_s \times FIR\right]\right] x\, AUF$$

where:

E_t = total exposure (mg/kg/day)

$Soil_j$ = chemical concentration in soil (mg/kg dry weight)

P_s = proportion of total food intake that is soil (kg soil/kg food)

FIR = food intake rate (kg food/kg body weight/day, dry weight)

B_{ij} = chemical concentration in biota type (i) (mg/kg, dry weight)

P_i = proportion of biota type (i) in diet (unitless)

AUF = area use factor (area of site/home range of receptor) (unitless).

The bird and mammal effects data (Section 7.3.1.2) were incorporated into the wildlife exposure model to calculate avian/mammal SSLs for nonradionuclides. The SSLs consist of soil concentrations that are associated with estimated dietary exposures equivalent to a selected effect level (i.e., the TRV), and were calculated using the following basic equation (the value of SSL is selected to set the result equal to 1 [i.e., an HQ of 1]):

$$1 = \frac{TRV}{\sum\left(SSL \times DFI\right) \times \left[\left(Frac_v \times C_v\right) + \left(Frac_i \times C_i\right) + \left(Frac_m \times C_m\right) + \left(C_s \times Frac_s\right)\right]}$$

[9] If the CSM had indicated that VOCs are a significant COPEC, focused analyses of the inhalation pathway may have been warranted, but VOCs were not COPECs in soil at 100-K.

where:

TRV = toxicity reference value (mg/kg body weight/day)

SSL = wildlife soil screening level (mg/kg)

$Frac_v$ = fraction of diet represented by vegetation (unitless)

DFI = daily ingestion rate of all food items (kg/kg body weight/day dry wt.)

C_v = concentration in vegetation tissue (mg/kg dry wt.)

$Frac_i$ = fraction of diet represented by terrestrial invertebrates (unitless)

C_i = concentration in soil invertebrate tissue (mg/kg dry wt.)

$Frac_m$ = fraction of diet represented by small mammals/birds (unitless)

C_m = concentration in small bird/mammal tissue (mg/kg dry wt.)

Cs = concentration in soil (mg/kg)

$Frac_s$ = fraction of diet represented by incidentally ingested soil (unitless).

The TRV denotes the level of toxicity of the chemical, as reported from literature sources. The wildlife SSLs use the LOAELs, which is consistent with protecting ecological receptors at the population and community level. The daily ingestion rate and dietary fractions are specific to bird and mammal receptors identified for the upland environment of the Hanford Site. The chemical concentration in the food item (vegetation, soil invertebrate, and small mammal) is estimated by using BAFs or bioaccumulation regression models to extrapolate to the food source. The equation above is solved for wildlife SSLs using the Microsoft Office Excel® goal seek tool, such that exposure (the denominator) equals the TRV (the numerator).

For the purposes of this risk assessment, the LOAEL-based wildlife SSLs were used to evaluate residual risks at the 100-K Source OUs waste sites. The SSLs were compared to EPCs developed for 100-K, as described in Section 7.3.3.

Wildlife Exposure Factors. Within the exposure models described in the previous subsection, species-specific exposure parameters are required to estimate exposure. These include body weight, food ingestion rate, diet composition represented by dietary fractions, and percent or fraction of diet as incidental soil ingestion. The following assumptions were part of the calculation of wildlife exposures used to develop the wildlife SSLs:

- For SSL development, it was conservatively assumed that wildlife forage exclusively within the waste site being evaluated, resulting in an AUF of 1.0. In other words, the resulting SSLs did not attempt to account for wildlife home range, instead assuming that prey tissue concentrations from food obtained outside the waste site boundaries might contain lower concentrations of contaminants. This assumption is discussed in more detail in the risk conclusions and the SMDP in Section 7.6, including accounting for home range and development of site-specific AUFs as warranted.
- Incidental soil ingestion was not included as part of the total dietary composition (e.g., composition of items contributing to daily energy demands) but instead was added to the total. For calculation purposes, it was not treated as a percentage of total dietary intake but rather was added to the dietary composition to result in a total intake greater than 100%. For example, California quail diet is equal to 100% plants plus an additional 6.1% incidental soil ingestion. This conservatively assumes that

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incidentally ingested soil is not a dietary item in that it does not contribute energy to the receptor and that the presence of soil in the gut does not displace dietary items that contribute bioenergetically. The equation above suggests it was included as part of the total diet but, as indicated in Appendix H (Table H-3), the fractions of food plus incidental soil will add to more than 100%.

- All animals were assumed to be year-round residents and migration away from areas contaminated with COPCs was not assumed to occur.
- Bioavailability of analytes was assumed equivalent to the chemical form used for developing TRVs in the toxicity studies.
- 100% of the estimated soil concentrations (EPCs) were assumed to be bioavailable for uptake into tissues within the exposure models.

The exposure parameters and source references used for each representative receptor species are summarized in Appendix H (Table H-3). All weight-based exposure parameters are listed on a dry-weight basis. Species-specific biological information was unavailable for some parameters. When this occurred, allometric equations that express general biological relationships for broader classes of animals were used to estimate the exposure parameters (Nagy, 2000, "Food Requirements of Wild Animals: Predictive Equations for Free-living Mammals, Reptiles, and Birds"). These allometric conversions are detailed in CHPRC-00784.

Estimation of Bioaccumulation into Food Items. A major component of the desktop food chain model described above is modeling the concentration of contaminants within the prey consumed by wildlife within the waste sites being evaluated. This modeled dose received through ingesting food was considered in the final estimate of the soil concentration that represents a toxic threshold (i.e., the SSL). Bioaccumulation models and assumptions that were used within the calculation of wildlife SSLs are described below. While some of them are the same as those within MTCA (WAC 173-340-7493) promulgated in 2001, advancements in estimating bioaccumulation into food items were published as part of the initial OSWER Directive 92857-55 in 2003 and subsequent updates. These models and assumptions represent the most recent equations used in ERA and are now the standard of practice; thus, they were employed for developing SSLs for Hanford.

- **Estimating Prey Tissue Concentration for SSLs**—The concentrations of COPCs in each food item were estimated rather than measured. For the purposes of exposure estimation, partitioning of analytes from environmental media to prey was estimated from literature values and models. The models presented in the EPA EcoSSLs methodology (OSWER Directive 9285.7-55) were used preferentially for estimation of bioaccumulation into biota from soil. Consistent with the approach employed for the EcoSSLs, regression-based models (if available) and median BAFs from the source selected by EPA were used. In the absence of applicable bioaccumulation models, a default value of one was assumed. In all cases, it was assumed that tissue uptake occurs under steady-state conditions. Bioaccumulation models used to derive wildlife SSLs are presented in Appendix H, Table H-4. The wildlife SSLs are presented in Table 7-3 for nonradionuclides. The methodology used to develop the SSLs is detailed in CHPRC-00784 (presented in Appendix H).

7.3.3 Estimation of Exposure Point Concentrations in Upland Waste Sites

As mentioned earlier, assuming that wildlife forage exclusively within the boundaries of a waste site or that the data collected from within a waste site represent the central tendency of exposure to wildlife is a highly conservative assumption. In reality, the concentration of contaminants to which a wildlife population is exposed includes points both in and out of the waste site being investigated unless there are physical barriers preventing exposure. Thus, a true exposure estimate would include data points both in

and out of the site boundary; and in some investigations for other sites, the points outside have been generated by either measured data or have been assumed to be at background. However, methods for this type of estimate of exposure are not defined in guidance and are not commonplace. What is common in ERA practice, and what was done for this ERA, is to initially perform a screening characterization of risk assuming an AUF of 1.0 (all exposure is within the site) and then refining that assumption should the highly conservative exposure estimate and risk characterization suggest an unacceptable risk warranting further evaluation. Hence, this section describes the method by which EPCs were derived within the waste sites that assumed an AUF of 1.0. The SMDP in Section 7.6 describes in detail how AUFs were used for evaluating upland waste sites as part of the baseline risk assessment refinement, in those cases where such consideration was necessary.

In total, 54 waste sites at 100-K with verification sampling data were included in this ERA. Chapter 6 details the computation of the EPCs for the 100-K waste sites. The 95% UCL of the arithmetic mean was calculated as the EPC for each decision unit (shallow, staging pile area, and overburden) within each waste site. Two separate statistical evaluations were performed, one used for the closeout documentation and one used for human health and ERAs, as follows:

- **Statistical Evaluation Used for Closeout Documentation:** For the closeout documentation, the primary statistical calculation to support cleanup verification was the 95% UCL on the arithmetic mean of the data. As in Ecology Publication 92-54, *Statistical Guidance for Ecology Site Managers*, a 95% UCL on the mean based on the Student's t-test statistic was used for normally distributed data, and the Land method using the H-statistic was used for lognormal data. This guidance also employs the use of a proxy value of one-half the detection limits for nondetect values. For small datasets (n <10), typically the maximum detected concentration was used as the EPC.

- **Statistical Evaluation Used for Soil Risk Assessment:** The most recent EPA guidance for calculating the UCL for EPCs, OSWER Directive 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, and ProUCL 4.00.05, *A Statistical Software*, were both used to recalculate EPCs for the 100-K waste site decision unit human health and ecological risk assessments. Although Ecology Publication 92-54, *Statistical Guidance for Ecology Site Managers*, has been used to calculate EPCs for all closeout documentation to date, EPCs were recalculated according to OSWER 9285.6-10 to allow for the use of more rigorous statistical methods to estimate exposure concentration and to eliminate the use of the one-half the detection limit used in Ecology Publication 92-54, which has the potential to underestimate exposure concentrations.

  The process used to calculate EPCs for each waste site and decision unit is documented in ECF-100KR1-11-0008, *Computation of Exposure Point Concentrations for the 100-KR-1 and 100-KR-2 Source Operable Units*, in Appendix G. The purpose of ECF-100 KR1-11-0008 is to document the data processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs. EPCs generated for use in this evaluation for each waste site, decision unit, and detected analyte at the 100-K Area is provided in Appendix H (Table H-7).

Table 7-3. Wildlife (Birds and Mammals) Tier 1 SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-Based Site-Specific SSLs									LOAEL-Based Site-Specific SSLs								
			California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
Metals	Aluminum	mg/kg	22,020	18,602	4,921	61,782	687	271	380	710	**271**	—	—	—	—	6,872	2,708	3,799	7,101	**2,708**
	Antimony	mg/kg	—	—	—	—	8.8	0.66	0.6	17	**0.6**	—	—	—	—	96.6	6.6	6.0	167	**6.0**
	Arsenic, Total all valence states	mg/kg	1,800	1,981	425	10,344	265	105	171	549	**105**	8,104	10,559	2,132	45,439	459	190	318	881	**190**
	Arsenic (III)	mg/kg	1,800	1,981	425	10,344	265	105	171	549	**105**	8,104	10,559	2,132	45,439	459	190	318	881	**190**
	Arsenic (V)	mg/kg	1,800	1,981	425	10,344	265	105	171	549	**105**	8,104	10,559	2,132	45,439	459	190	318	881	**190**
	Barium	mg/kg	1,229	1,271	660	14,442	2,082	1,889	4,605	18,843	**660**	2,464	2,548	1,323	28,954	3,470	3,148	7,676	31,405	**1,323**
	Beryllium	mg/kg	—	—	—	—	13.9	18.0	101	283	**13.9**	—	—	—	—	—	—	—	—	**—**
	Boron	mg/kg	63.9	86.5	140	797	39.8	49.90	284	767	**39.8**	222	300	485	2,766	133	167	949	2,563	**133**
	Cadmium	mg/kg	151	2.8	0.9	1,375	76.2	1.5	1.3	455	**0.9**	278	5.1	1.6	2,335	2,065	27.5	23.6	5,228	**1.6**
	Chromium (total)	mg/kg	334	96.5	36.5	1,286	320	74.7	78.0	752	**36.5**	349	101	38.2	1,355	1,284	299	313	3,536	**38.2**
	Chromium (III)	mg/kg	334	96.5	36.5	1,286	320	74.7	78.0	752	**36.5**	349	101	38.2	1,355	1,284	299	313	3,536	**38.2**
	Chromium (VI)	mg/kg	—	—	—	—	1,233	288	300	3,380	**288**	—	—	—	—	5,340	1,245	1,300	16,583	**1,245**
	Cobalt	mg/kg	1,425	305	109	1,601	2,174	261	250	1,346	**109**	1,461	313	112	1,633	3,233	388	372	1,869	**112**
	Copper	mg/kg	485	85.3	35.8	3,728	873	100	109	2,640	**35.8**	1,914	272	107	13,021	1,894	176	182	4,672	**107**
	Lead	mg/kg	247	48.7	15.5	979	1,204	151	153	2,005	**16**	537	115	35.6	2,433.2	2,544.2	332.0	336.4	4,108.4	**35.6**
	Lithium	mg/kg	—	—	—	—	3,189	1,258	1,749	257	**257**	—	—	—	—	6,379	2,517	3,498	515	**515**
	Manganese	mg/kg	16,369	24,184	9,588	113,951	4,227	4,115	18,430	20,464	**4,115**	31,823	48,820	19,636	221,536	5,828	5,798	27,720	28,213	**5,798**
	Mercury	mg/kg	3.1	0.35	0.04	24.6	0.49	0.03	0.03	9	**0.03**	35.5	21.3	3.6	134	8.0	1.9	3.3	43.4	**1.9**
	Molybdenum	mg/kg	34.5	27.0	17.9	97.7	1.7	1.4	2.8	7	**1.4**	345	270	179	977	16.7	14.0	27.7	71.2	**14.0**
	Nickel	mg/kg	1,081	79.4	30.8	6,037	303	17.8	16.3	637	**16.3**	1,912	136	52.9	11,078	676	35.8	32.6	1,438	**32.6**
	Selenium	mg/kg	5.6	3.7	1.7	158	2.1	1.2	1.8	32	**1.2**	10.5	8.2	4.3	417	3.0	1.9	3.2	60	**1.9**
	Silver	mg/kg	345	13	5	2,044	1,442	34.6	30.0	3,097	**5.0**	3,453	128	49.6	20,437	14,418	346	300	30,969	**49.6**
	Strontium	mg/kg	—	—	—	—	9,442	4,849	6,476	4,228	**4,228**	—	—	—	—	—	—	—	—	**—**
	Thallium	mg/kg	—	—	—	—	5.1	1.8	2.4	3	**1.8**	—	—	—	—	25.5	9.2	12.2	13.1	**9.2**
	Tin	mg/kg	82.2	128	231	1,852	187	252	2,691	5,107	**82.2**	204	318	575	4,603	279	377	4,025	7,639	**204**
	Uranium	mg/kg	2,502	2,691	785	18,730	56	36	68	155	**36**	—	—	—	—	556	359	682	1,549	**359**
	Vanadium	mg/kg	67.0	58.2	15.6	268	1,363	577	835	1,864	**15.6**	134	116	31.1	537	2,723	1,153	1,668	3,723	**31.1**
	Zinc	mg/kg	4,973	714	66.6	70,825	4,612	633	794	38,590	**66.6**	5,015	726	67.8	71,294	4,661	644	810	38,866	**67.8**
General Inorganics	Cyanide	mg/kg	—	—	—	—	27,971	20,693	78,123	38,061	**20,693**	—	—	—	—	—	—	—	—	**—**
	Fluoride	mg/kg	1,492	2,812	556	9,206	9,825	8,216	35,673	17,379	**556**	6,123	11,539	2,281	37,771	16,521	13,816	59,985	29,224	**2,281**
	Iodine	mg/kg	—	—	—	—	159	183	1,558	759	**159**	—	—	—	—	1,594	1,834	15,579	7,590	**1,594**
	Nitrate/Nitrite	mg/kg	—	—	—	—	206,422	152,711	576,537	280,885	**152,711**	—	—	—	—	460,073	340,361	1,284,984	626,035	**340,361**

Table 7-3. Wildlife (Birds and Mammals) Tier 1 SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-Based Site-Specific SSLs									LOAEL-Based Site-Specific SSLs								
			California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
Volatile Organics	1,1-dichloroethane	mg/kg	3,615	217	82.7	13,955	20,357	574	502	22,894	**82.7**	7,230	435	165	27,909	—	—	—	—	**165**
	1,1-dichloroethene	mg/kg	3,615	217	82.5	11,433	12,214	344	301	12,238	**82.5**	7,230	434	165	22,866	—	—	—	—	**165**
	1,1,1-trichloroethane	mg/kg	3,615	217	82.4	8,936	407,144	11,444	10,016	349,074	**82.4**	7,230	433	165	17,871	—	—	—	—	**165**
	1,1,2-trichloroethane	mg/kg	3,615	217	82.6	12,031	407,144	11,472	10,041	420,572	**82.6**	7,230	434	165	24,063	—	—	—	—	**165**
	1,1,2,2-tetrachloroethane	mg/kg	3,615	217	82.4	9,549	3,636	102	89	3,255	**82.4**	7,230	433	165	19,098	36,358	1,022	894	32,554	**165**
	1,2-dichlorobenzene	mg/kg	87.8	91.0	82.1	4,343	282	294	854	17,612	**82.1**	176	182	164	8,687	—	—	—	—	**164**
	1,2-dichloroethane (DCA)	mg/kg	3,615	222	84.3	16,084	20,357	586	513	24,710	**84.3**	7,230	444	169	32,168	—	—	—	—	**169**
	1,3-dichlorobenzene	mg/kg	96.1	95.9	82.0	4,051	310	314	854	16,652	**82.0**	192	192	164	8,103	—	—	—	—	**164**
	2-butanone (Methyl Ethyl Ketone/MEK)	mg/kg	2,102	1,041	312	11,538	721,052	159,713	176,661	970,851	**312**	21,017	10,406	3,123	115,382	1,861,055	412,224	455,968	2,505,793	**3,123**
	2-hexanone	mg/kg	2,102	548	186	9,653	2,036	244	237	2,512	**185.63**	21,017	5,483	1,856	96,532	14,698	1,759	1,708	18,135	**1,708**
	Benzene	mg/kg	8,554	513	195	27,053	285	8.0	7.0	286	**7.0**	—	—	—	—	2,850	80.2	70.2	2,856	**70.2**
	Butanol	mg/kg	—	—	—	—	50,893	2,906	2,626	67,049	**2,626**	—	—	—	—	203,572	11,625	10,503	268,194	**10,503**
	Carbon Tetrachloride	mg/kg	3,615	216	82.3	7,382	6,514	183	160	4,904	**82.3**	7,230	433	165	14,765	—	—	—	—	**164.56**
	Chlorobenzene	mg/kg	3,615	216	82.3	6,672	7,939	223	195	5,561	**82.3**	7,230	433	165	13,345	15,756	442	387	11,036	**165**
	Chloroform	mg/kg	3,615	217	82.6	13,003	6,107	172	151	6,600	**82.6**	7,230	434	165	26,006	16,693	470	412	18,041	**165**
	Cis-1,2-dichloroethylene	mg/kg	3,615	217	82.6	13,446	18,403	518	453	20,271	**82.6**	7,230	434	165	26,892	—	—	—	—	**165.11**
	Dichloromethane (Methylene Chloride)	mg/kg	3,615	218	82.9	17,281	2,382	67.3	58.9	2,999	**58.9**	7,230	436	166	34,562	20,357	576	504	25,632	**166**
	Ethyl Benzene	mg/kg	159	182	194	12,721	342	384	1,357	33,025	**159**	—	—	—	—	1,027	1,151	4,073	99,076	**1,027**
	Methyl Isobutyl Ketone	mg/kg	2,102	573	193	10,211	721,052	90,040	87,996	915,292	**193**	21,017	5,729	1,927	102,114	1,861,055	232,395	227,119	2,362,393	**1,927**
	n-butyl Benzene	mg/kg	301	263	193	7,857	530	485	1,092	18,135	**193**	—	—	—	—	1,589	1,454	3,275	54,406	**1,454**
	Tetrachloroethylene	mg/kg	3,615	216	82	7,733	570	16.0	14.0	443	**13.96**	7,230	431	164	15,467	2,850	79.8	69.8	2,216	**69.8**
	Toluene	mg/kg	8,554	512	195	17,200	21,171	594	520	15,763	**195**	—	—	—	—	211,715	5,944	5,202	157,633	**5,202**
	Trans-1,2-dichloroethylene	mg/kg	3,615	217	83	11,881	18,403	518	453	18,869	**82.55**	7,230	434	165	23,763	—	—	—	—	**165**
	Trichloroethene	mg/kg	3,615	217	82	7,498	285	8.0	7.0	217	**7.01**	7,230	434	165	14,996	2,850	80.1	70.1	2,169	**70.1**
	Xylene	mg/kg	149	175	194	13,419	422	481	1,787	45,266	**149**	—	—	—	—	826	940	3,495	88,509	**826**

Table 7-3. Wildlife (Birds and Mammals) Tier 1 SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-Based Site-Specific SSLs									LOAEL-Based Site-Specific SSLs								
			California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
Polycyclic Aromatic Hydrocarbons	Acenaphthene	mg/kg	6,831	285	110	38,362	71,250	1,396	1,211	96,952	**110**	68,306	2,849	1,096	383,617	142,500	2,793	2,422	193,905	**1,096**
	Acenaphthylene	mg/kg	3,506	19	7.4	38,362	24,321	91.4	77.9	96,952	**7.4**	43,766	186	73.6	383,617	54,132	183	156	193,905	**73.6**
	Anthracene	mg/kg	3,405	170	68	38,362	178,811	4,784	4,213	554,013	**68**	43,405	1,716	678	383,617	—	—	—	—	**678**
	Benzo(a)pyrene	mg/kg	47.2	6.0	2.4	767	60.4	8.1	7.6	554	**2.4**	—	—	—	—	635	81.2	76.4	5,540	**76.4**
	Benzo(a)anthracene	mg/kg	118	5.2	2.0	767	307	7.3	6.4	554	**2.0**	—	—	—	—	3,636	73.4	64	5,540	**64**
	Benzo(b)fluoranthene	mg/kg	22.5	3.0	1.3	767	24.7	4.1	3.9	554	**1.3**	—	—	—	—	247	40.8	39.2	5,540	**39.2**
	Benzo(ghi)perylene	mg/kg	12.2	2.6	1.1	767	12.6	3.5	3.5	554	**1.1**	—	—	—	—	88.95	32.4	34.7	5,540	**32.4**
	Benzo[k]fluoranthene	mg/kg	136	3.3	1.3	767	406	4.6	3.9	554	**1.3**	—	—	—	—	4,069	45.6	39.2	5,540	**39.2**
	Chrysene	mg/kg	118	3.7	1.4	767	307	5.1	4.5	554	**1.4**	—	—	—	—	3,636	51.4	44.5	5,540	**44.5**
	Dibenz(ah)anthracene	mg/kg	43.6	3.5	1.4	767	54.29	4.86	4.4	554	**1.4**	—	—	—	—	542.86	48.6	44.1	5,540	**44.1**
	Fluoranthene	mg/kg	14.9	2.5	1.1	767	1,957	421	420	69,252	**1.1**	—	—	—	—	3,915	841	839	138,503	**839**
	Fluorene	mg/kg	6,831	45	17.5	38,362	50,893	157	134	69,252	**17.5**	68,306	446	175.36	383.617	101,786	313	267	138,503	**175**
	Indeno[1,2,3-cd]pyrene	mg/kg	48.7	2.9	1.2	767	62.6	4.0	3.6	554	**1.2**	—	—	—	—	626	40	35.7	5,540	**35.7**
	2-Methylnaphthalene	mg/kg	5.0	5.7	155	38,362	5.0	5.5	500	27,867	**5.0**	8.4	9.5	1,547	383,617	6.0	6.6	1,132	63,047	**6.0**
	Naphthalene	mg/kg	34.0	36.9	416	38,362	33.3	36.2	116	27,701	**33.3**	340	369	378	383,617	100	109	348	83,102	**100**
	Phenanthrene	mg/kg	4,329	236	94	38,362	301,134	6,731	5,919	554,013	**94**	56,061	2,406	943	383,617	—	—	—	—	**943**
	Pyrene	mg/kg	10.7	3.9	1.9	767	825	360	436	41,551	**1.9**	—	—	—	—	1,375	600	727	69,252	**600**
	Low MW PAHs	mg/kg	6,592	12,623	2,316	38,362	25,369	19,170	74,597	36,343	**2,316**	67,600	128,679	23,165	383,617	130,652	97,560	372,987	181,716	**23,165**
	High MW PAHs	mg/kg	39.5	72.4	46.3	767.2	29.1	39	699	341	**29.1**	—	—	—	—	157	209	3,491	1,701	**157**
	TPH – Diesel	mg/kg	105,086	199,535	35,638	590,179	407,144	301,205	1,137,154	554,013	**35,638**	1,050,862	1,995,354	356,382	5,901,794	610,716	451,807	1,705,732	831,020	**356,382**
	TPH – Kerosene	mg/kg	105,086	199,535	35,638	590,179	407,144	301,205	1,137,154	554,013	**35,638**	1,050,862	1,995,354	356,382	5,901,794	610,716	451,807	1,705,732	831,020	**356,382**
Semivolatile Organics	Normal paraffin hydrocarbons	mg/kg	170,870	324,445	57,948	959,632	407,144	301,205	1,137,154	554,013	**57,948**	—	—	—	—	610,716	451,807	1,705,732	831,020	**451,807**
	Phenol	mg/kg	—	—	—	—	4,886	526	504	5,919	**504**	—	—	—	—	14,657	1,578	1,511	17,756	**1,511**
	2-methylphenol (o-cresol)	mg/kg	—	—	—	—	127,436	10,038	9,293	134,503	**9,293**	—	—	—	—	—	—	—	—	**—**
	4-methylphenol (p-cresol)	mg/kg	—	—	—	—	127,436	10,102	9,358	136,361	**9,358**	—	—	—	—	—	—	—	—	**—**
	2,4-dinitrotoluene	mg/kg	0.29	0.30	0.20	7.2	13.8	13.5	35.6	286	**0.20**	38.1	39.2	26.4	932	28.8	28.1	74.4	597	**26.4**
	Bis[2-ethylhexyl] phthalate[a]	mg/kg	111	0.35	0.14	263	1,733	5.4	4.6	3,599	**0.14**	—	—	—	—	17,332	53.5	45.4	35,994	**45.4**
	Total PCBs[b]	mg/kg	10.0	0.65	0.33	25.1	2.9	0.3	0.27	8	**0.27**	100	3.6	1.8	251	29.2	1.6	1.5	84.7	**1.5**
	Aroclor 1016[b]	mg/kg	6.5	0.64	0.33	21.8	35.2	2.8	2.5	150	**0.33**	64	3.6	1.8	218	88	5.3	4.9	377	**1.8**
	Aroclor 1221[b]	mg/kg	2.7	0.61	0.33	24.0	0.69	0.25	0.27	8	**0.25**	27	3.4	1.8	240	6.9	1.5	1.5	81.5	**1.5**
	Aroclor 1232[b]	mg/kg	2.2	0.59	0.33	26.2	0.55	0.24	0.27	9	**0.24**	22	3.4	1.8	262	5.5	1.4	1.5	88.1	**1.4**
	Aroclor 1242[b]	mg/kg	10.4	0.65	0.33	25.6	3.09	0.3	0.27	9	**0.27**	104	3.6	1.8	256	30.9	1.6	1.5	87.4	**1.5**
	Aroclor 1248[b]	mg/kg	9.4	0.65	0.33	24.3	0.35	0.06	0.06	1	**0.06**	94	3.6	1.8	243	3.5	0.4	0.3	10.6	**0.3**
	Aroclor 1254	mg/kg	11.5	0.65	0.33	27.3	3.5	0.3	0.27	9	**0.27**	115	3.6	1.8	273	34.8	1.6	1.5	91.1	**1.5**
	Aroclor 1260[b]	mg/kg	20.4	0.66	0.33	51.5	7.7	0.3	0.27	15	**0.27**	204	3.6	1.8	515	76.7	1.6	1.5	154	**1.5**
	Aroclor-1262[b]	mg/kg	37.8	71.8	12.8	212	27.7	20.5	77.3	38	**12.8**	378	718	128	2,125	277	205	773	377	**128**

Table 7-3. Wildlife (Birds and Mammals) Tier 1 SSLs for Nonradionuclides

Group	Soil Constituent	Units	NOAEL-Based Site-Specific SSLs									LOAEL-Based Site-Specific SSLs								
			California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	NOAEL Lowest	California Quail	Meadowlark	Killdeer	Red-Tailed Hawk	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	LOAEL Lowest
Pesticides	Aldrin	mg/kg	0.45	0.08	0.03	1.06	10.2	2.0	2.0	26.8	**0.03**	2.2	0.4	0.16	5.3	51.1	9.9	9.8	134	**0.16**
	beta-1,2,3,4,5,6-Hexachlorocyclohexane	mg/kg	4.1	3.7	2.7	112	1.9	1.7	4.0	67	**1.7**	6.2	5.5	4.1	168	9.4	8.7	19.9	335	**4.1**
	alpha-Chlordane	mg/kg	122	24	10	302	92.5	20.5	20.7	264	**10.1**	608	121	50.4	1,508	925	205	207	2,641	**50.4**
	gamma-Chlordane	mg/kg	122	24	10	302	92.5	20.4	20.6	264	**10**	608	121	50.2	1,508	925	204	206	2,641	**50.2**
	Dichlorodiphenyldichloroethylene	mg/kg	30.4	0.21	0.07	0.06	20.5	0.11	0.09	0.03	**0.03**	300	2.3	0.8	1.7	136	0.71	0.6	0.40	**0.40**
	Dichlorodiphenyltrichloroethane	mg/kg	30.4	0.30	0.10	2.5	20.5	0.16	0.14	1	**0.10**	300	3.5	1.2	46.3	136	1.1	0.9	12.68	**0.88**
	Dieldrin	mg/kg	1.9	0.06	0.02	1.6	0.28	0.01	0.01	0.35	**0.01**	6.1	0.2	0.08	5.2	0.57	0.02	0.02	0.69	**0.02**
	Endosulfan I	mg/kg	93.4	66.3	41.4	1,671	0.92	0.71	1.3	22	**0.71**	—	—	—	—	—	—	—	—	**—**
	Endosulfan II	mg/kg	93.4	66.3	41.4	1,671	0.92	0.71	1.3	22	**0.71**	—	—	—	—	—	—	—	—	**—**
	Endosulfan sulfate	mg/kg	62.9	55.4	41.4	2,160	0.61	0.56	1.3	27	**0.56**	—	—	—	—	—	—	—	—	**—**
	Endrin aldehyde	mg/kg	2.6	0.52	0.23	52.9	0.51	0.14	0.14	14	**0.14**	—	—	—	—	5.1	1.4	1.4	140	**1.4**
	Methoxychlor	mg/kg	—	—	—	—	59.8	11.2	10.9	441	**10.9**	—	—	—	—	120	22.4	21.84	882	**21.8**

Note: Shaded cells represent the lowest chemical specific NOAEL-based and LOAEL-based SSLs.

a. Values for diethyl phthalate and di-n-butyl phthalate were used as a surrogate for bis(2-ethylhexyl) phthalate.

b. Aroclor-1254 TRV was used as surrogate in the calculation of the SSL.

— = value not available
LOAEL = lowest observed adverse effects level
MW = molecular weight
NOAEL = no observed adverse effects level
PAH = polycyclic aromatic hydrocarbon
SSL = soil screening level
TPH = total petroleum hydrocarbon
TRV = toxicological reference value

7.4 Screening-Level Risk Characterization for Upland Habitats

The outcome of this step is a list of COPCs for each waste site-chemical-receptor combination evaluated. Risks at the 100-K Source OUs waste sites were estimated using the HQ method as follows:

$$HQ = EPC/SSL$$

where:

HQ = ecological hazard quotient (unitless)

EPC = soil concentration (µg/kg for nonradionuclides and pCi/g for radionuclides)

SSL = plant/invertebrate or wildlife soil screening level (µg/kg for nonradionuclides and pCi/g for radionuclides)

HQ values <1.0 indicate that adverse effects associated with exposure to a given analyte are unlikely (ERAGS [EPA 540-R-97-006]). These analytes were not considered to present a significant risk and were excluded from further evaluation. An HQ greater than or equal to 1.0 indicates data are insufficient to exclude the potential for risk, but does not indicate that risks are present; therefore, these COPCs were carried forward for further evaluation by comparing the EPCs to the background values found in Table 7-4. The details of the comparison are in Appendix H, Table H-8 and are summarized in Table 7-5 and Section 7.4.2.

Table 7-4. Soil Background Values for Radionuclides and Inorganic Chemicals used in Screening Risk Characterization

Group	Soil Constituent	Units	Background Soil Concentrations [a]
Radionuclides	Cesium 137	pCi/g	1.05
	Cobalt-60	pCi/g	0.0084
	Europium-154	pCi/g	0.033
	Europium-155	pCi/g	0.054
	Plutonium-238	pCi/g	0.0038
	Plutonium-239/240	pCi/g	0.025
	Radium-226	pCi/g	0.82
	Strontium 90	pCi/g	0.18
	Thorium-232	pCi/g	1.32
	Uranium-234	pCi/g	1.1
	Uranium-235	pCi/g	0.11
	Uranium-238	pCi/g	1.06
Metals	Aluminum	mg/kg	11800
	Antimony	mg/kg	0.13
	Arsenic (Total All Valence States) [b]	mg/kg	6.47
	Barium	mg/kg	132
	Beryllium	mg/kg	1.51

Table 7-4. Soil Background Values for Radionuclides and Inorganic Chemicals used in Screening Risk Characterization

Group	Soil Constituent	Units	Background Soil Concentrations [a]
Metals (con't)	Boron	mg/kg	3.89
	Cadmium	mg/kg	0.56
	Chromium (Total) [c,d]	mg/kg	18.5
	Cobalt	mg/kg	15.7
	Copper	mg/kg	22
	Lead	mg/kg	10.2
	Lithium [d]	mg/kg	13.3
	Manganese [d]	mg/kg	512
	Mercury	mg/kg	0.013
	Molybdenum	mg/kg	0.47
	Nickel	mg/kg	19.1
	Selenium	mg/kg	0.78
	Silver	mg/kg	0.17
	Thallium	mg/kg	0.19
	Uranium	mg/kg	3.21
	Vanadium	mg/kg	85.1
	Zinc[d]	mg/kg	67.8
General	Ammonia/Ammonium	mg/kg	9.23
Inorganics	Chloride	mg/kg	100
	Fluoride	mg/kg	2.81
	Nitrate/Nitrite	mg/kg	52
	Phosphate	mg/kg	0.79
	Sulfate/Sulfite	mg/kg	237

Sources: ECF-HANFORD-11-0038, *Soil Background for Interim Use at the Hanford Site*.

Ecology, 2013, "Issues Associated with Establishing Soil Cleanup Levels for Arsenic."

a. Background soil concentrations are selected according to the following hierarchy: the 90th percentile of Hanford Site background; Washington state-wide background. See the text for further discussion of sources.

b. Ecology, 2013, indicates that the Method A soil cleanup level of 20 mg/kg can be used to define natural background levels when developing soil cleanup levels for the Hanford Site.

c. When chromium (total) is not available, the lower of either Cr(III) or Cr(IV) as available was used as a surrogate.

d. Model Toxics Control Act (MTCA) plant and soil biota benchmarks were replaced by Washington state natural background concentrations.

— = value not available

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-102_Shallow_1	Boron (2.1)	--
	Chromium (20)	--
	Manganese (1.8)	--
	Mercury (50)	Mercury (2.7)
	Selenium (3.3)	--
	Vanadium (40)	Vanadium (2.6)
	Zinc (2.4)	Zinc (1.7)
100-K-102_Shallow_2	Boron (2.2)	--
	Chromium (15)	--
	Manganese (1.5)	--
	Mercury (12)	--
	Vanadium (23)	Vanadium (1.5)
100-K-102_Shallow_Focused	Boron (3.0)	--
	Chromium (27)	--
	Cobalt (1.1)	--
	Manganese (3.0)	--
	Selenium (1.3)	--
	Vanadium (43)	Vanadium (2.8)
	Zinc (1.6)	Zinc (1.2)
100-K-109_Shallow	Boron (1.8)	--
	Chromium (14)	--
	Manganese (1.5)	--
	Selenium (2.0)	--
	Vanadium (28)	Vanadium (1.9)
100-K-109_Shallow_Focused	Chromium (19)	--
	Manganese (1.6)	--
	Selenium (3.7)	Selenium (1.0)
	Vanadium (37)	Vanadium (2.4)
	Zinc (1.1)	--

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-110_Shallow	Chromium (18)	--
	Manganese (1.9)	--
	Mercury (4.3)	--
	Selenium (3.5)	Selenium (1.0)
	Vanadium (41)	Vanadium (2.7)
	Zinc (1.5)	Zinc (1.1)
100-K-110_Shallow_focused	--	Cadmium (1.2)
	Chromium (21)	--
	Mercury (1.1)	--
100-K-14, 126-KE-2_Shallow	Boron (21)	--
	Chromium (23)	--
	Manganese (1.8)	--
	Mercury (4.9)	--
	Selenium (2.2)	--
	Vanadium (49)	Vanadium (3.2)
	Zinc (1.1)	--
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5N	Boron (2.1)	--
	Chromium (15)	--
	Manganese (1.8)	--
	Selenium (4.5)	Selenium (1.2)
	Vanadium (42)	Vanadium (2.7)
	Zinc (1.1)	--
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5S	Boron (3.9)	--
	Chromium (15)	--
	Manganese (2.1)	--
	Mercury (2.4)	--
	Selenium (4.6)	Selenium (1.3)
	Vanadium (47)	Vanadium (3.1)
	Zinc (1.1)	--

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow	Boron (3.4)	--
	Chromium (22)	--
	Manganese (1.9)	--
	Selenium (2.0)	--
	Vanadium (43)	Vanadium (2.8)
	Zinc (1.2)	--
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow_Focused	Chromium (24)	--
	Manganese (1.3)	--
	Mercury (2.9)	--
	Selenium (3.3)	--
	Vanadium (41)	Vanadium (2.7)
	Zinc (1.1)	--
100-K-29_Shallow_Focused	Chromium (61)	--
	Lead (1.3)	Lead (1.8)
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P16	Boron (5.9)	--
	Chromium (21)	--
	--	Lead (1.2)
	Manganese (1.3)	--
	Vanadium (12)	--
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P17	Boron (3.2)	--
	Chromium (19)	--
	Manganese (1.4)	--
	Vanadium (17)	Vanadium (1.1)
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P18	Chromium (11)	--
	Manganese (1.3)	--
	Vanadium (15)	Vanadium (1.0)
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P19	Boron (1.6)	--
	Chromium (21)	--
	Manganese (1.5)	--
	Vanadium (17)	Vanadium (1.2)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-3, 100-K-36, 100-K-79:7_Shallow_Focused_P20	Boron (10)	--
	Chromium (16)	--
	Manganese (1.4)	--
	Vanadium (19)	Vanadium (1.2)
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_2	Chromium (11)	--
	Lithium (2.3)	--
	Manganese (1.7)	--
	Selenium (3.5)	--
	Vanadium (30)	Vanadium (1.9)
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_3	Chromium (16)	--
	Lithium (2.7)	--
	Manganese (1.4)	--
	Selenium (3.1)	--
	Vanadium (26)	Vanadium (1.7)
	Zinc (1.0)	--
100-K-30_Shallow_Focused	Chromium (38)	--
	--	Lead (1.0)
	Mercury (175)	Mercury (9.4)
100-K-31_Shallow_Focused	Chromium (25)	--
	--	Lead (1.2)
	Mercury (52)	Mercury (2.8)
100-K-32_Shallow_Focused	Chromium (42)	--
	--	Lead (1.2)
	Mercury (137)	Mercury (7.3)
100-K-33_Shallow_Focused	Chromium (57)	--
	Mercury (68)	Mercury (3.6)
100-K-34, 100-K-102, 1607-K3_Overburden_11A	Boron (2.5)	--
	Chromium (18)	--
	Manganese (1.6)	--
	Mercury (1.2)	--
	Vanadium (23)	Vanadium (1.5)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-34, 100-K-102, 1607-K3_Shallow	Boron (3.5)	--
	Chromium (27)	--
	Manganese (1.7)	--
	Mercury (1.9)	--
	Selenium (1.5)	--
	Vanadium (36)	Vanadium (2.4)
	Zinc (1.2)	--
100-K-34, 100-K-102, 1607-K3_Shallow_Focused	Antimony (1.5)	Antimony (1.3)
	Arsenic (1.5)	--
	Chromium (34)	--
	Lead (1.0)	Lead (1.4)
	Manganese (1.9)	--
	Mercury (1.0)	--
	Selenium (4.2)	Selenium (1.2)
	Vanadium (44)	Vanadium (2.9)
	Zinc (2.2)	Zinc (1.7)
100-K-34_Shallow	Chromium (12)	--
	Manganese (1.9)	--
	Selenium (1.8)	--
	Vanadium (47)	Vanadium (3.0)
	Zinc (1.1)	--
100-K-4_Shallow	Boron (33)	--
	Chromium (25)	--
	Lithium (5.1)	--
	Manganese (1.4)	--
	Selenium (2.9)	--
	Vanadium (28)	Vanadium (1.8)
	Zinc (1.1)	--

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-50, 1607-K2_Shallow	Boron (18)	--
	Chromium (29)	--
	Manganese (1.8)	--
	Mercury (1.3)	--
	Selenium (1.9)	--
	Vanadium (40)	Vanadium (2.6)
	Zinc (1.1)	--
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Overburden	Boron (16)	--
	Chromium (17)	--
	Lithium (2.8)	--
	Manganese (1.6)	--
	Selenium (3.5)	Selenium (1.0)
	Vanadium (29)	Vanadium (1.9)
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	Boron (3.9)	--
	--	Carbon-14 (2.1)
	Chromium (17)	--
	Lithium (3.3)	--
	Manganese (1.4)	--
	--	Rads SOF (2.1)
	Vanadium (20)	Vanadium (1.3)
100-K-6_Shallow	--	Carbon-14 (1.1)
	Chromium (13)	--
	Lithium (3.7)	--
	Manganese (1.3)	--
	--	Rads SOF (1.1)
	Vanadium (21)	Vanadium (1.4)
100-K-63_Shallow_1	Boron (5.9)	--
	Chromium (27)	--
	Manganese (1.7)	--
	Selenium (2.5)	--
	Vanadium (27)	Vanadium (1.8)
	Zinc (1.2)	--

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-63_Shallow_2	Boron (4.0)	--
	Chromium (43)	--
	Manganese (1.5)	--
	Selenium (1.7)	--
	Vanadium (23)	Vanadium (1.5)
	Zinc (1.4)	Zinc (1.0)
100-K-77_Shallow	Chromium (40)	--
	Lithium (6.1)	--
	Manganese (2.0)	--
	Selenium (1.8)	--
	Vanadium (35)	Vanadium (2.3)
	Zinc (1.2)	--
100-K-78_Shallow_Focused	Boron (3.1)	--
	Chromium (75)	--
	Manganese (1.3)	--
	Vanadium (21)	Vanadium (1.4)
100-K-84_Shallow	Boron (2.7)	--
	Chromium (23)	--
	Manganese (1.5)	--
	Mercury (4.9)	--
	Vanadium (29)	Vanadium (1.9)
	Zinc (1.0)	--
100-K-88_Shallow_Focused	Boron (19)	--
	Chromium (38)	--
	Manganese (1.2)	--
	Selenium (2.3)	--
	Vanadium (16)	Vanadium (1.1)
	Zinc (1.0)	--
100-K-89, 600-29_Shallow	Boron (4.2)	--
	Chromium (30)	--
	Manganese (1.9)	--
	Selenium (1.7)	--
	Vanadium (30)	Vanadium (1.9)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-89, 600-29_Shallow_Focused	Arsenic (1.5)	--
	Boron (5.0)	--
	Chromium (30)	--
	Manganese (1.9)	--
	Selenium (1.7)	--
	Vanadium (28)	Vanadium (1.9)
	Zinc (2.5)	Zinc (1.8)
100-K-91_Shallow_Focused	Boron (4.0)	--
	Chromium (24)	--
	Manganese (1.3)	--
	Mercury (27)	Mercury (1.5)
	Vanadium (18)	Vanadium (1.2)
	Zinc (2.3)	Zinc (1.7)
116-KE-5_Shallow_Focused	Chromium (75)	--
	Mercury (1.0)	--
116-KW-4_Shallow_Focused	Chromium (30)	--
118-K-1_P1_Shallow_2	Boron (5.2)	--
	Chromium (32)	--
	Manganese (1.8)	--
	Vanadium (36)	Vanadium (2.3)
	Zinc (1.5)	Zinc (1.1)
118-K-1_P1_Shallow_3	Boron (2.9)	--
	Chromium (27)	--
	Manganese (1.8)	--
	Vanadium (45)	Vanadium (2.9)
	Zinc (1.2)	--
118-K-1_P2_Shallow_11G	Boron (2.7)	--
	Chromium (20)	--
	Manganese (1.7)	--
	Vanadium (42)	Vanadium (2.7)
	Zinc (1.1)	--

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
118-K-1_P2_Shallow_7	Antimony (3.3)	Antimony (2.7)
	Boron (3.7)	--
	Chromium (25)	--
	Manganese (2.0)	--
	Mercury (1.3)	--
	Vanadium (39)	Vanadium (2.5)
	Zinc (1.5)	Zinc (1.1)
118-K-1_P2_Shallow_Focused_3	Boron (1.7)	--
	Chromium (43)	--
	Manganese (2.1)	--
	Vanadium (49)	Vanadium (3.2)
	Zinc (1.1)	--
118-K-1_P2_Shallow_Focused_6	Boron (2.8)	--
	Chromium (50)	--
	Manganese (1.4)	--
	Vanadium (22)	Vanadium (1.4)
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Overburden_7	Boron (5.3)	--
	Chromium (20)	--
	Manganese (1.8)	--
	Selenium (2.0)	--
	Vanadium (41)	Vanadium (2.6)
	Zinc (1.0)	--
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow	Boron (2.6)	--
	Chromium (18)	--
	Manganese (1.8)	--
	Selenium (2.2)	--
	Vanadium (41)	Vanadium (2.6)
	Zinc (1.1)	--

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow_Focused	Boron (10)	--
	Chromium (16)	--
	Manganese (1.4)	--
	Selenium (3.9)	Selenium (1.1)
	Vanadium (46)	Vanadium (3.0)
	Zinc (1.3)	--
128-K-1_Shallow_Focused	Chromium (33)	--
	Selenium (1.5)	--
128-K-2_Shallow	Boron (3.9)	--
	Chromium (27)	--
	Manganese (1.5)	--
	Selenium (1.9)	--
	Vanadium (24)	Vanadium (1.6)
128-K-2_Shallow_Focused	Boron (6.6)	--
	Chromium (36)	--
	Copper (1.5)	--
	Manganese (1.5)	--
	Mercury (1.0)	--
	Selenium (2.1)	--
	Total petroleum hydrocarbons - diesel range (2.8)	--
	Vanadium (22)	Vanadium (1.5)
	Zinc (1.8)	Zinc (1.3)
1607-K3_Shallow	Boron (3.3)	--
	Chromium (55)	--
	Manganese (2.0)	--
	Selenium (1.7)	--
	Vanadium (37)	Vanadium (2.4)
	Zinc (1.4)	Zinc (1.0)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
600-29_Shallow	Arsenic (1.0)	--
	Boron (3.5)	--
	Chromium (29)	--
	Manganese (1.6)	--
	Nickel (1.3)	Nickel (1.2)
	Selenium (1.9)	--
	Vanadium (34)	Vanadium (2.2)
	Zinc (1.1)	--
600-29_Shallow_Focused	Boron (4.0)	--
	Chromium (31)	--
	Manganese (1.6)	--
	Selenium (1.8)	--
	Vanadium (28)	Vanadium (1.8)
	Zinc (1.4)	Zinc (1.0)
100-K-111_East_Rip_Surface_Focused	Arsenic (1.9)	--
	Boron (2.4)	--
	Chromium (332.5)	Chromium (3.5)
	Manganese (2.8)	--
	Vanadium (28.4)	Vanadium (1.8)
	Zinc (1.8)	Zinc (1.3)
100-K-111_East_Subsurface	Boron (2.1)	--
	Chromium (67.4)	--
	Manganese (1.2)	--
	Vanadium (18.5)	Vanadium (1.2)
	Zinc (1.4)	Zinc (1.1)
100-K-111_East_Surface	Boron (2.7)	--
	Chromium (73.6)	--
	Manganese (1.1)	--
	Vanadium (17.4)	Vanadium (1.1)
	Zinc (2.5)	Zinc (1.9)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-111_West_Rip_Subsurface_Focused	Chromium (75.8)	Cadmium (1.1)
	Lead (1.4)	Lead (2.0)
	Vanadium (15.9)	Vanadium (1.0)
	Zinc (8.3)	Zinc (6.1)
100-K-111_West_Rip_Surface_Focused	Boron (3.4)	--
	Chromium (58.5)	--
	Lead (1.1)	Cadmium (1.8)
	Manganese (1.2)	Lead (1.5)
	Vanadium (21.0)	Vanadium (1.3)
	Zinc (5.5)	Zinc (4.0)
100-K-111_West_Subsurface	Boron (3.2)	--
	Chromium (48.8)	--
	Manganese (1.6)	--
	Vanadium (20.9)	Vanadium (1.3)
100-K-111_West_Subsurface_Focused_2	Boron (3.2)	--
	Chromium (206.5)	Chromium (2.2)
	Manganese (1.4)	--
	Vanadium (17.6)	Vanadium (1.1)
	Zinc (1.0)	--
100-K-111_West_Surface	Boron (3.5)	--
	Chromium (324.4)	--
	Manganese (2.1)	Chromium (3.4)
	Vanadium (23.4)	Vanadium (1.5)
	Zinc (2.3)	Zinc (1.7)
100-K-111_West_Surface_Focused_1	Boron (3.2)	--
	Chromium (40.3)	--
	Vanadium (15.4)	--
	Zinc (2.6)	Zinc (1.9)
100-K-111_West_Surface_Focused_2	Boron (3.2)	--
	Chromium (196.0)	Chromium (2.1)
	Manganese (1.4)	--
	Vanadium (17.8)	Vanadium (1.1)
	Zinc (1.4)	Zinc (1.0)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-111_West_Surface_Focused_3	Boron (4.4)	--
	Chromium (65.5)	--
	Manganese (1.3)	--
	Vanadium (22.6)	Vanadium (1.4)
	Zinc (1.4)	Zinc (1.0)
100-K-57_Focused_Subsurface	Boron (3.0)	--
	Chromium (46.8)	--
	Manganese (1.4)	--
	Vanadium (20.2)	Vanadium (1.3)
100-K-57_Focused_Surface	Boron (3.4)	--
	Chromium (68.5)	--
	Manganese (1.4)	--
	Vanadium (21.6)	Vanadium (1.4)
100-K-57_Rip_Surface_Focused	Chromium (88.8)	--
	Manganese (1.0)	--
	Vanadium (16.7)	Vanadium (1.1)
	Zinc (3.8)	Zinc (2.8)
100-K-64_Focused_Subsurface	Boron (2.4)	--
	Chromium (83.5)	--
	Manganese (1.8)	--
	Vanadium (29.6)	Vanadium (1.9)
	Zinc (1.1)	--
100-K-64_Focused_Surface	Boron (4.6)	--
	Chromium (220.3)	Chromium (2.3)
	Manganese (2.6)	--
	Mercury (1.5)	--
	Vanadium (28.9)	Vanadium (1.9)
	Zinc (1.3)	--
100-K-64_Subsurface	Boron (2.7)	--
	Chromium (55.7)	--
	Manganese (1.6)	--
	Vanadium (18.9)	Vanadium (1.2)
	Zinc (1.8)	Zinc (1.3)

Table 7-5. Summary of 100-K Upland Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soil (0 to 4.6 m [0 to 15 ft])

Waste Site/Decision Unit	Exceedances Based on Comparisons to SSLs and Background*	
	Plant/Invertebrate SSL-Based HQ	Wildlife SSL-Based HQ
100-K-64_Surface	Boron (3.9)	--
	Chromium (58.5)	--
	Manganese (1.3)	--
	Vanadium (20.5)	Vanadium (1.3)
	Zinc (2.1)	Zinc (1.6)
100-K-83_Focused_Subsurface	Boron (3.2)	--
	Chromium (56.8)	--
	Manganese (1.5)	--
	Vanadium (22.1)	Vanadium (1.4)
	Zinc (1.1)	--
100-K-83_Rip_Surface_Focused	Boron (2.4)	--
	Chromium (85.5)	Cadmium (1.0)
	Manganese (1.5)	--
	Vanadium (18.2)	Vanadium (1.2)
	Zinc (4.8)	Zinc (3.5)

*Analytes with exposure point concentrations consistent with background are excluded in these results.

-- = not applicable

HQ = hazard quotient

SSL = soil screening level

7.4.1 Screening Risk Characterization for Radionuclides and Aroclors

Because the dose from radionuclides is additive, the total contributions of radionuclides were calculated using the SOF approach. With the SOF method, contributions were considered significant if the EPC was greater than the SSL. The SOF equation is as follows:

$$\text{HI or SOF} = \sum_{j=1}^{n} \text{Exposure}_j/\text{SSL}_j$$

where:

HI = hazard index (Aroclors)

SOF = sum of fractions (radionuclides)

Exposure_j = exposure concentration for radionuclides

SSL_j = soil screening level for radionuclides

For this assessment, the HQs for each radionuclide were summed within each decision unit to equal an SOF. If the SOF was >1, then individual detected radionuclide isotope COPCs were carried forward to the background evaluation. For those COPCs that exceeded one or more SSLs, the EPC was then compared to the background value and summarized in the subsequent table (Appendix H, Table H-8), in Section 7.4.2.

Similarly, for Aroclors, the HIs were calculated to evaluate additive effects. If the HI for Aroclors was >1, then the detected Aroclors were identified for further evaluation. This approach of summing Aroclors to generate a total Aroclor HI is conservative because the measurement of Aroclors as mixtures of PCB congeners does produce some overlap of congeners in multiple Aroclor mixtures. While potential duplication could occur depending on which mixtures are detected, at most sites only one or two Aroclor mixtures are detected and tend to dominate. Also, if an HI >1 is carried forward for further evaluation, and it is ultimately concluded that there is no unacceptable risk, there is greater confidence in the conclusion due to the additional conservatism in the use of the total Aroclor HI versus individual Aroclors.

7.4.2 Screening Risk Characterization Relative to Background

Background concentrations for inorganic analytes in soil at the Hanford Site are described in the Non-Rad Soil Background document (DOE/RL-92-24). That document provides the 90th percentile background concentrations for several inorganic analytes. For selected inorganic analytes not included in the Non-Rad Soil Background document (DOE/RL-92-24), the 90th percentile concentration has been obtained from PNNL, as summarized in ECF-HANFORD-11-0038, and from the 100 Area RDR/RAWP (DOE/RL-96-17) for uranium. Background concentrations for radiological analytes in soil at the Hanford Site are described in Rad Soil Background document (DOE/RL-96-12), which provides the 90th percentile concentration of background concentrations for several radiological analytes. Background concentrations were not identified for organic chemicals; therefore, all organic chemicals, with HQs greater than or equal to 1.0 were carried forward. COPC EPCs that were less than the 90th percentile background concentration were excluded from further evaluation. COPCs with EPCs that were above the 90th percentile background concentration were carried forward to the baseline risk assessment (refinement) (Section 7.5).

7.4.3 Screening Risk Characterization Results

The comparisons of plant/invertebrate and wildlife SSLs and the calculated HQ values are provided in Appendix H, Table H-7 for the 100-K upland area. A detailed description of the results of the screening evaluation (i.e., comparison of EPCs with SSLs) of metals, PAHs, PCBs (as Aroclors), and other organics detected in soil is provided below and a summary of exceedances is provided in Table 7-5. COPCs with HQs equal to or greater than 1.0 were carried forward for further evaluation. COPCs for which appropriate toxicity data were unavailable were not evaluated further, but were retained as uncertainties. The SSLs and background were not available for nickel-63 (radionuclide) or 14 additional analytes. These COPCs were retained as an uncertainty and are further discussed in the baseline risk assessment described in Section 7.5.4.

The 100-K Area includes 55 upland waste sites that were evaluated in this ERA. Plant/invertebrate and avian/mammalian SSL HQs for the sites are provided in Appendix H, Table H-7. The SSL-based HQs were <1.0 for all COPCs in all of the decision units evaluated at 6 of the 55 waste sites. The 6 waste sites that did not require further evaluation of ecological risk include the following:

- 100-K-55:1
- 100-K-56:1
- 100-K-95
- 116-K-2
- 116-KE-4
- 116-KW-3

Within the 49 remaining waste sites, the EPCs of analytes exceeded the plant/invertebrate SSLs at each waste site, and some analyte concentrations exceeded the wildlife SSLs. These waste site decision units were carried forward into the background evaluation. The screening evaluation also identified the following:

- Aroclor HIs were <1.0 for all waste sites and all Aroclors were eliminated from further evaluation
- EPCs for the inorganic analytes antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, lithium, manganese, mercury, nickel, selenium, vanadium, and zinc exceeded one or more of the nonradionuclide SSLs
- The TPH – diesel range EPC exceeded the SSL

Table H-7 in Appendix H summarizes the 137 waste site/decision unit combinations where the EPC exceeded the SSL. Radionuclide SOFs were >1 at two waste sites (100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1 and 100-K-6_Shallow). These exceedances were based on the individual radionuclide, carbon-14, in exceedance of the Wildlife SSL (lowest Tier 1 Hanford-specific species values). Within the 49 waste sites, EPCs of analytes exceeded the plant/invertebrate SSLs at each waste site, while fewer analytes exceeded the wildlife SSLs. These waste site decision units were carried forward into the background evaluation.

7.4.4 Screening Risk Characterization - Results of Background Characterization

Although in exceedance of an SSL, the EPCs for many of the COPCs within the 49 remaining waste sites were below the 90th percentile or statewide background concentrations, so they were eliminated from further evaluation. The comparisons of COPC EPCs to the 90th percentile and statewide background for the remaining 49 waste sites are provided in Appendix H, Table H-8. At 13 of the remaining 49 waste sites, the COPCs did not exceed the 90th percentile or statewide background concentrations in all of the decision units evaluated. The 13 waste sites that did not require further evaluation of ecological risks are listed below:

- 100-K Area Sites: 100-K-105, 100-K-106, 100-K-3, 100-K-36, 100-K-53, 100-K-62, 100-K-85, 100-K-86, 100-K-90, 100-K-92
- 116-K Area Sites: 116-K-1, 116-KW-4
- 132-K Area Sites: 132-KE-1

Within the remaining 36 waste sites, 67 decision units had COPC EPCs in exceedance of both an SSL and background. COPC EPCs detected in exceedance of both SSL and background were carried forward to

the baseline risk assessment. The inorganic analytes antimony, arsenic, boron, cadmium, chromium, copper, lead, lithium, manganese, mercury, nickel, selenium, vanadium, and zinc were detected outside of the range of background. The radionuclide, carbon-14, and the organic TPH – diesel do not have background values, but exceeded SSLs and were carried into the baseline risk assessment evaluation because of SSL exceedances. A summary of SSL and background evaluation results for the 36 waste sites that moved forward to the baseline risk assessment is provided in Table 7-5.

7.5 Baseline Assessment of Risk in Upland Habitats

COPECs that were identified at waste sites as exceeding SSLs or background were further evaluated by comparing their EPCs to refined risk-based values (PRGs) by calculating an HQ. The outcome of this refinement step is a list of COPECs for each waste site-chemical receptor combination evaluated. Refined (baseline) risks at the 100-K upland area waste sites were estimated using the HQ method as follows:

$$HQ = EPC/PRG$$

where:

HQ = ecological hazard quotient (unitless)

EPC = soil concentration (mg/kg for nonradionuclides and pCi/g for radionuclides)

PRG = plant/invertebrate or wildlife soil preliminary remediation goal (mg/kg for nonradionuclides and pCi/g for radionuclides)

HQ values <1.0 indicate that adverse effects associated with exposure to a given analyte are unlikely (ERAGS [EPA 540-R-97-006]). These analytes were considered to present a negligible risk and were excluded from further evaluation. An HQ greater than or equal to 1.0 indicates data are insufficient to exclude the potential for risk, but does not indicate that risks are actually present; therefore, these COPECs were carried forward for further evaluation in the SMDP in Section 7.6. In the refined evaluation, the soil EPC for each waste site and decision unit (as applicable) was compared to the plant and invertebrate PRGs, and PRGs for all eight wildlife receptors. The HQs for these comparisons are provided in Appendix H, Tables H-9 and H-10.

7.5.1 Effects and Exposure Assessment Refinement Methods

The additional evaluation completed with a comparison to PRGs (developed for metals) helps identify which COPEC-receptor-waste site combinations should be brought forward to the SMDP in Section 7.6. In general, second tier risk-based values were used in this assessment (PRGs) and documented for wildlife in CHPRC-01311 and for plants/invertebrates in ECF-HANFORD-11-0158.

The effect assessment refinements were completed for the plant and invertebrate communities and included site-specific ambient media toxicity tests (plants and invertebrates). Site-specific ex situ bioassays on plants and invertebrates representing Hanford Site species were conducted to develop these PRGs for nonradiological COPECs. No measures of effects were refined for the wildlife (bird, mammal) PRGs (i.e., the same single chemical NOAEL and LOAEL TRVs used in SSL development, presented in Section 7.3.1, were also used in the PRG development).

Exposure assessment refinements introduced more Hanford Site-specific components into the exposure estimates for birds and mammals. The general form of the model used to estimate exposure of birds and mammals to chemicals in environmental media (Suter et al., 2000) is presented in Section 7.3.2.

One difference in exposure parameters within the refined models used to develop the nonradiological PRGs was the incorporation of biota tissue data for metals collected from species located at the

Hanford Site. The tissue data collected at the Hanford Site were not sufficiently robust to be used in isolation. Combining these data with the tissue data from across North America (as used in the SSL models) broadened the distribution of data underlying exposure estimates. The inclusion of data collected at the Hanford Site also improved the relevance of the refined models and data set to application at Hanford waste sites.

Another exposure parameter refinement was made defining the diets of insectivorous/omnivorous birds/mammals, which was adjusted from the default model of earthworms to consumption of arthropods; the latter being more realistic in the arid environment of southeastern Washington.

In some cases, refinement data were not available or recommended due to data quality (e.g., organics, radionuclides, and a few inorganics). Refined risk-based values (PRGs) for wildlife were developed only for those metals listed in the wildlife PRG summary in Section 7.5.1.2. For those cases where a refined PRG was not recommended, the waste site-decision unit-chemical combination was moved forward to the SMDP (i.e., the SSL-based HQs in Table 7-5 automatically will be addressed in the SMDP).

Further discussion of key exposure refinements underlying second tier risk-based values (PRGs) follows.

7.5.1.1 Estimating Dietary Tissue Concentration for PRGs

Development of the PRGs for birds and mammals focused on the integration of available site-specific bioaccumulation data for plants, terrestrial arthropods, and small mammals with data from existing bioaccumulation models (i.e., those from OSWER Directive 9285.7-55) that were used to develop the EcoSSLs in order to develop a set of integrated dietary bioaccumulation models[10]. The following Hanford Site-specific and literature-based data sets were used to develop these bioaccumulation models[11] as presented in Appendix H, Table H-5:

- Hanford Site-specific bioaccumulation data have been collected in support of the RCBRA (DOE/RL-2007-21) and other projects at the site. Data representing tissue from terrestrial plants (foliage, shoots, and other aboveground parts of grasses, shrubs, and trees), small mammals (whole single mice or composites of multiple whole mice), and terrestrial arthropods (whole individual invertebrates or composites of multiple whole invertebrates), and collocated soil data were extracted from HEIS. Only paired samples in which the target analytes were detected in both tissue and in soil were retained for the bioaccumulation database; observations that were nondetects in either the soil or tissue of a sample pair were excluded from consideration.

- Data from previously developed and published bioaccumulation models for plants were used to augment the Hanford Site-specific data. Specifically, the plant bioaccumulation database from BJC/OR-133, *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants*, and Efroymson et al., 2004, "Ecotoxicity Test Data for Total Petroleum Hydrocarbons in Soil: Plants and

[10] These bioaccumulation models integrate both site-specific data and data from published literature sources. This combining of Hanford-specific and literature data was performed to maximize utility of the Hanford-specific data collected over comparatively narrow concentration ranges by expanding the dataset to include literature data collected across a wider concentration range.

[11] Although site specificity is diminished when Hanford data are combined with non-Hanford data from the literature in bioaccumulation models, these bioaccumulation models are defined as more site-specific and site relevant than those based solely on published literature sources because they are based on both site-specific data and data from published literature sources. This combining of Hanford Site-specific and literature data was performed to maximize utility of the Hanford Site-specific data collected over comparatively narrow concentration ranges by expanding the dataset to include literature data collected across a wider concentration range. The wider range was necessary to develop a consistent set of values that could be applied across a variety of sites for ongoing and future assessments.

Soil-Dwelling Invertebrates," was used. Electronic copies of the original databases were obtained from the authors to facilitate integration with Hanford Site-specific data. The development of the plant bioaccumulation database is described by Efroymson et al., 2001, "Uptake of Inorganic Chemicals from Soil by Plant Leaves: Regressions of Field Data," as follows:

- Field and greenhouse studies in which concentrations of arsenic, cadmium, copper, lead, mercury, nickel, selenium, or zinc in both surface soil and collocated, aboveground plant tissue were identified. Information regarding soil and plant concentrations, soil parameters, exposure time, chemical form, dry or wet weight, extraction method, plant species, and plant part was compiled in a spreadsheet. The database included the following number of observations per growth form: 525, graminoid; 544, forb/herb; 4, forb/herb or vine; 69, forb/herb or shrub; 16, shrub; 18, tree or shrub; 49, tree; and 107, unknown or composited samples. Approximately 30% of the data represented chemical concentrations in plant leaves, excluding stems, fruits and seeds; and the remaining aboveground samples included clippings, unspecified aboveground parts or shoots. Samples of fruits or seeds alone were excluded from the database. Tests in which salts (e.g., cadmium chloride, copper sulfate, and sodium selenate) were added in solution to soil were excluded because of preliminary results that suggested that regressions of concentrations in plants on concentrations in soil were different for field and salt chemical forms.

- Only studies in which concentrations were expressed on an air- or oven-dry weight basis were used. Although most studies reported that plant material was washed, studies were not excluded if the extent of washing was not stated in the paper. Studies were used even if the individual investigators observed no correlation between concentrations of contaminants in soil and plants. Data for which measured concentrations were below detection thresholds were excluded. Concentrations of chemicals in soil or plants were sometimes estimated from a figure but only if estimates could be made within about 10%. Data for plant species that are known to hyperaccumulate metals were excluded. Hyperaccumulative plants belong to distantly related families but share the ability to grow on metalliferous soil and to accumulate, without suffering phytotoxic effects, extraordinarily high amounts of heavy metals in their aerial organs; amounts far in excess of the levels found in the majority of plant species. This type of extreme uptake behavior was excluded because it is not representative of the majority of typically encountered plant species, and because doing so would have made it impossible to develop generally applicable soil-plant uptake regressions.

- Each plant species or variety, soil type, location, and concentration of the test element in soil represented an independent observation in the dataset. Differences in exposure duration or aboveground plant part did not constitute separate observations; concentrations in soil or plants that differed on the basis of one of these two variables were averaged. The number of observations in these means, which ranged between one and six, was not retained in the subsequent statistical analysis.

- Concentrations of contaminants in soil at the time of plant sampling were used if known. If these concentrations were not measured (as was often the case in pot studies), the initial concentration of the element measured in or added to soil was assumed to be equivalent to the final concentration. In field experiments, the change in soil concentration of an element over time was assumed to be minimal.

- Observations were included in the database if the total chemical concentration in soil was measured, either by extraction with strong acid or by extraction with moderately strong acid (e.g., 4 N sulfuric acid) sometimes accompanied by heat. Studies in which concentrations of

contaminants in soil were determined by a partial extraction with diethylene triamine pentaacetic acid (DTPA), weak acids, or water were excluded from analysis.

- For studies in which contaminant concentrations at multiple depths were measured, the concentration at the 0 to 10, 0 to 15, or 0 to 20 cm (0 to 4, 0 to 6, or 0 to 8 in.) depth interval was recorded. Where only a single soil depth was measured, it ranged from 5 to 70 cm (2 to 28 in.).

- Studies included contamination from the following sources: mine wastes (ores, tailings), smelter deposits, other industrial sources, vehicle and other urban emissions, wastewater effluents, composts, fertilizers, dredged materials, sewage sludges, fly ashes, flue dusts, nuclear waste, and arsenical pesticide residues. Where materials such as fertilizers were added to soil, data were excluded if mixing with soil did not occur. In addition, some measurements were taken from background locations. For example, chemical data for arsenic included the following sources: mine waste (24 observations), smelter operations (23 observations), fly ash disposal (18 observations), pesticide use (19 observations), nuclear waste (4 observations), unidentified urban sources (3 observations), background or no apparent anthropogenic source (13 observations), and unknown source (18 observations). Field studies in which a current, local atmospheric source of contaminants was present were excluded from the database.

- The small mammal bioaccumulation database from ES/ER/TM-219, *Development and Validation of Bioaccumulation Models for Small Mammals*, was also used. The development of the small mammal bioaccumulation database was described in ES/ER/TM-219 as follows:

"A literature search was performed for studies that reported chemical concentrations in co-located small mammal and soil samples. Data were restricted to only studies that reported whole body or carcass (whole body minus selected organs or other tissues) concentrations. To ensure relevancy of UFs and models to field situations, only field studies in which resident small mammals were collected were considered. All small mammal tissue burdens were therefore assumed to be at equilibrium with soil concentrations. There is some uncertainty associated with this assumption based on the heterogeneity of concentrations in surface soil. However, the potential impact of this heterogeneity on the assumption of equilibrium is expected to be minimal based on the mobility of small mammals and the evaluation of multiple individuals, which would tend to provide an average estimate of tissue concentrations over the sampled areas. To ensure comparability of data, only 'total' chemical analyses of both soil and small mammals (i.e., resulting from extractions of metals using concentrated acids) were included. Data resulting from DTPA, acetic acid, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in soil and small mammal reported for each sampling location evaluated in each study was considered an observation. If data for multiple small mammal species were reported at a site, each was considered a separate observation. Soil and small mammal data in the database were reported as mg/kg dry weight. If studies reported small mammal concentrations in terms of wet weight, dry weight concentrations were estimated assuming a 68 percent water content (EPA, 1993). Data concerning soil characteristics [e.g., soil pH, percent organic matter, cation exchange capacity, soil texture] were rarely reported and therefore do not appear in the database. Because chemical uptake was expected to vary according to small mammal diet preferences, each species was assigned to one of the three trophic groups: insectivore (diet consisting primarily of insects and other invertebrates), herbivore (diet consisting primarily of plant material), and omnivore (diet consisting of both animal and plant material). A summary of the small mammal species included in the database and the trophic groups to which they were assigned is presented in Table 1. To validate the models developed from the literature-derived data, soil and small mammal data collected as part of Comprehensive Environmental Response, Compensation, and

Liability Act (CERCLA) remedial investigations at sites in Oklahoma (ES/ER/TM-219) and Montana (LaTier et al., 1995, "Bioaccumulation of trace elements and reproductive effects in deer mice [Peromyscus maniculatus]") were acquired as a validation dataset. Small mammal species in this validation dataset, however, represented only the herbivore and omnivore trophic groups. Validation data for insectivores were unavailable."[12]

– ***Literature-Derived Bioaccumulation Data for Terrestrial Arthropods.*** Estimating exposures to insectivorous or omnivorous wildlife involved estimating bioaccumulation into soil invertebrates. Soil invertebrate bioaccumulation models used for SSLs consisted of the earthworm models from ES/ER/TM-220, *Development and Validation of Bioaccumulation Models for Earthworms*, and Sample et al., 1999, "Literature-Derived Bioaccumulation Models for Earthworms: Development and Validation." Hanford Site-specific observations (as detailed in the RCBRA [DOE/RL-2007-21] and DOE/RL-2007-50, *Central Plateau Ecological Risk Assessment Data Package Report*), indicate that earthworms are nonexistent in upland soil, and have little or no contribution to the invertebrate portion of bird and mammal diets at the Hanford Site. Rather, insects and other arthropods (e.g., beetles, ants, and spiders) are the primary prey of invertebrate-feeding birds and mammals at the site. Consequently, the data collected to address Hanford Site-specific bioaccumulation into invertebrate prey of birds and mammals focused on arthropods (DOE/RL-2007-21). Additional bioaccumulation data for terrestrial arthropods were identified and extracted from published literature to supplement the Hanford Site-specific data. This database was largely developed to support bioaccumulation modeling for the U.S. Army Adaptive Risk Assessment Modeling Systems (ARAMS[13]) and was first presented in USACHPPM, 2004, *Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)*.

A literature search was performed for studies that reported chemical concentrations in collocated biota and media samples[14]. Literature databases searched included EPA, 2016, ECOTOX Database, and the U.S. National Library of Medicine, TOXNET Toxicology Data Network.

From the range of studies reviewed, 22 were identified as containing relevant data (i.e., reported collocated soil and biota concentrations). Terrestrial invertebrate data focused on studies of accumulation in insects or spiders and reported whole body concentrations. To ensure relevancy of the soil to biota factors and models to field situations, only field studies that collected resident terrestrial invertebrates were considered. Therefore, all terrestrial invertebrate residues were assumed to be at equilibrium with soil concentrations.

To ensure comparability of data, only "total" chemical analyses of both soil and biota (e.g., resulting from extractions of metals using concentrated acids) were included. Data resulting from acetic acid, DTPA, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in media and biota reported for each sampling location evaluated in each study was considered an observation.

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[12] References in this passage can be found in the original source (ES/ER/TM-219).

[13] ARAMS was previously known as the Army Risk Assessment Modeling System.

[14] Data usability requirements included only paired/collocated samples with detects in both tissue and soil at levels above detection limits; terrestrial invertebrate data on whole body tissue samples; field studies, not laboratory studies, except where noted; only total chemical analyses of both soil and biota – data resulting from mild acid extraction methods; the mean or composite chemical concentration in media and biota reported per location in each study was considered an observation; data on distinct species were considered separate observations; all wet weight measurements were converted to dry weight using study specific water content or estimations from EPA/600/R-93/187a. Additional detail on data usability are found in CHPRC-01311 within Appendix H.

If data for multiple species were reported at a site, each species was considered a separate observation. Soil and biota data in the terrestrial arthropod database were reported as mg/kg dry weight. If a study identified in the literature search reported biota concentrations in wet weight, then dry weight concentrations were either calculated using the water content presented in the study or estimated assuming water content percentages, as presented in EPA/600/R-93/187b, when water content was not presented in the study.

Data concerning species, soil pH, percent organic matter, cation exchange capacity, soil texture, and soil calcium concentration (mg/kg dry weight) were included in the database whenever reported. Additionally, class, order, and family taxonomic data were included for each species in the database. These data were used to develop uptake factors by taxon for terrestrial invertebrates. Because chemical uptake was expected to vary according to terrestrial invertebrate diet preferences, each species was assigned to one of three trophic groups: predator (diet consisting primarily of other insects), herbivore (diet consisting primarily of plant material), and detritivore (diet consisting primarily of organic matter in the leaf litter).

To ensure the accuracy of the terrestrial arthropod database, all data were verified by at least one reviewer. The reviewer would first examine the study for data presented and analytical methods used. The reviewer would then check all calculations and conversions necessary to obtain required units (e.g., mg/kg dry weight). Finally, a minimum of 25% of all data was checked. If an error was found during this check, then 100% of the data was verified. Unit conversion and transposition errors were the most common types of errors found; however, these were infrequent. All errors were corrected.

7.5.1.2 Development of Integrated Dietary Bioaccumulation Models and PRGs.

The Hanford Site-specific plant, soil invertebrate, and small mammal data were integrated with the literature-derived bioaccumulation data. Bioaccumulation analyses were performed once biota data were converted to standard units (mg/kg dry weight). Analyses were restricted to observations where the chemical of interest was detected in both soil and the matched tissue sample; all observations in which either soil or tissue concentrations were nondetects were excluded from the analyses. Analyses consisted of development of BAFs and nonlinear regression analyses. BAFs are simply the ratio between concentrations measured in tissue and that in soil. BAFs for all paired soil tissue observations and summary statistics (arithmetic mean, standard deviation, minimum, maximum, median, and 90th percentile) were calculated.

To evaluate if a log-linear relationship existed between the chemical concentration in soil and that in terrestrial biota existed, simple log-linear regressions were performed using SAS PROC REG (SAS Institute, 1999, *SAS/STAT User's Guide*). Chemical concentrations in both soil and biota tissues were transformed to natural-log (ln) before regression analyses. Regression analyses were considered significant and suitable for estimation purposes if all three of the following criteria were met: $p>0.05$, $r2>0.1$, and a positive slope. If regression analyses did not meet any one of these criteria, the median BAFs were used to estimate tissue concentrations in exposure models.

The wildlife PRGs (metals only) are presented in Table 7-6. In cases where the second tier of effect level (PRG) was not available or recommended (e.g., organics, radionuclides, and a few inorganics), no refined risk characterization was conducted. In those cases, HQ results >1.0 based on comparisons to the SSLs were carried forward to the SMDP (Section 7.6). For the purposes of this baseline ecological risk assessment (BERA), the LOAEL-based PRGs[15] (PRGs that used lowest effect levels from the Effects Assessment) were used to evaluate residual risks at the 100-K Area waste sites. To focus the assessment

[15]NOAEL-based PRGs in the BERA (refinement) or SSLs were used when no LOAEL was available.

on COPEC-receptor-waste site combinations that might require further evaluation in the SMDP, EPCs developed for the 100-K Area (as described in Section 7.3.3) were compared to these PRGs. The EPCs were compared to PRGs only for those COPECs that exceeded both SSLs and background as described in Section 7.4.4 and presented in Table 7-5[16].

7.5.2 Preliminary Remediation Goals

The PRGs presented in this report represent Hanford Site-specific values as presented in CHPRC-01311 and ECF-HANFORD-11-0158[17]. Much of the modeling used to develop PRGs for wildlife is presented earlier in this chapter because the PRGs build on the SSLs (CHPRC-00784), using the same receptors, exposure models, life history parameters, and TRVs, then using exposure refinements as discussed in Section 7.5.1. Development of the PRGs deviates from the process used to determine SSLs by using bioaccumulation models that included only arthropods as the invertebrate portion of receptors' diets[18] and integrating Hanford Site-specific data (Section 7.5.1). In contrast, development of the SSLs included prey tissue estimation models that were generic and included a wide variety of species, only some of which are likely to occur within the arid environment at the Hanford Site.

The development of PRGs corresponds to the analysis step for characterizing exposure and ecological effects, conducted as part of a baseline ERA within ERAGS (EPA 540-R-97-006), and reflects OSWER Directive 9385.7-28 P, which encourages the use of site-specific ecological risk data to support cleanup decisions, whenever practicable. The process for development of PRGs also is consistent with MTCA (WAC 173-340-7493). Differences between the PRGs and the MTCA Table 749-3 soil screening values were not a result of recalculations of the original datasets and models used to derive the *Washington Administrative Code* values. Rather, all of the changes from MTCA (WAC 173-340) Table 749-3 are based on updated exposure models (from OSWER Directive 9285.7-55) and toxicological literature reviews that were not available at the time MTCA Table 749-3 was developed. PRGs are intended to be applied to all upland environments across the Hanford Site. Although additional receptors may also be present in riparian areas, the wildlife PRGs and the supporting bioaccumulation and exposure models and TRVs are applicable for riparian areas and can be used in conjunction with values for those additional receptors.

Hanford Site-specific wildlife PRGs are presented in Table 7-6. Hanford Site-specific PRGs were researched for inorganic and organic constituents, but not radionuclides. Ultimately, Hanford Site-specific PRGs were only recommended for inorganics, because Hanford Site-specific data were limited for organics and radionuclides.[19] Confidence in these PRGs as a whole is greater than for the SSLs because they were developed specifically for Hanford using site-specific data (e.g., paired soil and tissue samples). Relative to each other, confidence in some PRGs is greater than in others. The additional confidence in the PRGs versus the SSLs is the result of a combination of the total number of Hanford Site-specific paired soil and tissue samples and the strength of the relationship between tissue and soil concentration

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[16] For nine chemicals, the lowest wildlife PRGs were lower than the lowest wildlife SSLs, so a check was performed (ECF-l00NRI-12-0045, *Ecological Risk Evaluation for the 100-N Source Operable Units*) to confirm that there were no EPCs that were above PRGs but below SSLs. This is discussed further in the Uncertainty Assessment (Section 7.5.4).

[17] For some chemicals, final PRGs presented in later chapters of the RI/FS present Tier 1 SSLs from CHPRC-00784 when a Tier 2 PRG was unavailable or when the quality was considered low and unreliable (e.g., poor correlation between soil and chemical uptake or when based on less than 10 samples).

[18] Further detail on the estimation of invertebrate tissue concentrations is found in Section 7.5.1.1.

[19] In Chapter 7, if a second tier risk-based value (e.g., PRG) was not available or recommended for use, chemical-waste site combinations were retained for further evaluation in the SMDP (Section 7.6) if the exposure point concentration exceeded the SSL.

(correlation). Details regarding the confidence in specific PRGs were included in the SMDP in Section 7.6 as needed.

PRGs for inorganic chemicals protective of plants and invertebrates are presented in Table 7-7. When Hanford Site-specific toxicological data on the effects of chemicals on plants and soil invertebrates were available, these data were considered for PRG selection. These data are summarized in the following three documents:

- ECF-HANFORD-11-0158 (presented in Appendix H)
- RCBRA (DOE/RL-2007-21)
- Ecology Publication 11-03-006, *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology*

All site-specific toxicological thresholds for plants and invertebrates presented in these documents are no observed effect concentrations (NOECs). As noted in Subsection 7.3.1.2, measures of effects selected for population and community level assessment endpoints are LOAELs or LOECs, when available. However, LOECs for effects to plants and invertebrates were not established at the highest bioassay concentrations measured and produced no significant effects in most cases[20] (ECF-HANFORD-11-0158). Thus, for each chemical studied in one or more of these documents, the highest NOEC among these documents was selected as the PRG for that chemical. If Hanford Site-specific thresholds for plants and invertebrates were not presented in any of these three documents, the EcoSSL was selected as the PRG because it included more recent TRV information than what was available when the MTCA (WAC 173-340) Table 749-3 was developed. If an EcoSSL was not available, the *Washington Administrative Code* value was selected. The two exceptions were as follows:

- The Hanford Site-specific background value for cobalt was selected as the PRG for both plants and invertebrates. There is no *Washington Administrative Code* or EcoSSL value for invertebrates. The background value of 15.7 mg/kg is greater than the plant EcoSSL of 13 mg/kg.
- Although the *Washington Administrative Code* plant value of 20 mg/kg is greater than the background value, it is based on the value from ORNL and the original authors gave the value low confidence. Site-specific plant and invertebrate NOEC values of 11.2 and 12.2 mg/kg were also available from the RCBRA, but these values were the highest measured concentrations and were lower than background.

[20] In a few cases, as described in ECF-HANFORD-11-0158, some of the plant and invert PRGs were not site-specific NOECs, mainly because other no-effect levels were greater or because site-specific soil samples were not detected at high enough concentration to perform meaningful statistical analysis (i.e., detected, but at very low concentration relative to waste sites).

Table 7-6. PRGs for Wildlife (Birds and Mammals)

Analyte	Units	California Quail	Western Meadowlark	Killdeer	Red-Tailed Hawk	Lowest Avian PRG	Great Basin Pocket Mouse	Deer Mouse	Grasshopper Mouse	Badger	Lowest Mammal PRG	Lowest Wildlife PRG
Aluminum	mg/kg	19,217	31,220	7,214	74,599	7,214	4,883	**3,988**	13,059	7,811	3,988	3,988
Antimony	mg/kg	NTD	NTD	NTD	NTD	NTD	97	**92**	366	325	92	92
Arsenic	mg/kg	4,776	7,403	2,284	40,102	2,284	201	**127**	302	847	127	127
Boron	mg/kg	**54**	68	91	2,714	54	**32**	39	170	2,516	32	32
Barium	mg/kg	1,721	2,335	**1,687**	8,101	1,687	2,265	2,617	11,873	12,430	2,265	1,687
Beryllium	mg/kg	NTD	NTD	NTD	NTD	NTD	**14**	20	181	289	14	14
Cadmium	mg/kg	294	103	**29**	1,711	29	2,203	624	858	4,704	624	29
Cobalt	mg/kg	1,397	2,050	**484**	4,798	484	2,901	2,136	5,610	4,234	2,136	484
Chromium	mg/kg	193	221	**109**	610	109	544	**517**	1,424	1,765	517	109
Copper	mg/kg	423	461	**213**	12,881	213	233	193	1,217	4,631	193	193
Lead	mg/kg	559	664	**156**	2,300	156	2,672	1,578	3,807	3,966	1,578	156
Lithium	mg/kg	NTD	NTD	NTD	NTD	NTD	**1,664**	1,797	8,347	6,522	1,664	1,664
Mercury	mg/kg	36	4.7	2	92	2	7.9	**1.6**	1.8	33	1.6	1.6
Manganese	mg/kg	20,746	26,026	14,407	150,899	14,407	**3,322**	3,467	11,780	21,916	3,322	3,322
Molybdenum	mg/kg	125	117	95	515	95	5.9	**5.7**	14	38	5.7	5.7
Nickel	mg/kg	2,051	1,127	361	11,625	361	711	**247**	342	1,520	247	247
Selenium	mg/kg	10	4.9	2.4	24	2	2.7	**1.4**	1.9	8.8	1.4	1.4
Silver	mg/kg	4,238	3,973	**983**	20,186	983	24,465	9,806	14,362	30,778	9,806	983
Strontium (Elemental)	mg/kg	NTD	NTD	NTD	NTD	NTD	**1,214**	1,449	6,540	8,256	1,214	1,214
Thallium	mg/kg	NTD	NTD	NTD	NTD	NTD	8.7	**6.2**	12	25	6.2	6.2
Uranium (Calculated Total)	mg/kg	2,002	339	139	82	82	371	59	57	**22**	22	22
Vanadium	mg/kg	81	107	**43**	505	43	260	297	4,531	3,596	260	43
Zinc	mg/kg	6,289	4,662	**856**	906	856	6,711	3,331	12,666	1,037	1,037	856

Note: Bold values represent lowest PRG for that analyte.

Shaded values are based on NOAELs because of the lack of LOAELs.

LOAEL = lowest observed adverse effects level

NOAEL = no observed adverse effects level

NTD = no toxicity data (for selected analyte)

PRG = preliminary remediation goal

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Table 7-7. Final Recommended Soil PRGs for Plants and Invertebrates [a]

Analyte Name	Plant (mg/kg)	Plant Basis	Invertebrate (mg/kg)	Invertebrate Basis
Antimony	842	Site specific (2011 study [b])	842	Site specific (2011 study)
Arsenic	128	Site specific (Ecology Publication-11-03-006)	128	Site specific (Ecology Publication-11-03-006)
Barium	500	ORNL (ES/ER//TM—85/R3)	358	Site-specific (RCBRA)
Beryllium	10	ORNL (ES/ER//TM—85/R3)	40	EcoSSL (OSWER Directive 9285.7-64, 2005)
Boron	29.6	Site-specific (RCBRA)	28.6	Site-specific (RCBRA)
Cadmium	9.84	Site specific (2011 study)	20	ORNL (ES/ER//TM—126/R2)
Chromium	259	Site specific (2011 study)	149	Site-specific (RCBRA)
Cobalt	15.7	Background	15.7	Background
Copper	70	EcoSSL (OSWER Directive 9285.7-68, 2007)	58	Site specific (Ecology Publication-11-03-006)
Lead	9,090	Site specific (2011 study)	1,700	EcoSSL (OSWER Directive 9285.7-70, 2005)
Manganese	1,260	Site specific (2011 study)	1,260	Site specific (2011 study)
Mercury	0.3	ORNL (ES/ER//TM—85/R3)	12.5	Site specific (2011 study)
Molybdenum	2.0	ORNL (ES/ER//TM—85/R3)	28	Site specific (2011 study)
Nickel	38	EcoSSL (OSWER Directive 9285.7-76, 2007)	280	EcoSSL (OSWER Directive 9285.7-76, 2007)
Selenium	2.02	Site specific (2011 study)	4.1	EcoSSL (OSWER Directive 9285.7-72, 2007)
Silver	560	EcoSSL (OSWER Directive 9285.7-77, 2006)	2.99	Site specific (2011 study)
Thallium	1.0	ORNL (ES/ER//TM—85/R3)	0.459	Site specific (2011 study)
Tin	838	Site specific (2011 study)	838	Site specific (2011 study)
Uranium	250	PNEC (Sheppard et al., 2005)	100	PNEC (Sheppard et al., 2005)
Vanadium	89.4	Site specific (2011 study)	116	Site specific (2011 study)
Zinc	621	Site-specific (RCBRA)	8,980	Site specific (2011 study)

References: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment.*

ECF-Hanford-11-0158, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site.*

Ecology Publication-11-03-006, *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology.*

ES/ER/TM-85/R3, *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision.*

ES/ER/TM-126/R2, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision.*

OSWER Directive 9285.7-64, *Ecological Soil Screening Levels for Beryllium Interim Final.*

OSWER Directive 9285.7-68, *Ecological Soil Screening Levels for Copper: Interim Final.*

OSWER Directive 9285.7-70, *Ecological Soil Screening Levels for Lead: Interim Final.*

OSWER Directive 9285.7-72, *Ecological Soil Screening Levels for Selenium: Interim Final.*

OSWER Directive 9285.7-76, *Ecological Soil Screening Levels for Nickel: Interim Final.*

OSWER Directive 9285.7-77, *Ecological Soil Screening Levels for Silver: Interim Final.*

Table 7-7. Final Recommended Soil PRGs for Plants and Invertebrates [a]

Analyte Name	Plant (mg/kg)	Plant Basis	Invertebrate (mg/kg)	Invertebrate Basis

Sheppard et al., 2005, "Derivation of Ecotoxicity Thresholds for Uranium."

a. All PRGs presented in Table 7-7 are from ECF-Hanford-11-0158. Those listed as 2011 study were performed in 2011 by CHPRC. Others, while summarized in ECF-Hanford-11-0158, were presented in other reports as noted.

b. All Site specific study values are unbound NOECs. No effects were attributed to the chemical at the highest concentration measured, thus they are NOECs with no upper bound.

EcoSSL = ecological soil screening level
NOEC = no observed effects concentration
ORNL = Oakridge National Laboratory
PNEC = probable no effect concentration
PRG = preliminary remediation goal
RCBRA = River Corridor Baseline Risk Assessment

The cadmium value for invertebrates of 20 mg/kg from the *Washington Administrative Code* was selected as the PRG over the EcoSSL of 140 mg/kg. The *Washington Administrative Code* value was based on an ORNL recommendation where the authors gave a moderate to high confidence in the recommendation and this was considered of equal weight with the EcoSSLs, so the lower of the values with equal confidence was selected.

The recommended PRG represents a value, supported by the most recent defensible data available, that met the criteria set forth in ERAGS (EPA 540-R-97-006) and MTCA (WAC 173-340-7493) guidelines for selecting site-specific criteria. In selection of values that differ from MTCA (WAC 173-340) Table 749-3, when multiple recent toxicological data sources were available, the value with the highest confidence or the lower of two values with equally high confidence was chosen. The site-specific values are preferred over those from published literature in that they are more recent data that were not available at the time MTCA (WAC 173-340) guidance or EcoSSLs were developed, and they reflect the potential for toxicity under conditions found specifically at the site. However, with some COPECs, site-specific sampling efforts did not generate concentration ranges above those from published literature. With all of the site-specific studies conducted for the RCBRA (DOE/RL-2007-21), by Ecology, and recently by CH2M HILL Plateau Remediation Company, significant toxicity to plants and invertebrates attributable to site soil contaminants was not observed; thus, recommended toxicological values represent unbound NOECs. Hence, in some cases, published literature values above these unbound NOECs were selected as PRGs over site-specific values. Final selection of the PRGs for plants and invertebrates is discussed in detail in ECF-HANFORD-11-0158. Details regarding the confidence in specific PRGs were included in the SMDP in Section 7.6.

Detailed information regarding the source areas for the samples used for the most recent bioassays are included within ECF-HANFORD-11-0158. These source areas included the old central shop area, 120-KW-1, 600-218, 600-220, 600-228, and 600-281. Each of the waste sites where samples were collected is depicted on a map and the WIDS general summary reports are included. These descriptions include site location, and process descriptions as well as summaries of the waste types, categories, physical state, and dimensions as available. The forms of the specific chemicals that may be expected can be generalized from these summaries but not specifically determined. Using lead as an example, welding flux materials and lead-based paints found in metals shops of the old central shop area could yield highly bioavailable forms of lead. The representativeness of these samples to the concentration, chemical form, bioavailability, and bioaccessibility of metals throughout the rest of the Hanford Site is uncertain.

The concentration ranges tested in the bioassays are by design representative of the broader Hanford Site, as a specific range of concentrations was targeted for testing based on known concentration distributions for the Hanford Site. Concentration ranges targeted for testing were largely achieved (ECF-HANFORD-11-0158). The design was intended to maximize the representativeness of the contaminant concentration distributions. It was an implicit assumption that the analyte forms, and therefore, bioavailability and bioaccessibility at sampled locations (for which sample bioassays were conducted) would represent locations not sampled. However, whether the forms and bioavailability of metals in samples used for bioassays truly represent the forms and actual bioavailability of metals in soil from other individual waste sites at which bioassays were not conducted and to which resulting PRGs are applied, is unknown and may vary by waste site.

7.5.3 Baseline Risk Characterization Using PRGs

In the risk characterization refinement based on PRGs, the soil EPC for each waste site and decision unit (as applicable) was compared to the plant/invertebrate PRGs and the wildlife PRGs for all COPCs carried forward from the screening assessments (Section 7.4). Risks were evaluated based on the magnitude of the resulting PRG (Section 7.5) HQs and are provided in Appendix H (Table H-9 for the lowest receptor HQs and Table H-10 for a summary of species-specific HQs >1.0) and summarized in Table 7-8. COPCs with HQs equal to or greater than 1.0 were retained as COPECs. COPECs were then given further consideration in the SMDP.

The methodology used in this step of the refined/baseline risk characterization is provided in Appendix H (ECF-100KR1-11-0010, *Ecological Risk Evaluation for the 100-KR-1 and KR-2 Source Operable Units*). For any chemical-waste site EPC that exceeded both the SSL and background (Section 7.4), if a PRG was not available (see Tables 7-6 and 7-7), the chemical-waste site combination was automatically retained for additional evaluation in the SMDP (see Section 7.6).

Results indicate the following 15 waste sites did not exceed the plant/invertebrate PRGs or wildlife PRGs (HQs were all <1.0), are identified as posing negligible ecological risk, and were eliminated from further evaluation:

- 100-K Area Sites: 100-K-29; 100-K-3, 100-K-36, 100-K-79:7; 100-K-50, 1607-K2; 100-K-57; 100-K-63; 100-K-64; 100-K-77; 100-K-78; 100-K-83; 100-K-88; 100-K-89, 600-29
- 116-K Area Sites: 116-KE-5
- 128-K Area Sites: 128-K-1
- 1607 Area Sites: 1607-K3
- 600 Area Sites: 600-29

Sites and analytes with ecological risk identified following baseline refinement are summarized in Table 7-8.

The EPCs for the inorganic analytes chromium, copper, mercury, selenium, and vanadium exceeded at least one PRG and background. PRGs are not available for TPH-D or radionuclides, including carbon-14. Thus, TPH-D and SOFs for radionuclides detected at concentrations exceeding wildlife SSLs as shown in Table 7-5, were carried forward to the SMDP.

Table 7-8. Summary of Refined Baseline Risk Characterization for 100 K Upland Area Waste

Sites Surface Soil (0 to 4.6 m [0 to 15 ft])		
Waste Site/Decision Unit	**Analyte**	**Action Level Basis**
100-K-102 Shallow 1	Mercury	Western Meadowlark PRG
		Killdeer PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
	Selenium	Deer Mouse PRG
100-K-102 Shallow 2	Mercury	Plant PRG
100-K-102 Shallow Focused	Vanadium	California Quail PRG
		Killdeer PRG
100-K-109 Shallow Focused	Selenium	Deer Mouse PRG
		Grasshopper Mouse PRG
100-K-110 Shallow	Mercury	Plant PRG
	Selenium	Deer Mouse PRG
100-K-14, 126-KE-2_Shallow	Mercury	Plant PRG
	Vanadium	California Quail PRG
		Killdeer PRG
		Plant PRG
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7 Overburden 5N	Selenium	Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
		Killdeer PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
	Vanadium	California Quail PRG
		Killdeer PRG
		Plant PRG
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7 Shallow	Vanadium	California Quail PRG
		Killdeer PRG
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow_Focused	Selenium	Deer Mouse PRG
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_2	Selenium	Deer Mouse PRG
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_3	Selenium	Deer Mouse PRG
100-K-30 Shallow Focused	Mercury	Western Meadowlark PRG
		Killdeer PRG

Table 7-8. Summary of Refined Baseline Risk Characterization for 100 K Upland Area Waste

Sites Surface Soil (0 to 4.6 m [0 to 15 ft])		
Waste Site/Decision Unit	**Analyte**	**Action Level Basis**
		Great Basin Pocket Mouse PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
		Invertebrate PRG
100-K-31 Shallow Focused	Mercury	Western Meadowlark PRG
		Killdeer PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
100-K-32 Shallow Focused	Mercury	Western Meadowlark PRG
		Killdeer PRG
		Great Basin Pocket Mouse PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
		Invertebrate PRG
100-K-33 Shallow Focused	Mercury	Western Meadowlark PRG
		Killdeer PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
100-K-34, 100-K-102, 1607-K3 Shallow Focused	Selenium	Deer Mouse PRG
		Grasshopper Mouse PRG
		Plant PRG
	Vanadium	California Quail PRG
		Killdeer PRG
100-K-34 Shallow	Vanadium	California Quail PRG
		Killdeer PRG
		Plant PRG
100-K-4 Shallow	Selenium	Deer Mouse PRG
100-K-6, 100-K-46, 100-K-62, 132-KE-1_Overburden	Selenium	Deer Mouse PRG
100-K-84 Shallow	Mercury	Plant PRG
100-K-91 Shallow Focused	Mercury	Killdeer PRG
		Deer Mouse PRG
		Grasshopper Mouse PRG

Table 7-8. Summary of Refined Baseline Risk Characterization for 100 K Upland Area Waste

Sites Surface Soil (0 to 4.6 m [0 to 15 ft])		
Waste Site/Decision Unit	**Analyte**	**Action Level Basis**
		Plant PRG
118-K-1_P1_Shallow_3	Vanadium	California Quail PRG
		Killdeer PRG
		Plant PRG
118-K-1_P2_Shallow_11G	Vanadium	California Quail PRG
		Killdeer PRG
118-K-1_P2_Shallow_Focused_3	Vanadium	California Quail PRG
		Killdeer PRG
		Plant PRG
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow_Focused	Selenium	Deer Mouse PRG
		Grasshopper Mouse PRG
	Vanadium	California Quail PRG
		Killdeer PRG
		Plant PRG
128-K-2 Shallow Focused	Copper	Plant PRG
		Invertebrate PRG
100-K-111 East Rip Surface Focused	Chromium	Killdeer PRG
100-K-111 West Surface	Chromium	Killdeer PRG

PRG = preliminary remediation goal

7.5.4 Uncertainty Assessment

Uncertainties are present in all risk assessments because of the limitations of the available data and the need to make certain assumptions and extrapolations based on incomplete information. In addition, the use of various models (e.g., uptake and food web exposures) carries with it some associated uncertainty as to how well the model reflects actual conditions. Because conservative assumptions were generally used in the screening exposure and effects assessments, and to a lesser extent in the refined assessments, these uncertainties are more likely to result in an overestimation rather than an underestimation of the likelihood and magnitude of risks to ecological receptors.

Uncertainties and limitations associated with the methodology used and available data for the ERA are discussed in the following subsections.

7.5.4.1 Exposure Depth

The quantitative evaluation of chemical concentrations in soil included surface soil from the 0 to 4.6 m (0 to 15 ft) depth range. Ecology uses a standard point of compliance in soil of 4.6 m (15 ft) for demonstrating protection of ecological receptors (MTCA; WAC 173-340-7490(4)(b), “Terrestrial Ecological Evaluation Procedures”). This depth range may over-estimate the depth to which many terrestrial receptors would be exposed. As noted in Sample et al. 2015, the maximum penetration depth (i.e., biologically active zone) across all Hanford receptors was 3.0 m (9.8 ft) bgs. MTCA

(WAC 173-340) identifies the biologically active zone as 0 to 1.8 m (0 to 6 ft). Evaluation of data that extend beyond the biologically active zone would overestimate risk. For this ERA, the depth from 1.8 to 4.6 m (6 to 15 ft) is also included because human activities could bring materials from that depth to the surface, creating a complete exposure pathway, and in spite of the content summarized in Sample et al. 2015, the depth of biomobilization at the Hanford Site is still not fully understood.

7.5.4.2 Availability of Toxicological Data

No toxicological data or background data were available or the data were limited for some COPC/ receptor combinations:

- Acetone
- Carbazole
- Di-n-butylphthalate
- Ethylene glycol
- Nickel-63
- Nitrogen in nitrite and nitrate
- Total petroleum hydrocarbons[21]
- Total petroleum hydrocarbons - diesel range extended to C36[21]
- Total petroleum hydrocarbons - motor oil (high boiling)[21]

Exclusion of COPCs from SSL development (Tables 7-1 to 7-3) may not adequately address aggregate risk at a site, although it should be noted that remedial alternatives that are protective of receptors with SSLs should also be protective of receptors lacking sufficient toxicity data such as other birds and mammals or reptiles and amphibians. In addition, the absence of SSLs for plants and soil invertebrates was addressed by performing site-specific soil bioassays, the results of which are a component of Tier 2 plant and invertebrate soil PRGs (Sections 7.5.1 and 7.5.2).

7.5.4.3 TPH-Motor Oil

No SSL or PRG was developed for soil for TPH-motor oil (identified in the 100-K dataset as TPH-motor oil [high boiling], and TPHs up to carbon range 36) and TPHs, but published literature is available to provide some perspective. Efroymson et al., 2004, compiled a literature review on toxicological effects to plant and invertebrates with the results suggesting invertebrates are more sensitive to some petroleum hydrocarbons than plants. Using lube oil to represent TPH, no effect thresholds ranged from 15 to 1,490 mg/kg in soil and EC20 were found as low as 15 to 149 mg/kg. Conversely, lube oil NOAECs for plants ranged from 969 mg/kg to 12,000 mg/kg. MTCA lists ecological indicator soil concentrations (MTCA; WAC 173-340, Table 749-3) for soil biota for diesel and gasoline range organics at 200 mg/kg and 100 mg/kg, respectively, based on original work published at ORNL (ES/ER/TM-126/R2). Motor oil and high boiling hydrocarbons were measured at the following 13 waste-site decision units:

- 100 K 106_Overburden_Focused_2
- 100 K 106_Shallow_Focused_3
- 100 K 106_Shallow_Focused_6
- 100 K 86_Shallow_Focused

[21] Refer to Uncertainty Assessment (Section 7.5.4) for additional description. Value for TPH Motor oil is a range of no adverse effect concentrations and does not represent a PRG. SSLs and PRGs were not developed for TPH. Values are strictly to provide some context to concentrations detected.

- 100 K 89, 600 29_Shallow
- 100 K 89, 600 29_Shallow_Focused
- 100 K 92_Shallow_Focused
- 100 K 95_Shallow
- 128 K 2_Shallow
- 128 K 1_Shallow_Focused
- 128 K 2_Shallow_Focused
- 600 29_Shallow
- 600 29_Shallow_Focused

Concentrations were detected as high as 1,200 mg/kg, above the lower range of values at 11 of these waste site decision units. Thus, these waste site decision units within the 100-K Area with detected motor or extended diesel range >20 mg/kg were considered in the SMDP.

7.5.4.4 Bioavailability and Toxicity of Metals

Bioavailability and toxicity of metals are functions of many factors including soil pH with metals (e.g., aluminum, lead, and mercury). Metals are generally more bioavailable and toxic at low pH (OSWER Directive 9285.7-55). The pH for soil used to develop plant toxicity values ranges from 3 to 8 (mean = 6.3) (CHPRC-00784). The pH for soil used to develop invertebrate toxicity values ranges from 3.8 to 8.1 (mean = 5.6) (CHPRC-00784). The minimum soil pH reported in the RCBRA (DOE/RL-2007-21) in riparian and upland soil was 6.6. Soil pH in the Outer Area of the Central Plateau ranges from 3.6 to 9.9, with 93% of observations greater than 6.6. Because the range of pH values in soil associated with plant and soil invertebrate toxicity values within the published literature includes pH values that are substantially lower than those present throughout most of the Hanford Site, it is likely that the resulting SSLs for plants and soil invertebrates do not accurately represent toxicity potential of metals in Hanford soil. Metals are less bioavailable at the higher pH conditions common to Hanford soil. The SSLs may overestimate concentrations in Hanford Site soil that would be toxic to plants and soil invertebrates; thus, risk estimates made by comparing to these SSLs may be overly conservative. Evaluating this potential overestimation of bioavailability was the goal of a 2011 Hanford Site field effort to collect soil with a pH range more reflective of Hanford Site soil. With the exception of four samples collected within the 100-K Area, the range of pH values from samples collected for the 2011 study was between 5.8 and 8.7 with all but 5 of 67 samples above the minimum pH of 6.6 identified in previous RCBRA soil samples. Thus, the PRGs developed from bioassays conducted with Hanford soil reflect the bioavailability of potential contaminants within the Hanford Site soil (and its associated pH with resultant bioavailability), rather than relying on published data from laboratory studies conducted at other sites, as was done for the SSLs.

7.5.4.5 PCB Congener Data

PCB congener data can be more beneficial than Aroclor data. Congener analysis is more precise with less interference in the analysis from other chemicals, the quantitation is more accurate, and composition of weathered, degraded, or metabolized mixtures is easier. Congener analysis may be more appropriate when PCB hot spots have been identified, lower detection limits are needed, fingerprinting is necessary, adverse effects have been observed, or cleanup will be based on congener-specific toxicity equivalency factors. However, disadvantages of using congeners include more limited availability of toxicological data, more costly analysis, significant variation between laboratories, and a greater amount of effort in data management. Given that PCBs are not the primary constituent of concern at this site, collection and analysis of Aroclor data was used for risk screening purposes with the understanding that congener

analysis could be performed as an additional analytical step if it was determined from the conservative evaluation of the Aroclor data that further evaluation of risk associated with PCBs is necessary. The screening assessment of Aroclor data in soil at 100-K did not produce results suggesting further analysis using congeners was warranted.

PCB congeners were analyzed in all media evaluated in the CRC (DOE/RL-2010-117). This study analyzed sediment, island soil, surface water, and fish tissue for the 209 PCB congeners and presented results in Chapters 3 and 6 (DOE/RL-2010-117). In the CRC, Table 3-1 lists the analytical parameters by medium, and summary statistics for each medium analyzed in Tables 3-3 through 3-12. The CRC provides RBSLs and their basis for each media type in Tables 3-15 through 3-17, and COPCs selection in Tables 3-18 through 3-36. Risk characterization results in the CRC are presented in Sections 6.5.1 and 6.5.2. In summary, the dioxin-like and nondioxin PCBs were not retained as COPCs or if they were retained and carried forward into the risk characterization, they were not identified as risk drivers. In all cases, dioxin-like and nondioxin PCBs were identified as reference COPCs (not correlated with a Hanford Site release).

7.5.4.6 Wildlife Toxicity Reference Values

Data on the toxicity of many chemicals to the receptor species were sparse or lacking, requiring the extrapolation of data from other wildlife species or from laboratory studies with nonwildlife species. This is a typical limitation, and extrapolation for ERAs is common practice because so few wildlife species have been tested directly for most chemicals. The uncertainties associated with toxicity extrapolation were minimized through the selection of the most appropriate test species for which suitable toxicity data were available. The factors considered in selecting a test species to represent a receptor species included taxonomic relatedness, trophic level, foraging method, and similarity of diet.

A second uncertainty related to the derivation of TRVs applies to metals. Most of the toxicological studies on which the TRVs for metals were based used forms of the metal (such as soluble salts) that do not reflect the bioavailability of metals in soil. This is likely to result in an overestimation of potential risks for these chemicals in soil. A recent study was conducted comparing the toxicity of laboratory spiked soil versus aged field collected soil and the ability of the European Union to predict no effect concentrations for five metals. The study concluded that total metals concentrations in field-collected soil are poor indicators of toxicity (Smolders et al., 2009, “Toxicity of Trace Metals in Soil as Affected by Soil Type and Aging After Contamination: Using Calibrated Bioavailability Models to Set Ecological Soil Standards”). For mercury, inorganic mercury species are the predominant form that will occur in oxic soil, such as those found at the Hanford Site. The baseline risk characterization used wildlife dosing studies based on the more toxic form of methyl mercury to develop wildlife TRVs for SSL and PRG calculations. Given that methyl mercury is highly unlikely to be found in or produced by sulfate-reducing bacteria within the oxic soil environments at the Hanford Site, the wildlife evaluations for mercury based on toxicity data for methyl mercury will overestimate risk. Since the evaluation of risk, including the SMDP (Section 7.6), concludes that wildlife populations are not adversely affected by exposure to mercury, this conservative assumption based on methyl mercury toxicity information is not refined further to reflect actual Hanford Site conditions.

As explained earlier, LOAEL TRVs were used when available. In some cases, a LOAEL TRV was available for mammals but not birds, or vice versa. In these cases, the lower of the SSL was used for EPC comparisons. In other words, the available number for birds was used and the available number for mammals was used. Avian LOAEL TRVs were not available for the evaluation of detected concentrations of high molecular weight (MW) PAHs, total uranium isotopes, uranium, and bis-2-ethylhexyl phthalate for 100-K. When the lowest SSL based on NOAELs was used to evaluate screening level risk to birds for high

molecular weight (MW) PAHs, total uranium isotopes, and uranium, no waste site-decision unit combinations exceeded the avian SSL. Bis-2-ethylhexyl phthalate concentrations exceeded the avian SSL (HQ of 6.2) in one waste site-decision unit combination. This case was not considered a concern given that the EPC only exceeded a screening level based upon a dose at which no effects have been observed and LOAEL TRV based evaluations of other receptors indicated no unacceptable risk.

7.5.4.7 Chemical Mixtures

The SSLs employed in this assessment are based on exposure to individual analytes. Information on the ecotoxicological effects of chemical interactions is generally lacking or insufficiently developed for all the COPCs evaluated, which required (as is standard for ERAs) that the chemicals be evaluated on a compound-by-compound basis during the comparison to SSLs. This could result in an underestimation of risk (if there are additive or synergistic effects among chemicals) or an overestimation of risks (if there are antagonistic effects among chemicals). EPA 120/R-07/001 discusses these concepts and some modeling approaches that can be used to try to predict the toxicity of chemical mixtures. However, significant understanding of chemical bioavailability is required and would be complicated across the many waste sites and decision units evaluated. Since these data were not available and such modeling is not standard practice within ERAs, single chemical evaluations were deemed sufficient.

7.5.4.8 Receptor Species Selection

Reptiles were identified as being part of the food web present at the Hanford Site, but were not evaluated quantitatively even when exposure pathways were complete because of a lack of toxicity data for these species. It was assumed that reptiles were neither exposed to significantly higher concentrations of chemicals nor were more sensitive to chemicals than the other receptor species evaluated. This assumption was a source of uncertainty in the ERA. There is also some uncertainty associated with the use of specific receptor species to represent larger groups of organisms (e.g., guilds), though this is not an uncommon practice in terrestrial ecological risk assessment.

7.5.4.9 Food Web Exposure Modeling

Although much life history data are available for many of the wildlife species found at the Hanford Site, Hanford Site-specific data were unavailable for several specific parameters included in the desktop food web models used to estimate exposure to wildlife. These factors included food ingestion rate, incidental soil ingestion as a percent or as a rate, home range, and dietary composition established as the percent of stomach contents. As a result of this lack of Hanford Site-specific data, exposure parameters were modeled based on either allometric relationships or on data from the same species in other portions of its range. Because diet composition as well as food, water, and soil ingestion rates can differ among individuals and locations, published parameter values may not accurately reflect individuals present at the Hanford Site. Consequently, SSLs may be either overly conservative or not conservative enough. For example, the wildlife EcoSSLs were derived with a model that incorporates prey tissue items that comprise 100% of the receptor's diet coming from the site, not accounting for any food obtained in adjacent uncontaminated areas, whereas MTCA (WAC 173-340) values do account for some offsite prey consumption. Therefore, the assumed contributions of ingestion of analytes in prey tissues for the wildlife EcoSSLs are greater than those used to develop the MTCA (WAC 173-340) values and would be expected to overestimate risk.

Ultimately, there is some uncertainty with both the MTCA (WAC 173-340) and EPA values used as SSLs with respect to site-specificity. The wildlife PRGs employed in this risk assessment are more site-specific than the SSLs because prey (dietary) concentrations were estimated with Hanford Site data. However, there is also some uncertainty in those values associated with the percentage of diet obtained from the site. In applying the PRGs, the assumption was that 100% of the food ingestion was from the site, which in many cases overestimates exposure when a mobile organism's foraging (home) range may be larger

than the site(s) under evaluation. This assumption was evaluated on a case-by-case basis to aid the SMDP presented in Section 7.6.

7.5.4.10 Central Tendency Versus Maximum Exposure Concentration Estimates

As is typical in an ERA, a finite number of samples of environmental media is used to develop the exposure estimates. The maximum measured concentration provides a conservative estimate for immobile biota or those with a limited home range. The most realistic exposure estimates (EPC) for mobile species with relatively large home ranges and for species populations (even those that are immobile or have limited home ranges) are those based on an estimate of the central tendency of chemical concentrations in each medium to which these receptors are exposed. This is reflected in the wildlife dietary exposure models contained in EPA/600/R-93/187a. It is possible, however, that receptors could spend additional time foraging at a nearby waste site causing them to be exposed to analytes from more than one site. Thus, EPC estimates of contaminants in individual waste site media and food sources may not accurately represent contaminant exposure to a receptor ranging into other sites. It is likely, however, that assuming an AUF of 1.0 will result in a conservative estimate of exposure because it is likely that offsite foraging would be conducted in uncontaminated areas than at other waste sites (which in many cases lack quality habitat to support dietary foraging). Given the mobility of the upper trophic level receptor species used in the ERA, the use of maximum chemical concentrations as EPCs when UCLs were not calculated by ProUCL to estimate the exposure via food webs is conservative. However, this conservatism was reduced in the screening and refinements when the number of samples collected was adequate in size to develop a UCL on the mean for a particular analyte (Table G-5). A detailed description of the uncertainties associated with using maximum concentrations when a calculated 95% UCL was greater than site maximum value is provided in Chapter 6 (Section 6.2.6.2).

7.5.4.11 Comparisons to Background Concentrations

Background concentrations were used to judge whether measured concentrations within waste sites are reflective of site-related activities, background, or a combination. If site chemical concentrations were consistent with these background levels, it was assumed that the concentrations were not site-related. Comparisons to background in this evaluation include the use of the 90th percentile of the background dataset as compared to the EPC. Thus, 10% of the background dataset is even higher than the 90th percentile. Concentrations measured above background may be within the distribution of background variability and could represent a false positive risk. The possibility also exists that concentrations below background were indeed site-related, rendering the assumption false. However, the impact of this possibility is minimal because metals and radioisotopes at concentrations consistent with background conditions should exhibit no different ecological effects than those commonly occurring in areas not affected by releases, regardless of their source.

7.5.4.12 Risk Characterization Uncertainty

The plant/invertebrate and wildlife SSL values for nine COPCs (arsenic, boron, lithium, mercury, manganese, molybdenum, selenium, thallium, and uranium) presented in Tables 7-1 and 7-3 were higher than the corresponding PRG values presented in Tables 7-6 and 7-7. Since the PRG values are considered more relevant for the Hanford site, SSLs for these nine chemicals cannot be used exclusively as a screening tool without understanding whether concentrations are also below PRGs. EPCs for these chemicals were compared to both SSLs and PRGs to confirm the EPCs were below both the SSL and the PRG. The chemical was dismissed from further consideration only if the EPC was below both the SSL and PRG values. For these nine chemicals, if an EPC was greater than either the SSL or PRG, the chemical was carried into the background evaluation for that specific waste site decision unit. However, there were no waste site decision unit-chemical-receptor combinations for these nine chemicals with PRGs less than SSLs where the EPC was greater than the PRG but below the SSL. In all cases, the EPC

was either below both values or above both values. Thus, the initial screening characterization with SSLs did not underestimate risk by eliminating risks that should have been considered further. Waste site decision unit-chemical-receptor combinations where the EPC was above both the SSL and PRG are discussed in the SMDP (Section 7.6).

7.5.4.13 Groundwater Pathway Completeness

Wildlife are exposed to contaminants through multiple pathways as described in Section 7.3 and shown in Figure 7-1. Most exposure is through consumption of contaminated prey and incidental ingestion of contaminated media (soil) and from external radiation for radionuclides. The risk models presented in Section 7.3 include the primary exposure associated with the soil medium, but do not include any exposure contribution from contaminated groundwater or seeps when used as a drinking water source. Neither of these pathways (groundwater or seep ingestion) represent a significant contribution to total contaminant exposure. However, the uncertainty of the contribution of drinking water as a significant pathway of exposure was explored further qualitatively for groundwater and quantitatively for seeps as a drinking water source.

Groundwater Exposures to Wildlife

Groundwater was identified as an exposure medium for ecological receptors in the upland environment under a potential scenario where groundwater is used for crop irrigation. This is not the current exposure scenario for the 100-K Area as there is an IC on the application of irrigation water for residential scenarios with crop irrigation until groundwater concentrations meet drinking water standards. This potential future scenario is not expected to be significant relative to other pathways that were directly evaluated in this BERA. Under a crop irrigation scenario, the water would infiltrate the soil and contaminants would either be taken up into plant tissues, partition to soil, or leach through soil to the groundwater table. Under any of these scenarios, the exposure to biota would either be direct exposure to contaminated soil, through the consumption of plants that have taken up contaminants (both radiological and nonradiological) from the groundwater, or from incidental ingestion of soil to which groundwater contaminants have partitioned. This complete pathway is intended for irrigation with groundwater only in areas where crops are grown for human consumption. Effects of irrigation on native plant communities would not be an assessment endpoint for this scenario because a crop irrigation land-use scenario is intended to grow specific types of crops (plants) by design and not support a diverse plant community. Crop fields also provide a lower habitat quality for many wildlife species depending upon the time of year and height of aboveground portions of crops, which may limit exposure. Overall, exposure to wildlife resulting from crop irrigation would be minimized due to wildlife and nuisance pest management programs that will be in place to discourage use by wildlife and kill pests (invertebrates) for successful large-scale or domestic farm crop production. This lower quality habitat will provide limited exposure to birds and mammals because of these pest and wildlife management programs. Exposure is also limited to the portions of the year when edible portions of crops are present. Under neither scenario would there be sufficient exposure to wildlife to result in a population level effect. Inclusion of groundwater as a drinking water ingestion pathway in the development of SSLs and PRGs is, therefore, not considered warranted (negligible exposure pathway).

Estimating Exposure to Nonradionuclides in Seeps

Estimating drinking water exposure can be complicated. Limited data are available and the presence of seeps and observed concentrations depend on river stage and, for several species of birds, migration patterns are also a factor. Assuming that wildlife meet their daily drinking water requirements from the seeps instead of a more available source, such as the river, is a conservative approach meant to evaluate the upper-bound risk estimate. Therefore, although it represents an overestimate, EPCs of the seep concentrations in 100-K were used for simplicity, and calculated using ProUCL software in the same way

as were soil EPCs (Section 7.3.3). As with soil, the 95% UCL of the arithmetic mean concentration of the analyzed constituent in seeps was employed as the drinking water EPC, when sufficient data were available, else the EPC was the maximum detect. While filtered (dissolved) water data are used in evaluations of the effects on aquatic receptors because concentrations are bioavailable, unfiltered (total – dissolved and particulate) concentrations are more appropriate for drinking water, as bioavailability may change within the digestive tract. Both were included to be comprehensive as in rare cases filtered measurements can be higher than unfiltered.

The estimates of nonradionuclide (chemical) exposure from drinking water ingestion by wildlife include the use of a simplified model whereby the rate of ingestion is standardized to the body weight of the receptor on a per kilogram basis. The simplified allometric scaling equations presented in Calder and Braun, 1983, "Scaling of Osmotic Regulation in Mammals and Birds," were used to estimate water ingestion as the number of liters consumed per kilogram body weight per day. These rates of ingestion were then multiplied by the concentration of COPECs to calculate the total dose from the drinking water pathway as shown below:

$$Dose = \lfloor [Water \times DWIR] \rfloor x\ AUF$$

where:

Dose = drinking water exposure (mg/kg body weight/day)

Water = chemical concentration in seep water (mg/L)

DWIR = drinking water ingestion rate (L/kg body weight/day)

AUF = area use factor (area of site/home range of receptor) (unitless).

Drinking water ingestion was estimated for several species of birds and mammals (Table H-11) expected to occur in the 100-K riparian area along the Columbia River, with the initial assumption that they reside at the site and fulfill their drinking water requirements exclusively from the seeps, but only for 9 months of the year (AUF = 0.75). For all species, seeps are not available when the river stage is high from snowmelt[22]. For one quarter of the year between mid-April and mid-July, which coincides with when migratory species are present, the seeps are below the river and are inaccessible. Bats use a combination of hibernating and seeking alternative sources of emergent insects during the winter months (WDFW, 2004, *Living with Wildlife: Bats*) (AUF = 0.5). Estimates are not included for small mammals because they maintain water balance through excreting concentrated urine, obtaining water from food and water generated during metabolism (Verts and Kirkland, 1988, "*Perognathus parvus*").

Freshwater seep drinking ingestion HQs for nonradiological chemicals were estimated as the ratio of estimated ingestion doses to TRVs. The TRVs employed were the same as those used to develop the wildlife PRGs as presented in CHPRC-00784 and CHPRC-01311.

$$HQ = Dose/TRV$$

where:

HQ = ecological hazard quotient (unitless)

Dose = drinking water exposure (mg/kg body weight/day)

TRV = toxicological reference value (mg/kg-body weight-day).

[22] More information on river stage is found in Chapter 4.

Estimating Exposure to Radionuclides in Seeps

For radionuclides, the HQs for evaluating freshwater seep drinking water ingestion were simply a ratio of the measured concentrations in water multiplied by the AUF and divided by the BCGs for wildlife. The lowest water BCG of terrestrial or riparian animal receptors were taken from the Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) or were calculated using DOE/EH-0676 when not available. EPCs were estimated with the same approach as described for nonradionuclides (UCL-95 or maximum detect). The same AUFs employed for non-radionuclides were used for radionuclides (0.75 [9 months] for all animals except bats [AUF of 0.5; 6 months]). SOFs were calculated as described in Section 7.4.1.

$$HQ = (EPC*AUF)/BCG$$

where:

HQ = ecological hazard quotient (unitless)

EPC = radionuclide concentration in seep (pCi/L)

AUF = area use factor

BCG = biota concentration guides (pCi/L).

Total Combined Pathway Exposure Evaluation

A total combined pathway analysis was completed with extremely conservative assumptions. The highest receptor drinking water ingestion HQ was added to the highest receptor food ingestion based HQ at each waste site decision unit to estimate the total contaminant ingestion, regardless of species. More specifically, the highest food ingestion and drinking ingestion HQs at a given waste site decision unit may not be for the same species. However, for simplicity and conservatism, the two were added to understand the additional risk to any wildlife from drinking from seeps and whether it is a significant pathway (i.e., contributing significantly toward the total HQ).

The lowest soil PRG is less than the lowest soil SSL for 10 COPCs, so the lowest soil PRG was conservatively used in the evaluation. For those chemicals for which the lowest soil PRG is greater than the lowest SSL, EPCs were also compared to SSLs.

Results

The results of the comparisons for nonradionuclides and radionuclides are provided in Appendix H (Tables H-11 to H-15). Results of filtered concentration and unfiltered concentration data were evaluated separately. Results were not pooled so as not to bias any one sampling event at which both measurements occurred. The drinking water ingestion HQs for each waste site decision unit from Table H-11 for nonradionuclides and the wildlife terrestrial pathway ingestion HQs from Tables H-7 (food ingestion HQs based on SSLs) and H-9 (food ingestion HQs based on PRGs), are inputs for a total combined exposure HQ (Tables H-13 and H-14). The radionuclide SOFs from drinking water ingestion in Table H-12 and waste site-specific terrestrial pathway ingestion by wildlife/external radiation to wildlife from Table H-7 are shown in Table H-15 as inputs for total radionuclide SOF. The addition of drinking ingestion to the exposure models presented in this chapter (Section 7.3.2) does not alter the risk characterization results presented in Table 7-5 (screening level) or the baseline refinement summarized in Table 7-8.

Evaluation of EPCs for seeps along the 100-K riparian area to TRVs resulted in HQs of <0.1 for all chemicals (Tables H-11 and H-12), except for aluminum, carbon-14, and the additive exposures of radionuclide SOF. As noted in Section 7.1.3, the potential for aluminum toxicity in the upland environment was not estimated because the pH of the upland soil limited the bioavailability. Therefore, riparian wildlife risk from aluminum exposure to seeps is the primary exposure and as noted in

Tables H-13 and H-14, where HQs are well below 1.0, the results indicate that no further evaluation in drinking water is warranted.

The evaluation of carbon-14 seep data resulted in an HQ of 1.1. Carbon-14 is also the driver for the radionuclide SOF of 1.2 (Table H-15) at all waste sites evaluated. As shown in Table 7-9, carbon-14 was detected in 21 samples from two seeps, 100-K Spring 63-1 and 100-K Spring 68-1. Two samples collected in 2013 from 100-K Spring 63-1 exceeded the BCG of 609 pCi/L, but concentrations declined in subsequent years to levels below the BCG. While there have been individual measurements of carbon-14 above the generic BCG of 609 pCi/L, these measures do not constitute an unacceptable risk to a population of riparian wildlife frequenting the 100-K Area. BCGs are intended to be used in exposure modeling; therefore, the comparison of EPCs is appropriate (even for screening evaluations) rather than maximum detected concentrations. However, the EPCs presented in Appendix H, Table H-12, collected from three seeps and a very small area are more representative of the overall chronic exposure to an individual, not the exposure to a wildlife population that would be drinking from seeps and directly from the Columbia River shoreline, upstream and downstream of the one seep at 100-K with higher concentrations of carbon-14. As discussed in Chapter 4, the BCGs are intended to protect endemic populations. When exposure to an individual is less than the BCG, populations of wildlife (not just individuals) are considered adequately protected. In this case, while the EPCs are slightly above the BCG, they are heavily driven by two samples from 5 years ago. Given that patterns since then have not exceeded the BCG, and that the EPC is a gross overestimate of actual exposure to wildlife populations, there is no significant risk to wildlife populations from carbon-14 in seeps and no further evaluation is warranted.

Table 7-9. Carbon-14 Results in 100-K Area Seeps

Date	Result (pCi/L)		Date	Result (pCi/L)	
100-K SPRING 63-1			**100-K SPRING 63-1**		
9/21/2016	45.4		10/21/2014	254	
9/20/2016	70.4		10/8/2014	414	
7/21/2016	302		9/23/2013	1480	
7/21/2016	-6.37	U	9/9/2013	2150	
5/18/2016	83.9		10/29/2012	137	
5/18/2016	0.547	U	8/29/2012	63.6	
1/27/2016	110		10/20/2003	608	
1/27/2016	-1.98	U	**100-K SPRING 68-1**		
10/5/2015	82		10/27/2014	16.2	
9/30/2015	51.7		10/8/2014	22.1	U
9/30/2015	15.5	U	10/8/2013	38.7	
7/8/2015	341		10/18/2012	57.3	
100-K SPRING 63-1 (con't)			**100-K SPRING 68-1 (con't)**		
7/8/2015	-11.8	U	10/1/2012	8	U
4/9/2015	92.3		11/10/2005	10.5	
4/9/2015	8.41	U	11/10/2003	97	

Table 7-9. Carbon-14 Results in 100-K Area Seeps

Date	Result (pCi/L)		Date	Result (pCi/L)	
1/14/2015	9.18	U	**100-K SPRING 82-2**		
1/14/2015	-6.64	U	9/20/2016	10.1	U
1/14/2015	-6.51	U	10/22/2015	-0.722	U
1/14/2015	-8.62	U	10/27/2014	0.126	U

U = non detect at the reporting limit shown

The same conclusion is reached even when considering the drinking ingestion in combination with total ingestion from terrestrial pathways (Appendix H, Table H-15). The total exposures exhibited in radionuclide SOFs is greater than 1 at all waste sites presented in Table H-15, which is driven by the carbon-14 seeps EPC except at two locations (100-K-6_Shallow and 100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1). For those driven by the seeps HQ, the total risk is insignificant since the drinking water risk is not significant. For the 100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1 decision unit and the 100-K-6_shallow decision unit, the HQ is driven by soil but as shown in the SMDP, these soil samples were collected deeper than 4.6 m (15 ft) bgs. Also, any animals residing at the waste site would be extremely unlikely to meet their metabolic needs for water exclusively from the small areas represented by the 100-K seeps. Thus, the added risk from seep water consumption was considered minimal, there is no unacceptable risk to wildlife populations from carbon-14 in seeps or soil, and no further evaluation of carbon-14 is warranted.

7.5.4.14 Risk Estimates Associated with Remedial Investigation and Limited Field Investigation Soil Data

In addition to the waste site remediation data (CVP/RSVP), two additional sources of data were considered for use in the ERA. These sources of data include (1) vadose zone soil analytical data collected for the RI to fill data gaps associated with the nature and extent of contamination or associated with understanding the fate and transport of contaminants and (2) LFI data collected in 1992 from the 100-K Area (detailed in Chapter 1). These data were collected for purposes other than fulfilling needs of risk assessment; as such, they were not used to quantitatively evaluate risks. However, these data were evaluated qualitatively by comparing concentrations of analytes to risk-based thresholds to determine if the results could be useful for risk management decisions.

RI and LFI data are summarized in more detail in Chapter 6. All RI and LFI soil data from the soil borings and wells described in Chapter 6 were compared to the PRGs used in the ecological risk assessment. Detailed data sets and vertical profiles are provided in Chapter 4, and a summary of the soil borings/wells and associated depth intervals for data in the ecological risk assessment is provided in Appendix H (Table H-16).

Similar to the CVP/RSVP data, soil data from each soil boring, well, or test pit were grouped by depth. Soil data were processed and reduced using the same methods as those described in Section 7.1. Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs were combined, and the maximum detected concentration was compared to the Hanford Site background concentration and the

lowest available ecological PRG value[23]. Soil samples collected from depth intervals greater than 4.6 m (15 ft) bgs were not evaluated because they extend beyond the standard point of compliance for ecological receptors defined by MTCA ("Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]).

A comparison of the range of detected concentrations to Ecological PRGs from each of these sample locations is provided in Table H-17. A summary of the wells and test pits that report any detected concentration greater than the ecological PRG is provided in Table 7-10. Four RI boreholes (199-K-184, 199-K-186, 199-K-188, 199-K-189) and three LFI sample locations (199-K-40, 100-KR-1-TP1, and 100-KR-1-TP-2) report soil concentrations greater than ecological PRGs. For all the LFI sample locations, these waste sites have been remediated under the Interim Action ROD. Analytical results at the remediated waste sites (from samples collected before remedial actions were implemented) show detections of mercury, selenium, and phthalate above ecological PRGs. Interim remedial actions (RTD) have mitigated any potential ecological impacts associated with these waste sites.

- At 199-K-184, a single chromium result (276 mg/kg) from the 1.5 to 2.3 m (5.0 to 7.5 ft) bgs depth interval was greater than the ecological PRG value of 109 mg/kg. However, this value is one of four split measurements recorded at the same location (for the purposes of conducting batch leach tests). The other three measurements at the same location are 5.1, 6.2, and 13.9 mg/kg, with an average concentration at this location of about 75 mg/kg, which is below the ecological PRG. All the individual measurements throughout this borehole are below background with one exception (concentration value of 26.9 mg/kg) at a depth of 20 m (67 ft) bgs.
- At 199-K-186, a single vanadium result (90.4 mg/kg) from the 1.5 to 1.8 m (5.0 to 6.0 ft) bgs depth interval was greater than the ecological PRG value of 43 mg/kg. While this is the only detected vanadium concentration (out of over 20 measurements) above background (90th percentile of Hanford soil background data set), it is lower than the maximum observed background concentration (97.9 mg/kg) and is within the expected range of background concentrations. No ecological effect associated with vanadium is expected at this location.
- At 199-K-188, a single mercury result (0.63 mg/kg) from the 1.5 to 1.9 m (5.0 to 6.25 ft) bgs depth interval was greater than the ecological PRG value of 0.30 mg/kg. Out of 25 mercury measurements at this well, 23 non-detects were found; and two values were above background. No ecological impact is expected associated with mercury at this location.
- At 199-K-189, a single molybdenum result (2.19 mg/kg) from the 3.1 to 3.9 m (10.2 to 12.7 ft) bgs depth interval was greater than the ecological PRG value of 2 mg/kg. This measurement is bracketed by two detections below 1 mg/kg at depths from about 2.7 to 5.2 m (9 and 17 ft) bgs. No ecological impact is expected associated with molybdenum at this location.

[23] For example, a wildlife risk for a specific contaminant was driven by an estimated exposure to a badger; but the size of the site is 20 m^2, representing a minimal portion of the total required foraging area for a badger; and the site does not represent a preferential feeding area.

Table 7-10. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone Ecological Risks?	CVP/RSVP Data	Shallow Zone Ecological Risks?	LFI Data	Shallow Zone Ecological Risks?
Soil Borings Installed to Characterize Residual Contamination Beneath the Remediated Waste Site						
116-K-2 Effluent Trench (West end)	199-K-200 (C7831)	No samples collected from this depth range.	CVP-2006-00001	No individual risks > thresholds	199-K-41 (A5748)	No individual risks > thresholds
116-K-2 Effluent Trench (East end)	199-K-201 (C7832)	No samples collected from this depth range.				
Wells Installed to Characterize Contamination in the Unconfined Aquifer						
199-K-183 (C7683)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--
199-K-185 (C7685)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--
199-K-187 (C7687)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--
199-K-190 (C7690)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--
199-K-189 (C7689)	No individual risks > thresholds	Molybdenum (3.1 to 3.9 m [10.2 to 12.7 ft] bgs)	--	--	--	--
199-K-191 (C7691)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--
199-K-193 (C7693)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--

Table 7-10. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone Ecological Risks?	CVP/RSVP Data	Shallow Zone Ecological Risks?	LFI Data	Shallow Zone Ecological Risks?
199-K-194 (C7694)	No samples collected from this depth range.	No samples collected from this depth range.	--	--	--	--
199-K-186 (C7686)	No individual risks > thresholds	Vanadium (1.5 to 1.8 m [5 to 6 ft] bgs)	--	--	--	--
Wells Installed to Characterize Contamination Beneath the Unconfined Aquifer in the RUM						
K RUM Well 1	199-K-184 (C7684)	Chromium (1.5 to 2.3 m [5 to 7.5 ft] bgs)	--	--	--	--
K RUM Well 2	199-K-192 (C7692)	No individual risks > thresholds	--	--	--	--
K RUM Well 3 at 120-KE-6	199-K-188 (C7688)	Hg (1.5 to 1.9 m [5 to 6.25 ft] bgs)	--	--	--	--
K RUM Well 4 at 100-K-97	199-K-195 (C7695)	No individual risks > thresholds	--	--	--	--
Soil Borings Installed during LFI to Characterize Priority Waste Site in 100-KR-1 OU						
116-K-1 Crib	--	--	CVP-2003-00024	No individual risks > thresholds	199-K-40 (A5747)	Hg (0 to .3 m [0 to 1 ft], 1.2 to 1.8 m [4 to 6 ft] bgs)
116-KW-3 Retention Basin	--	--	CVP-2004-00001	No individual risks > thresholds	199-K-38 (A5745)	No individual risks > thresholds
116-KW-3 Retention Basin	--	--			100-KR-1-TP-3 (7105)	No individual risks > thresholds
116-KW-3 Retention Basin	--	--			100-KR-1-TP-4 (7106)	No individual risks > thresholds
116-KE-4 Retention Basin	--	--	CVP-2005-00002		199-K-39 (A5746)	No individual risks > thresholds

Table 7-10. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone Ecological Risks?	CVP/RSVP Data	Shallow Zone Ecological Risks?	LFI Data	Shallow Zone Ecological Risks?
116-KE-4 Retention Basin	--	--		No individual risks > thresholds	100-KR-1-TP-1 (7103)	Bis(2-ethylhexy) phthalate (0 to 3 m [0 to 10 ft] bgs), Se (0 m [0 ft] bgs)
116-KE-4 Retention Basin	--	--			100-KR-1-TP-2 (7104)	Hg (0 to 4.5 m [0 to 15 ft] bgs)
Wells Installed During LFI to Characterize Water Quality in 100-KR-4 OU						
--	--	--	--	--	199-K-32A	No samples collected from this depth range.
--	--	--	--	--	199-K-33	No samples collected from this depth range.
--	--	--	--	--	199-K-34	No samples collected from this depth range.
--	--	--	--	--	199-K-35	No samples collected from this depth range.
--	--	--	--	--	199-K-36	No samples collected from this depth range.
--	--	--	--	--	199-K-37	No samples collected from this depth range.

Sources: CVP-2003-00024, *Cleanup Verification Package for the 116-K-1 Crib*.
CVP-2004-00001, *Cleanup Verification Package for the 116-KW-3 Retention Basin*.
CVP-2005-00002, *Cleanup Verification Package for the 116-KE-4 Crib*.
CVP-2006-00001, *Cleanup Verification Package for the 116-K-2 Effluent Trench*.
CVP = cleanup verification package
LFI = limited field investigation
RSVP = remaining site verification package

7.6 Risk Conclusions and Scientific Management Decision Point for Upland Habitats

RCBRA (DOE/RL-2007-21) COPCs were evaluated in this ERA for each decision unit (shallow, shallow-focused, and overburden) at each waste site by comparing the EPCs to the plant/invertebrate SSL, wildlife SSL, background, plants/invertebrates PRG, and wildlife PRG values. This evaluation included 55 of the 100-K Area waste sites, which have been reclassified as interim closed or no action, through the TPA (Ecology et al., 1989a) process. Waste sites were retained for additional consideration in this SMDP based on concentrations of 7 COPECs (chromium, carbon-14 (and Rads SOF), copper, mercury, selenium, vanadium, and TPH [diesel; extended carbon range; and motor oil]) (as presented in Section 7.5).

At the SMDP, the results of the ERA were considered in the context of other factors (e.g., spatial coverage, data, chemical specifics, receptors at risk, and confidence in PRGs) to support conclusions on the COECs to be brought forward to the risk manager and considered for the FS. This included agreement on the assessment endpoints, representative receptors, and complete exposure pathways that correspond to those COECs. As explained in this section, the SMDP concluded that there were no potential risks to ecological receptors in the 100-K upland waste sites and 100-KR-1 and 100-KR-2 OUs warranting further evaluation in the FS.

7.6.1 Scientific Management Decision Point Considerations

Within the process for conducting ERAs at CERCLA sites, several decision points occur at which risk managers and risk assessors agree on a path forward with respect to ecological risk associated with a site. Typical variations include the following risk assessment outcomes:

- No unacceptable potential risks to ecological receptors (e.g., risks are sufficiently low and below risk-based thresholds such as SSLs or PRGs)
- Potential for risks to ecological receptors, but the risks do not warrant the evaluation of remedial alternatives in the FS because of a number of considerations[24]
- Potential for risks to ecological receptors, but there is uncertainty in one or more component of the ERA that warrants the evaluation of remedial alternatives in the FS
- Need to evaluate remedial alternatives in the FS based on the protection of another receptor or exposure pathway (e.g., human health) that would address any potential ecological risks
- Potential for risk to ecological receptors warranting evaluation of remedial alternatives in the FS

With the various risk assessment outcomes listed above, agreement is needed on the following elements to assist in the evaluation of remedial alternatives in the FS: COCs, assessment endpoints, exposure pathways, and risk questions. In order to achieve one of the risk assessment outcomes with confidence, several factors and supporting information were considered in the conclusion of the risk assessment to assist risk management decisions. These outcomes were considered within the context of other exposure pathways and receptors evaluated at the same site. The following factors were considered to interpret the

[24] For example, a wildlife risk for a specific contaminant was driven by an estimated exposure to a badger but the size of the site is 20 m^2 (215.2 ft^2), representing a minimal portion of the total required foraging area for a badger and the site does not represent a preferential feeding area.

results of the baseline ecological risk characterization and determine whether the site requires evaluation of remedial alternatives in the FS:

- Spatial characteristics of the remediated waste site (area and excavation depth of the remediated waste site)
- Proximity and size of nearby waste sites and unimpacted habitat
- Number and location of samples collected at the site
- Data quality (presence of qualifiers and adequacy of detection limits)
- Frequency that risk-based thresholds are exceeded and the location(s) of those exceedances
- Chemical-specific properties of each COC (e.g., potential to biomagnify in the food web or persist in the environment)
- Identification of specific receptors that have the potential for adverse health effects (feeding guild [plants; insects; or omnivorous, herbivorous, insectivorous, or carnivorous wildlife], proportion of receptors affected, likelihood of population or community level effects, home range of the receptors at risk relative to the area exceeding risk-based thresholds)
- Recalculation of the EPC based on the home range (home ranges are found in Appendix H, Table H-6) of the receptor or estimating the residual risk after the removal action has been implemented
- Evaluation of PRG (i.e., level of confidence, basis, and relation to other PRGs such as those for human health or groundwater protection)

Within the 100-K Area, 20 waste sites were reported with COPEC concentrations greater than their respective PRGs (or SSLs for carbon-14 and TPH-D), and 7 additional waste sites were retained due to an uncertainty needing further consideration (TPH). Figures showing the location and concentration of COPECs reported with an HQ greater than 1.0 or an uncertainty are provided in Appendix H. During development of the risk assessment, the factors described in this subsection were evaluated and resulted in a conclusion, as part of the SMDP, that no waste sites be carried forward into the FS for evaluation of remedial alternatives. Decisions for the 100-K Area were based on the following subset of factors:

- Depth of samples exceeding thresholds relative to the 4.6 m (15 ft) bgs standard point of compliance for ecological receptors defined by MTCA (WAC 173-340), depths for Hanford receptors reported in Sample et al., 2015.
- Number and frequency of exceedances of the risk thresholds (PRGs)
- Magnitude of exceedance relative to the risk thresholds (HQ)
- Confidence in the ecological risk thresholds defining the exceedances
- Quality of the sample data defining the exceedances
- Location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances
- Area of exceedance relative to home range of receptor exceeding and relative to area of unimpacted nearby habitat

A summary of the rationale by chemical and receptor is provided in the following subsections with the details for each specific waste site-decision unit-chemical combination found in Table 7-11. Further details supporting the analysis in Table 7-8 are found within Appendix H, Table H-10.

7.6.2 Plants

Copper (1 waste site decision unit), mercury (10 waste site decision units), selenium (3 waste site decision units), vanadium (6 waste site decision units), and carbon-14 (1 waste site decision unit) were measured at concentrations above terrestrial plant PRGs. The maximum acceptable adverse effect levels generally selected for community level assessment endpoints are LOECs, however, LOECs were not established because the highest concentrations measured produced no significant effect in most cases (ECF-HANFORD-11-0158); therefore, plant PRGs are conservatively based on NOECs with no upper bound (i.e., the NOEC could be even higher). The conclusion was that there is no unacceptable risk to plant communities as described below:

- Copper is not expected to have an adverse effect on the plant community at a single site where one sample is slightly above the PRG that is based on a NOEC. In addition, plant roots in soil have an ability to sequester metals and to regulate their uptake (Badri, et al., 2009).
- Risks to plants from mercury are unlikely because of low confidence in the PRG[25]. Inorganic mercury plant PRG exceedances were infrequent and, in most cases, spatially distinct or have been remediated, so would not cause a community level effect.
- Selenium is not expected to affect the plant community adversely because there is low confidence in the analytical method; detected concentrations and method detection limits (MDLs) at the decision unit waste sites are reported within the same range as the PRG values. Selenium is not expected to affect the plant community adversely because the PRG is based upon an unbounded NOEC (i.e., no data are available to define the threshold where low level effects begin to occur); thus, there is no certainty of any risk being associated with exceeding a no effect concentration.
- Risk to plants from vanadium is unlikely because the PRG is based upon an unbounded NOEC (i.e., no data are available to define the threshold where low level effects begin to occur); thus, there is no certainty of any risk being associated with exceeding a no effect concentration. If effects did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby.
- Carbon-14 exceeded the SSL in a soil sample that was collected from a depth greater than the standard point of compliance at 4.6m (15ft) bgs. The SOF for radionuclides, of which 94% or greater is comprised of carbon-14, was driven by this location also. In other words, without exposure to this one sample deeper than the point of compliance, neither carbon-14 nor the SOF would exceed the protective radiation dose threshold. Direct contact to elevated concentrations within the measurement area and biomobilization are incomplete.

[25] This PRG is from a report by DOE contractors at the Oak Ridge National Laboratory (ES/ER/TM-85/R3) who reported low confidence in the likelihood that effects would occur at this level reported to be toxic in one study. However, few published studies on effects of mercury on plants were available. The value from Oak Ridge was selected for the Hanford Site because it is greater than the PRG reported in the RCBRA (DO/RL-2007-21), which was a NOEC.

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Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-102	100-K-102_Shallow_1	Non-Rad	Mercury	5.09	0.3	1.6	16	2,973 m^2 (32,001 ft^2)	Driven by a single result from an area >4.6 m (15 ft)	1	<0.046 to 5.56	0.22 to 18.53	0.04 to 3.48	No. The single soil sample that exceeded the PRGs was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-102	100-K-102_Shallow_1	Non-Rad	Selenium	1.7	2.02	1.4	16	2,973 m^2 (32,001 ft^2)	9.8 m (0 to 32 ft)	7	0.665 to 2.3	0.33 to 1.14	0.48 to 1.64	No. 3 of 16 exceeded the plant PRG. However, there is low confidence in the analytical method and the size of the waste site is very small. The plant PRG is a NOEC established at the highest concentration tested among site specific studies, so the lowest concentration at which an effect may occur is unknown but is greater than the PRG. The EPC is only slightly higher than this NOEC. If adverse effects to plants did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby. For wildlife, the EPC only exceeded the PRG for the deer mouse, and exposure estimates do not include consideration of AUFs. As shown in Table H 6 in Appendix H, the deer mouse has the smallest home range of any receptor (890 m^2 [9,670 ft^2]; Bowers and Smith, 1979) and its home range is over three times greater than the acreage of the site. Thus, employing AUFs yields hazard quotients below 1 indicating population level adverse effects are not likely.
100-K-102	100-K-102_Shallow_2	Non-Rad	Mercury	1.21	0.3	1.6	21	2,973 m^2 (32,001 ft^2)	Driven by two results from an area >4.6 m (15 ft)	2	<0.025 to 3.43	0.14 to 11.43	0.03 to 2.14	No. The two soil samples that exceeded the PRGs were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete. Further, The EPC is only slightly greater than the low confidence plant PRG for inorganic mercury. Also, the EPC was less than the lowest wildlife PRG for a biomagnifying compound.
100-K-102	100-K-102_Shallow_Focused	Non-Rad	Vanadium	86.7	89.4	43.2	18	2,973 m^2 (32,001 ft^2)	>4.6 m (15 ft)	16	34.5 to 86.7	0.39 to 0.97	0.80 to 2.01	No. The soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-106	100-K-106_Overburden_ Focused_2	Non-Rad	Total petroleum hydrocarbons - m otor oil (high boiling)	43	No effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	3	3,000 m^2 (32,291 ft^2)	Surface to 10.8 m (35 ft)	1	<10 to 43	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.
100-K-106	100-K-106_Shallow_ Focused_3	Non-Rad	Total petroleum hydrocarbons - motor oil (high boiling)	46	No effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	1	Sample representative of 37 m^2 (398 ft^2)	>4.6 m (15 ft)	1	46	—	—	No. The 46 mg/kg sample was collected at the deep zone interface (4.6 m [15 ft]). Direct contact within point of compliance is incomplete.
100-K-106	100-K-106_Shallow_ Focused_6	Non-Rad	Total petroleum hydrocarbons - motor oil (high boiling)	50	No effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	1	Sample representative of 37 m^2 (398 ft^2)	>4.6 m (15 ft)	1	50	—	—	No. The 50 mg/kg sample was collected at the deep zone interface (4.6 m [15 ft]). Direct contact within point of compliance is incomplete.
100-K-109	100-K-109_Shallow_Focused	Non-Rad	Selenium	1.9	2.02	1.4	2	1,040 m^2 (11,194 ft^2)	>4.6 m (15 ft)	2	1.6 to 1.9	0.79 to 0.94	1.14 to 1.36	No. The two soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-110	100-K-110_Shallow	Non-Rad	Mercury	0.43	0.3	1.6	36	32,738 m^2 (352,388 ft^2)	0.91 m (0 to 3 ft)	5	<0.0063 to 2.54	0.24 to 8.47	0.05 to 1.59	No. 5 of 36 samples slightly exceeded the low confidence plant PRG based on inorganic mercury. Adverse effects to plants are unlikely. If effects did occur, community level adverse effects are not likely given the small size of the site compared to the available habitat refugia nearby. Also, the EPC is less than the lowest wildlife PRG for a biomagnifying compound.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-110	100-K-110_Shallow	Non-Rad	Selenium	1.8	2.02	1.4	36	32,738 m^2 (352,388 ft^2)	0.91 m (0 to 3 ft)	11	<3.2 to 2.31	0.30 to 1.14	0.44 to 1.65	No. All 36 selenium results were qualified as estimated because the reported concentrations were greater than the MDL (0.32 to 0.34 mg/kg) but less than the PQL (3.2 to 3.4 mg/kg). 20 of the 36 results were additionally qualified due to method blank contamination. The PQL (3.2 to 3.4 mg/kg) reported by the WSCF laboratory for the selenium results was greater than the RDL of 1.0 mg/kg (as defined in the 100-K SAP for EPA methods 200.8 and 6020). Due to inherent uncertainty associated with detected concentrations (0.62 to 2.3 mg/kg) reported within the MDL-PQL range and because background values are also within MDL-PQL range, it is likely that the estimated selenium concentrations from the WSCF data were less than or equal to the background values. The WSCF estimated detected results can be used as indicators that selenium was present but they cannot be used with certainty as quantified concentrations or to confirm that selenium was present due to site related activities and not naturally occurring background. Therefore, the calculated EPC of 1.8 mg/kg cannot be used for decision making purposes at 100-K-110-shallow decision unit. Further details are found in Chapter 6.
100-K-111	100-K-111_East_Rip_ Surface_Focused	Non-Rad	Chromium	133	149	109	1	Focused Sample #J1RR98 taken from 1 m^2 area (10.76 ft^2)	No depth given Surface	1	133	0.89	1.22	No. One sample exceeded the killdeer LOAEL based PRG in this small sampling area. As shown in Table H-6 in Appendix H, the home range of the killdeer is significantly greater than the acreage of the site. The killdeer has the smallest home range of any of the wildlife evaluated at 80,128 m^2 (862,488 ft^2) (Mace, 1971), over 10,000 times greater than the size of the waste site. Thus, employing AUFs yields hazard quotients below 1 indicating population level adverse effects are not likely.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-111	100-K-111_West_Surface	Non-Rad	Chromium	129	149	109	12	Sampling decision area = 140,000 m^2 (1,506,947 ft^2)	Sample #J1RR00, no depth given J1RR00 was from the surface; other samples in this set were up to 0.8 m (8.6 ft) deep	1	12.7 to 257	0.09 to 1.72	0.12 to 2.36	No. One sample exceeded the killdeer LOAEL based PRG in this small sampling area. As shown in Table H-6 in Appendix H, the home range of the killdeer is 80,128 m^2 (862,488 ft^2) (Mace, 1971). The EPC is driven by one elevated concentration in 12 samples. The single exceedance within the site is limited in spatial extent. Killdeer and other receptors would not forage exclusively in the area of this single elevated exceedance but instead across the full extent of their home ranges, the remainder of which contained chromium at concentrations between 12.7 mg/kg and 66.6 mg/kg, and 9 of the 12 samples below 20 mg/kg. An area weighted average would indicate limited exposure to wildlife populations. Thus, there is no unacceptable risk of population level adverse effects to wildlife.
100-K-14, 126-KE-2	100-K-14, 126-KE-2_Shallow	Non-Rad	Mercury	0.49	0.3	1.6	12	125.3 m^2 (1,348.7 ft^2)	3.4 m (0 to 11 ft)	3	<0.0042 to 1.43	0.02 to 4.77	0.003 to 0.89	No. The size of the waste site is very small at 125.3 m^2 (1,349 ft^2). Effects to plants are uncertain given the low confidence in the PRG based on inorganic mercury. If adverse effects did occur, community level adverse effects are highly unlikely given the small size of the site compared to the available habitat refugia nearby.
100-K-14, 126-KE-2	100-K-14, 126-KE-2_Shallow	Non-Rad	Vanadium	99.1	89.4	43.2	12	125.3 m^2 (1,348.7 ft^2)	3.4 m (0 to 11 ft)	12	75.8 to 123	0.85 to 1.38	1.75 to 2.85	No. The EPC exceeded the killdeer and California quail PRGs but the exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the home ranges of the killdeer and California quail are significantly greater than the acreage of the site. The killdeer has the smallest home range at 80,128 m^2 (862,488 ft^2) (Mace, 1971), greater than 1,000 times the size of the waste site. Thus, employing AUFs yields hazard quotients below 1 indicating population level effects are highly unlikely. Finally, there are no known sources of vanadium. The PRG for plants is an unbounded NOEC, thus there is uncertainty as to what concentration at the site would result in an adverse community level risk. If effects did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5N	Non-Rad	Selenium	2.4	2.02	1.4	8	195 m^2 (2,099 ft^2)	11.0 m (0 to 36 ft)	8	2.1 to 2.5	1.04 to 1.24	1.50 to 1.79	No. All samples detected only slightly exceeded the PRGs. However, there is low confidence in the analytical method and the size of the waste site is very small. The plant PRG is a NOEC, so the lowest concentration indicating an effect will be higher than the PRG. The EPC is only slightly higher than this NOEC and will not likely cause community level adverse effects. The area of the waste site is insignificant given availability and size of nearby suitable habitat without contamination outside of the 100-K Area. For wildlife, exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the deer mouse has the smallest home range of any receptor (890 m^2 [9,670 ft^2]; Bowers and Smith, 1979) and its home range is over four times greater than the acreage of the site. The PRG for the deer mouse is also the lowest. Thus, employing AUFs yields hazard quotients below 1 indicating population level adverse effects are not likely and there is no unacceptable risk.
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5S	Non-Rad	Selenium	2.4	2.02	1.4	4	195 m^2 (2,099 ft^2)	11.0 m (0 to 36 ft)	4	2.1 to 2.4	1.04 to 1.19	1.50 to 1.71	No. All samples detected only slightly exceeded the PRGs. However, there is low confidence in the analytical method and the size of the waste site is very small. The plant PRG is a NOEC established at the highest concentration tested among site specific studies, so the lowest concentration at which an effect may occur is unknown but is greater than the PRG. The EPC is only slightly higher than this NOEC. If adverse effects to plants did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby. For wildlife, exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the deer mouse has the smallest home range of any receptor (890 m^2 [9,670 ft^2]; Bowers and Smith, 1979) and its home range is over 4 times greater than the acreage of the site. The PRG for the deer mouse is also the lowest. Thus, employing AUFs yields hazard quotients below 1 indicating population level adverse effects are not likely and there is no unacceptable risk.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5S	Non-Rad	Vanadium	94.9	89.4	43.2	4	195 m^2 (2,099 ft^2)	11.0 m (0 to 36 ft)	4	72.8 to 94.9	0.81 to 1.06	1.69 to 2.20	No. The EPC exceeded the killdeer and California quail PRGs but the exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the home ranges of the killdeer and California quail are significantly greater than the acreage of the site. The killdeer has the smallest home range at 80,128 m^2 (862,488 ft^2) (Mace, 1971), hundreds of times greater than the size of the waste site. The PRG for the killdeer is also the lowest. Thus, employing AUFs yields hazard quotients below 1 indicating population levels effects are unlikely. Finally, there are no known sources of vanadium. The PRG for plants is an unbounded NOEC, thus there is uncertainty as to what concentration at the site would result in an adverse community level risk. If effects did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby.
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow	Non-Rad	Vanadium	87.5	89.4	43.2	20	195 m^2 (2,099 ft^2)	11.0 m (0 to 36 ft)	19	34.8 to 103	0.39 to 1.15	0.81 to 2.38	No. The EPC exceeded the killdeer and California quail PRGs but the exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the home ranges of the killdeer and California quail are significantly greater than the acreage of the site. The killdeer has the smallest home range at 80,128 m^2 (862,488 ft^2) (Mace, 1971), hundreds of times greater than the size of the waste site. The PRG for the killdeer is also the lowest. Thus, employing AUFs yields hazard quotients below 1 indicating population levels effects are unlikely. Finally, there are no known sources of vanadium. The EPC is less than the PRG for plants, which is an unbounded NOEC, thus no adverse community level effects are expected.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7	100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow_Focused	Non-Rad	Selenium	1.7	2.02	1.4	1	195 m^2 (2,099 ft^2)	11.0 m (0 to 36 ft)	1	1.7	0.84	1.21	No. All samples detected only slightly exceeded the PRGs. However, there is low confidence in the analytical method and the size of the waste site is very small. The plant PRG is a NOEC established at the highest concentration tested among site specific studies, so the lowest concentration at which an effect may occur is unknown but is greater than the PRG. The EPC is only slightly higher than this NOEC. If adverse effects to plants did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby. For wildlife, exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the deer mouse has the smallest home range of any receptor (890 m^2 [9,670 ft^2]; Bowers and Smith, 1979) and its home range is over 4 times greater than the acreage of the site. The PRG for the deer mouse is also the lowest. Thus, employing AUFs yields hazard quotients below 1 indicating population level adverse effects are not likely.
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_2	Non-Rad	Selenium	1.8	2.02	1.4	1	Not researched, samples > 4.6 m (15 ft)	>4.6 m (15 ft)	1	1.8	0.89	1.29	No. The single soil sample that exceeded the PRG was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71	100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_3	Non-Rad	Selenium	1.6	2.02	1.4	1	Not researched, samples > 4.6 m (15 ft)	>4.6 m (15 ft)	1	1.6	0.79	1.14	No. The single soil sample that exceeded the PRG was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-30	100-K-30_Shallow_Focused	Non-Rad	Mercury	17.5	0.3	1.6	4	36 m^2 (3, 88ft^2)	N/A - Further remediation was performed at this location after this sample was collected	4	4.3 to 17.5	14.33 to 58.33	2.69 to 10.94	No. The sample locations were remediated.
100-K-31	100-K-31_Shallow_Focused	Non-Rad	Mercury	5.2	0.3	1.6	4	36 m^2 (3,88ft^2)	N/A - Further remediation was performed at this location after this sample was collected	3	0.17 to 5.2	0.57 to 17.33	0.11 to 3.25	No. The sample locations were remediated.
100-K-32	100-K-32_Shallow_Focused	Non-Rad	Mercury	13.7	0.3	1.6	5	38 m^2 (3,88ft^2)	N/A - Further remediation was performed at this location after this sample was collected	5	2.2 to 13.7	7.33 to 45.67	1.38 to 8.56	No. The sample locations were remediated.
100-K-33	100-K-33_Shallow_Focused	Non-Rad	Mercury	6.8	0.3	1.6	9	38 m^2 (3,88ft^2)	N/A - Further remediation was performed at this location after this sample was collected	4	<0.02 to 6.8	0.20 to 22.67	0.04 to 4.25	No. The sample locations were remediated.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-34	100-K-34_Shallow	Non-Rad	Vanadium	94.4	89.4	43.2	1	4 m^2 (43 ft^2)	>4.6 m (15 ft)	1	94.4	1.06	2.19	No. The single soil sample that exceeded the PRG was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-34, 100-K-102, 1607-K3	100-K-34, 100-K-102, 1607-K3_Shallow_Focused	Non-Rad	Selenium	2.2	2.02	1.4	9	3,219 m^2 (34,649 ft^2)	>4.6 m (15 ft)	7	1 to 2.2	0.50 to 1.09	0.71 to 1.57	No. The seven soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-34, 100-K-102, 1607-K3	100-K-34, 100-K-102, 1607-K3_Shallow_Focused	Non-Rad	Vanadium	89.2	89.4	43.2	9	3,219 m^2 (34,649 ft^2)	>4.6 m (15 ft)	8	38.8 to 89.2	0.43 to 1.00	0.90 to 2.06	No. The eight soil samples that exceeded the PRG was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-4	100-K-4_Shallow	Non-Rad	Selenium	1.51	2.02	1.4	4	679 m^2 (7,309 ft^2)	>4.6 m (15 ft)	2	1.18 to 1.51	0.58 to 0.75	0.84 to 1.08	No. The two soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-6	100-K-6_Shallow	Rad	Carbon-14/Rads SOF	34.8	60.7	32	1	5 m^2 (54 ft^2)	>4.6 m (15 ft)	1	34.8	0.57	1.09	No. The sum of the Rads includes analytes that are <3% of the total sum. The primary driver of the exceedance is Carbon-14 (97%). The single soil sample that exceeded the PRGs was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area and biomobilization are incomplete. Thus, there is no unacceptable risk to wildlife populations.
100-K-6, 100-K-46, 100-K-62, 132-KE-1	100-K-6, 100-K-46, 100-K-62, 132-KE-1_Overburden	Non-Rad	Selenium	1.83	2.02	1.4	15	357 m^2 (3,842 ft^2)	>4.6 m (15 ft)	7	0.845 to 2.38	0.42 to 1.18	0.60 to 1.70	No. The soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
100-K-6, 100-K-46, 100-K-62, 132-KE-1	100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1	Rad	Carbon-14/Rads SOF	65.5	60.7	32	8	357 m^2 (3,842 ft^2)	>4.6 m (15 ft)	1	<0.45 to 65.5	0.02 to 1.08	0.03 to 2.05	No. The sum of the Rads includes analytes that are <6% of the total sum. The primary driver of the exceedance is Carbon-14 (94%). The single soil sample that exceeded the PRGs was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area and biomobilization are incomplete. Thus, there is no unacceptable risk to wildlife populations.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-84	100-K-84_Shallow	Non-Rad	Mercury	0.49	0.3	1.6	12	1,166 m^2 (12,550 ft^2)	0.91 m (3 ft)	1	<0.0048 to 0.78	0.02 to 2.60	0.004 to 0.49	No. The EPC is slightly greater than the low confidence plant PRG based on inorganic mercury. Also, there were no soil concentrations greater than the lowest wildlife PRG for a biomagnifying compound. The size of the waste site is small and the likelihood of community level adverse effects for plants is low. If adverse effects did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby.
100-K-86	100-K-86_Shallow_Focused	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	160	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	5	258 m^2 (2,777 ft^2)	0.3 to 1.5 m (1 to 5 ft)	4	9.6 to 160	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.
100-K-89, 600-29	100-K-89, 600-29_Shallow	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	60	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	13	Approximately 7,500 m^2 (24,606 ft^2)	0.3 to 3m (1 to 10 ft)	2	1.3 to 130	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-89, 600-29	100-K-89, 600-29_Shallow_Focused	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	140	200 for diesel and no effect thresholds ranged from 15- ,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	6	Representative maximum sample (14 mg/kg) 10 m^2 (1,08 ft^2) from one dig area of 15 separate dig areas	0.3 m (1 ft)	3	6.4 to 140	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.
100-K-91	100-K-91_Shallow_Focused	Non-Rad	Mercury	2.7	0.3	1.6	1	2.8 m^2 (30.1ft^2)	1.4 m (0 to 4 ft)	1	2.7	9	1.69	No. The size of the waste site is very small at 2.8 m^2 (30.1 ft^2). The home range of the deer mouse is over 270 times greater (890 m^2 [9,670 ft^2]) (Bowers and Smith, 1979) than the site size. Employing an AUF would result in a HQ <1 indicating population level adverse effects are unlikely. Effects to plants are uncertain given the low confidence in the PRG. If adverse effects did occur, community level adverse effects are not likely given the small size of the site compared to the available habitat refugia nearby.
100-K-92	100-K-92_Shallow_Focused	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	29	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	2	6 m^2 (65 ft^2)	0.6 m (2 ft)	1	11 to 29	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
100-K-95	100-K-95_Shallow	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	39	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	12	15,000 m^2 (161,458 $ft^{2)}$	0.3 to 1.5 m (1 to 5 ft)	5	2.7 to 96	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.
118-K-1	118-K-1_P1_Shallow_3	Non-Rad	Vanadium	90.5	89.4	43.2	4	33,349 m^2 (358,966 ft^2)	4.6 m (15 ft)	4	60.6 to 90.5	0.68 to 1.01	1.40 to 2.09	No. The EPC exceeds the killdeer and California quail PRGs but the exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the home ranges of the killdeer and California quail are significantly greater than the acreage of the site. The killdeer has the smallest home range at 80,128 m^2 (862,488 ft^2) (Mace, 1971), more than twice the size of the waste site. The killdeer is also the lowest wildlife PRG. Thus, employing AUFs yields hazard quotients below 1 indicating population levels effects are unlikely. Finally, there are no known sources of vanadium. The PRG for plants is an unbounded NOEC, thus there is uncertainty as to what concentration at the site would result in an adverse effect. If effects did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby.
118-K-1	118-K-1_P2_Shallow_11G	Non-Rad	Vanadium	85.4	89.4	43.2	4	33,349 m^2 (358,966 ft^2)	Surface	4	70.4 to 87.4	0.79 to 0.98	1.63 to 2.02	No. The EPC exceeds the killdeer and California quail PRGs but the exposure estimates do not include consideration of AUFs. As shown in Table H-6 in Appendix H, the home ranges of the killdeer and California quail are significantly greater than the acreage of the site. The killdeer has the smallest home range at 80,128 m^2 (862,488 ft^2) (Mace, 1971), more than twice the size of the waste site. And the lowest wildlife PRG is for the killdeer. Thus, employing AUFs yields hazard quotients below 1 indicating population levels effects are unlikely. Finally, there are no known sources of vanadium.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
118-K-1	118-K-1_P2_Shallow_ Focused_3	Non-Rad	Vanadium	99.1	89.4	43.2	3	33,349 m^2 (358,966 ft^2)	>4.6 m (15 ft)	2	41.7 to 99.1	0.47 to 1.11	0.97 to 2.29	No. The soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow_Focused	Non-Rad	Selenium	2	2.02	1.4	4	40.3 m^2 (433.8 ft^2)	>4.6 m (15 ft)	4	1.4 to 2	0.69 to 0.99	1.00 to 1.43	No. The soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4	120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4_Shallow_Focused	Non-Rad	Vanadium	93.6	89.4	43.2	4	40.3 m^2 (433.8 ft^2)	>4.6 m (15 ft)	4	71.6 to 93.6	0.80 to 1.05	1.66 to 2.17	No. The soil samples that exceeded the PRG were collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete.
128-K-2	128-K-2_Shallow_Focused	Non-Rad	Total petroleum hydrocarbon - diesel range	73.6	200[a]	193	4	18,899 m^2 (203,427 ft^2)	4.6 m (15 ft)	1	13.7 to 73.6	0.24 to 1.27	0.07 to 0.38	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
128-K-2	128-K-2_Shallow_Focused	Non-Rad	Copper	73.6	58	193	4	18,899 m^2 (203,427 ft^2)	4.6 m (15 ft)	1	13.7 to 73.6	0.24 to 1.27	0.07 to 0.38	No. Only one of four samples exceeded the invertebrate (58 mg/kg) and plant (70 mg/kg) PRGs, which are NOECs. No effects have been observed at the highest concentration of copper detected (58 mg/kg) in three separate Hanford-specific toxicity testing programs conducted on invertebrates exposed to Hanford Site soil. Thus, the PRG is an unbound NOEC because no effects were observed up to the highest concentration tested. Also, an elevated concentration at a point site does not suggest exposure is sufficient to cause an adverse effect to the plant communities. There is no certainty of any risk being associated with exceeding a no effect concentration. If effects did occur, community level effects are not likely given the small size of the site compared to the available habitat refugia nearby. Further, plants have an ability to sequester metals and to regulate their uptake (Badri, et al., 2009). Also, there are no soil concentrations greater than the lowest wildlife PRG for biomagnifying compound. There is ample unimpacted habitat for terrestrial invertebrates available in adjacent areas and along the River Corridor.
128-K-2	128-K-2_Shallow_Focused	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	1200	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	4	Each sample representative of 1 m^2 (11 ft^2) from a remediation footprint = 18,900 m^2 (20,343 ft^2)	Maximum sample location collected from >4.6 m (15 ft); second highest sample at 3 m (10 ft)	2	2.5 to 1,200	—	—	No. The maximum soil sample that exceeded the PRG was collected from a depth greater than the standard point of compliance at 4.6 m (15 ft) bgs. Direct contact within the measurement area is incomplete for this sample. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The second highest detected concentrations are within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent areas and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.

Table 7-11. Summary of Factors Considered for SDMP for the 100-KR-1 and 100-KR-2 OUs

Waste Site and Waste Site Description	Decision Unit	Analyte Group	COPEC	EPC (mg/kg or pCi/g)	Plant/ Invertebrate PRG (mg/kg or pCi/g)	Wildlife PRG (mg/kg or pCi/g)	Number of Sampling Locations	Area of Remedial Action Excavation [a]	Depth of Samples that Exceeded (bgs)	Number of Results that Exceeded PRG [b]	Range of Concentrations (mg/kg or pCi/g)	Plant/ Invertebrate Range of HQ	Avian/ Mammal Range of HQ	Carry Waste Site into FS for Remedy Evaluation?
600-29	600-29_Shallow	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	31	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	13	30,000 m^2 (322,917ft^2)	0.3 to 3 m (1 to 10 ft)	1	1.1 to 71	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.
600-29	600-29_Shallow_Focused	Non-Rad	Total petroleum hydrocarbons - die sel range extended to C36	39	200 for diesel and no effect thresholds ranged from 15-1,490 [a] for motor oil	For TPH/Diesel organics, Tier 1 SSL = 356,382 mg/kg, MTCA- EISC = 6,000 mg/kg	5	100 m^2 (1,076 ft^2)	0.3 m (1 ft)	3	1.9 to 39	—	—	No. The TPH toxicity review by Efroymson et al., 2004, indicates the risk for TPH is primarily for invertebrates. The maximum detect is within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below the MTCA EISC for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The area is sufficiently insignificant in size such that any residual contamination would not adversely impact the local terrestrial invertebrate community.

References: Bowers and Smith, 1979, "Differential Habitat Utilization by Sexes of the Deer Mouse, Peromyscus maniculatus."

Efroymson et al., 2004, "Ecotoxicity Test Data for Total Petroleum Hydrocarbons in Soil: Plants and Soil Dwelling Invertebrates."

Mace, 1971, *Nest Dispersion and Productivity of Killdeers.*

a. Refer to Uncertainty Assessment (Section 7.5.4) for additional description. Value for TPH Motor oil is a range of no adverse effect concentrations and does not represent a PRG. SSLs and PRGs were not developed for TPH. Values are strictly to provide some context to concentrations detected.

— = value not available`
AUF = area use factor
bgs = below ground surface
COPEC = contaminant of potential ecological concern
EISC = ecological soil indicator concentration
EPC = exposure point concentration
HQ = hazard quotient
MTCA = Model Toxics Control Act
N/A = not applicable
NOEC = no observed effect concentration
PRG = preliminary remediation goal
SSL = soil screening level
TPH = total petroleum hydrocarbons

7.6.3 Invertebrates

Copper (1 waste site decision unit) and TPH (12 waste site decision units) were measured at concentrations above terrestrial invertebrate PRGs. Copper is not expected to affect the invertebrate community adversely because the PRGs are based on unbounded NOECs; a single exceedance at a concentration similar to the NOEC based invertebrate PRGs at each of the decision units does not indicate a community level effect. TPH (diesel range, diesel range extended to 36, and motor oil range) is not expected to have an adverse effect on the invertebrate community because site concentrations in soil are within the lower range of concentrations for motor oil that have been documented as no-effect thresholds and below for the MTCA (WAC 173-340) ecological indicator soil concentration (EISC) for diesel. Further, there is ample unaffected habitat for terrestrial invertebrates available in adjacent area and along the River Corridor. The conclusion was that there is no unacceptable risk to invertebrates from copper or TPH.

7.6.4 Wildlife

Chromium (2 waste site decision units), mercury (6 waste site decision units), selenium (12 waste site decision units), vanadium (10 waste site decision units), and carbon-14 (3 waste site decision units) were measured at concentrations above wildlife PRGs (SSL for carbon-14) (Table 7-11). These COPCs were eliminated from further consideration in the FS due to the limited area of contamination, the depth of elevated concentrations, and the chemical form of the PRG, as presented in Table 7-11 and summarized below.

These COPECs are not expected to affect wildlife receptors adversely because many waste site decision units are smaller than the relative home range of wildlife receptors. When the size of the area represented by the sample(s) was considered relative to the home range of wildlife receptors (i.e., application of an AUF), HQs were below 1.0 (chromium, mercury, selenium, and vanadium decision units), except at one location for chromium (100-K-111, Figure 7-4). Many of the exceedances were for samples taken deeper within the profile (i.e., below the maximum depth at which Hanford Site wildlife has been observed to burrow [1 m [3.3 ft] pocket mouse]; Cline et al., 1980, “Loose Rock as Biobarriers in Shallow Land Burial”). The chromium EPC at one of the two waste sites is driven by one elevated concentration, which is limited in spatial extent. Killdeer and other receptors would not forage exclusively in the area of this single elevated exceedance but instead across the full extent of their home ranges. A spatially weighted average[26] with just the one elevated sample would indicate limited exposure to wildlife populations.

At numerous waste site decision units (mercury, vanadium, selenium, carbon-14), soil samples collected from a depth greater than the standard point of compliance of 4.6 m (15 ft) bgs were included in the ERA, deviating from the risk characterization process, although these data are not representative of ecological or human health exposure. This occurred because these decision units were assigned as shallow during the waste site closeout process in order to be protective of both direct contact and groundwater protection for human health and for consistency the same shallow decision units were evaluated for both human health and ecological risk assessment. Direct contact with ecological receptors within the measurement area for these sites with data only below 4.6 m (15 ft) bgs is incomplete.

In addition, as mentioned in the uncertainty discussion, the mercury TRVs for wildlife were based on the methylated form. While there is some methyl mercury present in some site soil, the dominant form in oxic soil is inorganic mercury. Thus, the hazard quotients for the less toxic inorganic mercury would be lower

[26] The EPCs estimated using Pro UCL assume that each sample is given equal weight. A spatially weighted average would provide weight to each sample based on the spatial coverage each sample represents, simplistically determined by distance between samples.

and the comparison presented represents an overestimate risk. The final conclusion was that there are no population-level effects to avian and mammalian receptors at any of the waste sites evaluated including those with some measured samples above PRGs.

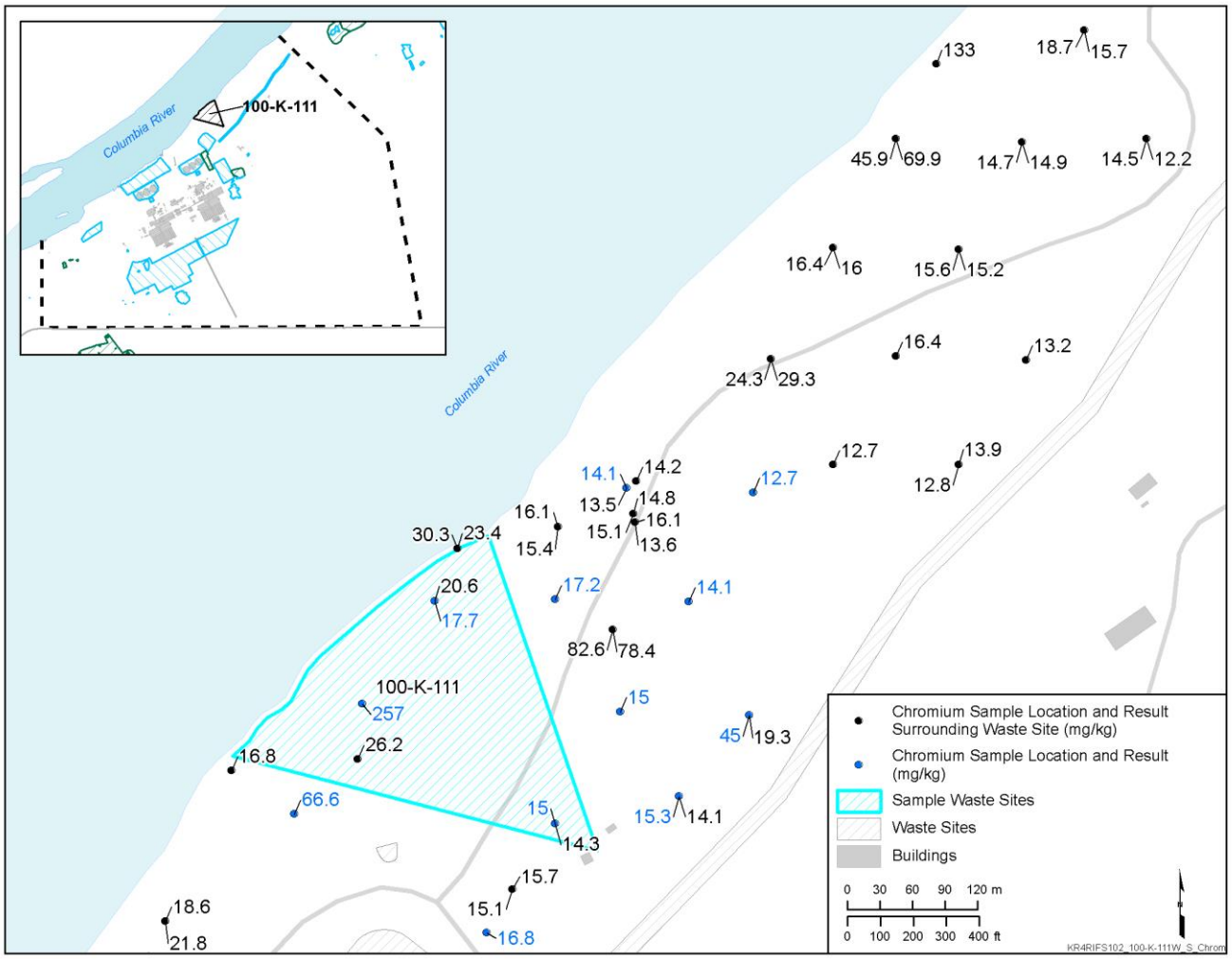

Figure 7-4. Soil Chromium Concentrations near 100-K-111

7.6.5 Scientific Management Decision Point Conclusion

Consideration of factors listed above resulted in the conclusion of no unacceptable risks to wildlife or plants and invertebrates exposed to vadose zone soil and a recommendation of no further action for any of the waste sites within the 100-K Area based on ecological risk. The process and conclusions for this SMDP is strong evidence that remedial actions to human health direct contact levels is sufficient to address population and community level ecological risk, and leave no residual risk that warrants further action.

7.7 Baseline Ecological Risk Assessment in Columbia River Environments

The following evaluation was completed to assess the risk of exposure to and adverse effects from Hanford Site-related contaminants on populations of fish and wildlife in the Hanford Reach of Columbia River. The evaluation is considered a BERA because a screening assessment of the Columbia River Environments was already completed within both the RCBRA and the CRC. This evaluation does not repeat those evaluations, but rather summarizes and builds upon the results.

This aquatic BERA (hereinafter in this section referred to as "BERA") was completed for biota exposed to surface water, sediment, sediment pore water, riparian soil, and Columbia River island soil within the riparian zone, nearshore, and riverine habitats of the Columbia River adjacent to 100-K.

This BERA summarizes the elements of a baseline problem formulation included in step 3 of ERAGS (EPA 540-R-97-006), followed by a baseline risk characterization and final conclusions at the SMDP. This BERA was informed by the RCBRA (DOE/RL-2007-21)[27] and CRC (DOE/RL-2010-117), both of which were extensive efforts with significant documentation of the full elements of a BERA. Thus, this BERA presents a summary of the problem formulation and risk characterization from those documents, along with additional risk characterization, to complete a BERA specifically for the 100-K Area. While some discussion of analytical chemistry relative to effects levels or benchmarks is included, a screening assessment is not presented since a SLERA and BERA have already been completed.

The RCBRA (DOE/RL-2007-21) evaluated risk from exposures to contaminants in soil, sediment, and water located in riparian and nearshore areas. Interim actions addressed risks to human health from direct contact with soil and threats to groundwater and surface water as a result of leaching from soil, but did not directly address risks to ecological receptors, except those protected through compliance with AWQC. The ERA conducted as part of the RCBRA addressed residual contaminant concentrations at waste sites in the upland zones and the transport of contaminants from those waste sites to Columbia River riparian and nearshore zones (Integrated Work Plan [DOE/RL-2008-46]).

The CRC evaluated island soil, sediment, water, and fish tissue from the Columbia River beyond the nearshore environment evaluated in the RCBRA. Figure 7-5 depicts the lateral investigation areas of both investigations. Several investigations conducted on effluent pipelines that discharged to the Columbia River are discussed in this BERA.

The results of both the RCBRA and the CRC, which identified COPECs for the Columbia River itself (including Hanford sources as well as upstream and non-Hanford Site sources), are re-examined in this BERA to determine whether those COPECs might be associated with Hanford Site activities. Figure 7-6 shows how the RCBRA and CRC efforts support the final BERA for the Columbia River and completion of the RI/FS for the 100-K Area.

Additional data were also collected since the completion of the RCBRA and CRC reports. Data were collected from pore water (collected by hyporheic sampling) seeps/springs, groundwater, surface water, sediments, and riparian soil data, obtained from a range of Hanford Site sources. These sources included groundwater monitoring activities documented in the annual groundwater monitoring reports, and sampling of sediments, seeps, and surface water conducted as part of the Surface Environmental Surveillance Program (SESP). The locations of these samples are presented in Subsection 7.7.1. These data are also examined in this BERA.

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[27] The RCBRA, including all appendices, is over 2,000 pages.

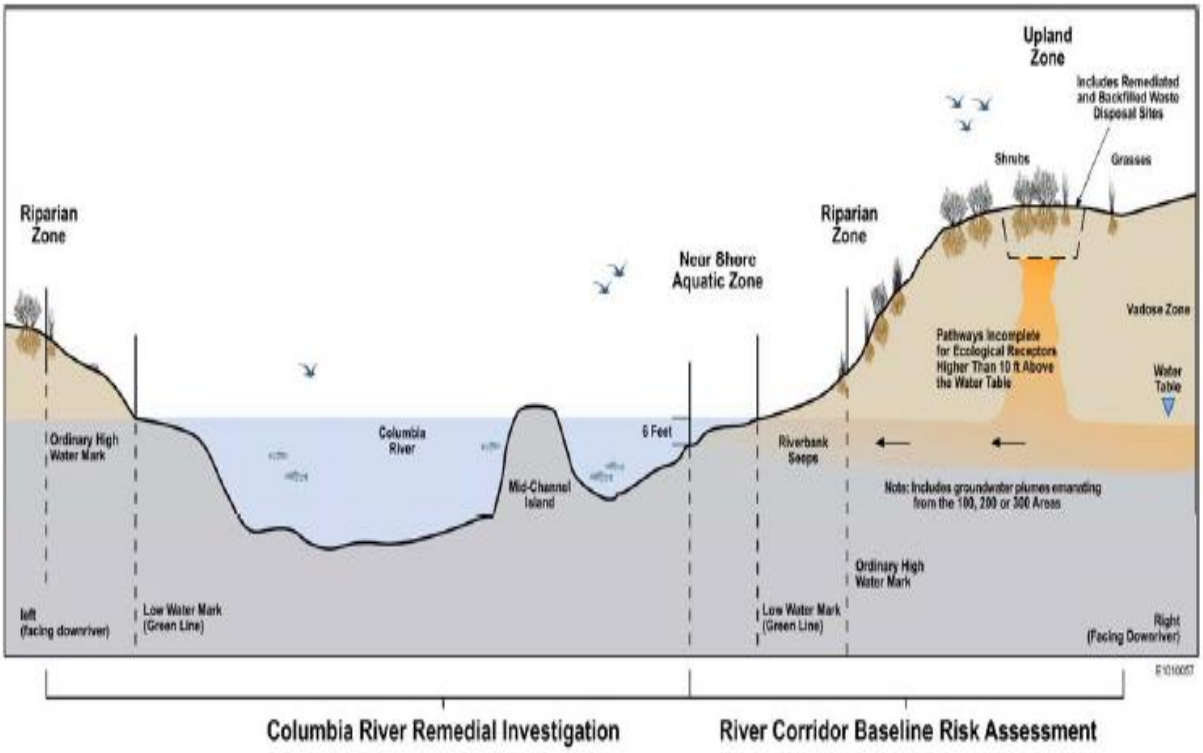

Figure 7-5. Columbia River Remedial Investigation Area Adjacent to the Hanford Site

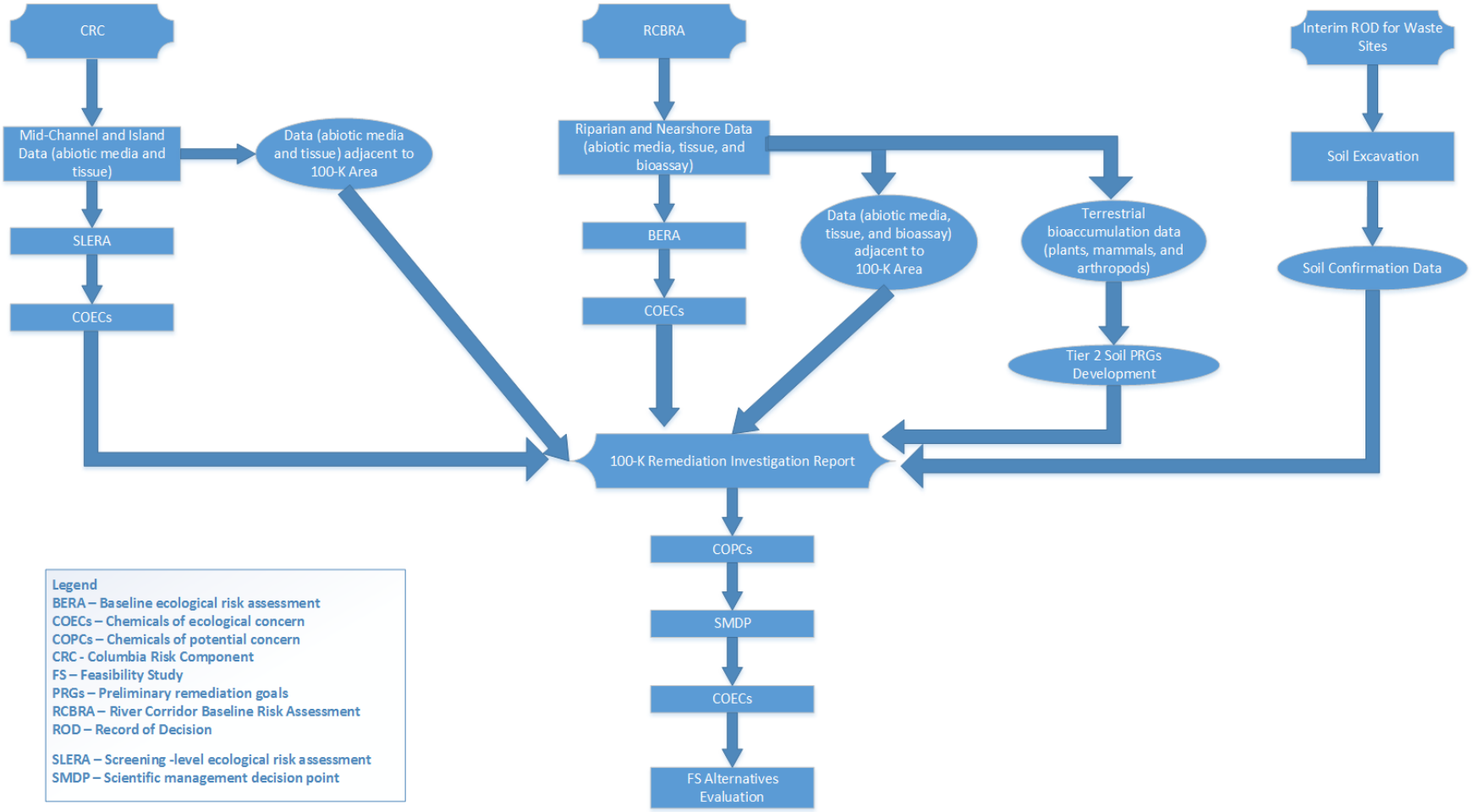

Figure 7-6. Relationship of the RCBRA and CRC to the 100-K RI/FS Process

7.7.1 Identification of Contaminants of Potential Ecological Concern for Columbia River Habitats

This section describes the sources of data used in the aquatic ERA habitats, the data processing and data validation process, and the identification process for COPCs.

7.7.1.1 Data Summary

Analytical data collected from the riparian and nearshore zones were evaluated to focus on COPCs that could be related to Hanford Site operations. Analytical data included calculated radionuclide SOFs, metals, organics, and contaminants related to the OU. This data evaluation encompassed groundwater (characterized by near-river wells and aquifer tubes), pore water (characterized by historical trident probe samples and more recent sampling, seeps/springs, surface water, sediments, and riparian soil data, obtained from a range of Hanford Site sources. The data included groundwater monitoring activities documented in the annual groundwater monitoring reports; sampling of sediments, seeps, and surface water conducted as part of the SESP; and sampling of sediments, pore water, surface water, and riparian soil conducted as part of the RCBRA. Surface water, pore water, fish tissue, and riparian soil data from the CRC are also discussed.

The type of analytical data, in particular filtered versus unfiltered water samples, was taken into consideration in making the comparisons with benchmarks and criteria. The spatial relationships of contaminant concentrations in surface water, pore water, and groundwater were evaluated to assess whether detected contaminants were related to Hanford Site operations (i.e., originated from upland groundwater sources) or reflected ambient background conditions.

Data Sources and Data Processing

The dataset used in this BERA consisted of sampling and analysis data collected from 24 nearshore monitoring wells, 52 aquifer tubes, 4 pore water locations, 3 seep/spring locations, and 13 surface water locations within the boundaries of the 100-KR-4 OU. A list of the groundwater wells and aquifer tubes used in this evaluation is provided in Appendix J, Table J-1. Pore water, seep/spring, and surface water sampling locations are based on sampling locations identified in the RCBRA. Figure 7-7 shows the sampling locations for each type of water media, riparian soil, and sediment.

The dataset used in this BERA was obtained from the HEIS and included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

The analytical data were processed to eliminate unusable results and identify one set of results per sampling location and date of sample collection. The data processing steps are described in the following subsections.

No data from the CRC are presented in tables within this report because the data were already evaluated in the CRC and because the nearshore data from the RCBRA and ongoing monitoring programs are more relevant for evaluating Hanford OUs as potential sources of COPCs for the Columbia River. Data evaluation tables are available in the CRC. However, CRC data will be provided as a supplement on compact disc as part of Appendix H.

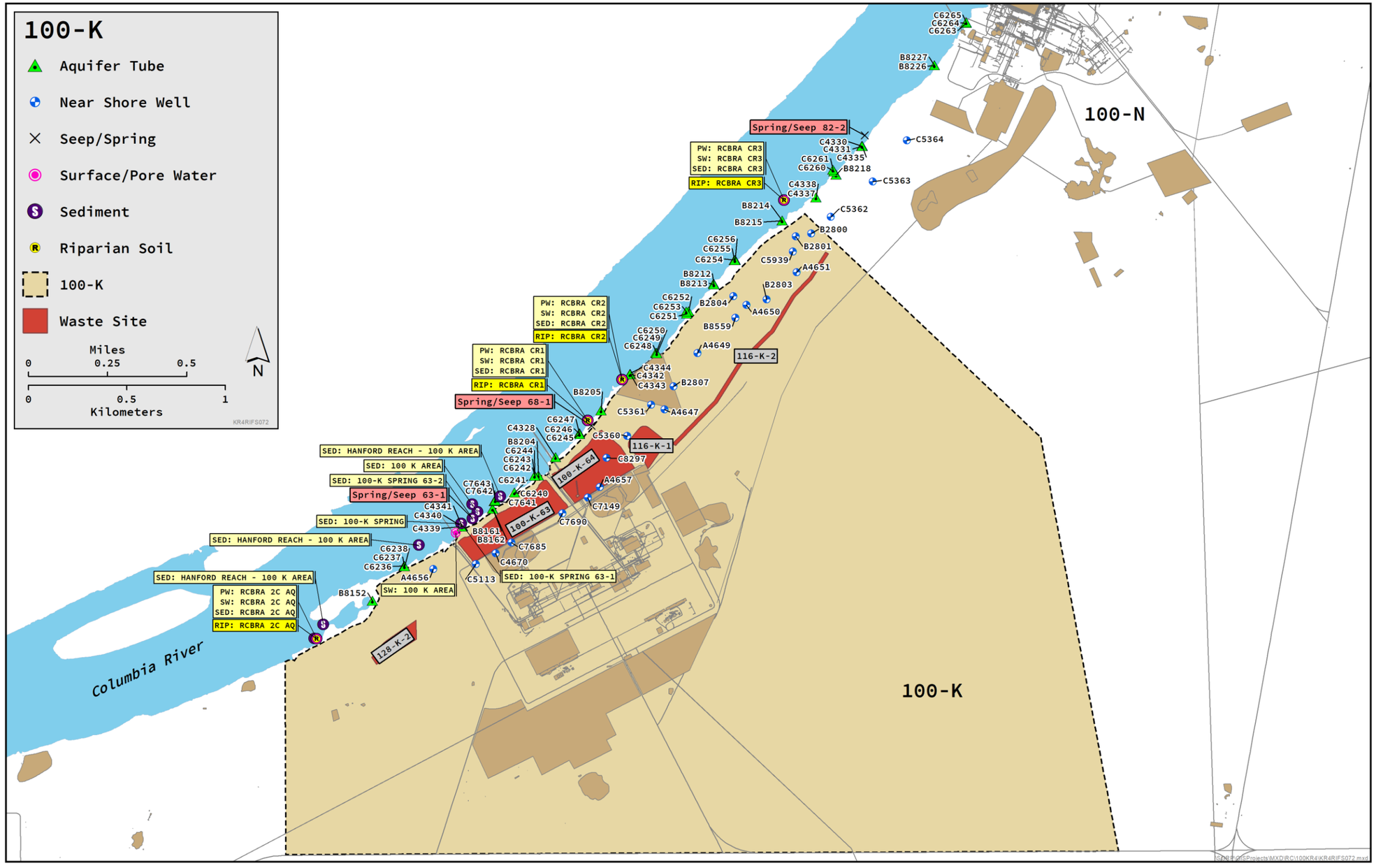

Figure 7-7. Sampling Locations Evaluated in the Riparian/Nearshore Conceptual Site Model

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Laboratory and Data Validation Flags

Analytical data are received from the laboratory with data qualification flags. Validation qualifiers are assigned during the data validation process. The following rules determine how flagged and qualified sample results are used in identifying COPCs:

- Sample results flagged with a "U" qualifier, or combination of qualifiers that include a "U," such as a "UJ," are considered non-detected results.
- Sample results without a "U" qualifier are considered detected concentrations, including results with no qualifier or with a "J" qualifier.
- Sample results that are rejected and flagged with an "R" qualifier are not used in the BERA for identifying COPCs.

Analytes Reported by Numerous Analytical Methods

Often analytes are reported by more than one analytical method, resulting in multiple results for the same analyte from the same location and sample data. When analytes are reported by more than one analytical method for a sample, only the set of data that best represents the actual concentrations is retained for use in the BERA. For example, the gamma spectroscopy method provides concentration results for the uranium isotopes; however, uranium concentrations reported by a uranium-isotope-specific method are preferred.

Field Duplicate and Field Split Results

Field QC samples (field duplicates and field splits) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (i.e., monitoring well) on the same date, resulting in more than one sample per location/date. The following criteria are used to reduce multiple field duplicate and field split sample results for an individual location or date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If two or more non-detected results exist, the lowest detection limit is used.

7.7.1.2 COPCs Identification for Columbia River Habitats

After extracting and processing the analytical dataset from HEIS, a multi-step evaluation process was used to identify COPCs:

- Apply exclusion criteria
- Identify non-detected analytes
- Identify analytes with maximum detected concentrations less than their respective effect levels
- Identify analytes with maximum detected concentrations greater than their respective effect levels

Apply Exclusion Criteria

The first step in the COPC identification process is to apply certain exclusion criteria. Analytes that meet the exclusion criteria were eliminated as a COPC. The only exclusion criterion used was the absence of toxicity information for an analyte; if there were no effect levels available, that analyte was not carried into the next step of the data evaluation process. Analytes that did not meet any of the exclusion criteria were carried forward into the next step.

The analytes in nearshore groundwater wells, aquifer tubes, pore water samples, seeps, and surface water samples that do not have effect levels (Tables J-2 to J-4) are summarized by media in Appendix J,

Tables J-5 through J-9. These chemicals were analyzed as part of analytical suites that included other chemicals suspected at the site. However, additional effort was not taken to identify surrogate or site-specific effect levels for the chemicals in these tables because historical site use indicates only anthropogenic or nonsite related concentrations may be present. These chemicals include volatile and semivolatile organics, essential nutrients and rare earth elements and other inorganic chemicals, or nontarget radionuclides. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Appendix J, Tables J-5 through J-9.

Identify Non-detected Analytes

The next step in the COPC identification process was to identify non-detected analytes. Chemicals and radionuclides that were analyzed but not detected in any sample (collected from appropriate locations, with adequate detection limits) were eliminated as COPCs. All analytes detected at least once were carried forward to the next step.

Analytes that were not detected in near-river groundwater wells, aquifer tubes, pore water, seep/spring, or surface water samples are summarized in Appendix J, Tables J-10 through J-14.

Identify Analytes with Maximum Detected Concentrations Less Than Effect Levels

This step identifies analytes with maximum concentrations less than effect levels. In this evaluation step, the maximum concentration of each detected analyte was compared to its effect level, to identify analytes not likely to contribute significantly to overall risk. If the maximum detected concentration of an analyte was less than its effect level, the analyte was eliminated as a COPC.

A list of analytes with maximum concentrations less than their effect level in groundwater, aquifer tubes, pore water, seep/spring, and surface water samples is presented in Appendix J, Tables J-15 through J-19.

Identify Analytes with Maximum Detected Concentrations Greater Than Effect Levels

This step results in the identification of analytes with maximum concentrations greater than their respective effect levels in groundwater, aquifer tubes, pore water, seep/spring, and surface water samples. Such analytes are likely to contribute to overall risk. If the maximum detected concentration of an analyte is greater than its effect level, the analyte is identified as a COPC. Appendix J, Tables J-20 through J-23 provide a summary of the analytes with maximum detected concentrations greater than their respective effect level for each water medium. Table J-24 summarizes the results for all water media and all COPCs.

The human health risk assessment identified groundwater COPCs related to Hanford operation in Section 6 of this RI/FS. These COPCs are also included in this BERA.

7.7.1.3 COPECs Identification for Columbia River Habitats

The contaminants of interest (i.e., COPCs in the RCBRA and CRC reports) were further examined in the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117). Those evaluations resulted in a refined list of COPECs estimated to pose ecological risks to aquatic receptors in the Columbia River habitats[28]. The RCBRA went a step further by evaluating the COPECs to identify COECs, which were principally metals and pesticides recommended for further consideration. The CRC COPECs and RCBRA COECs (Table 7-12) were the focus of this BERA. However, the potential for the RCBRA COECs in the nearshore environment to have originated from the 100-K Area was not previously evaluated, so for the

[28] The CRC was a SLERA that identified COPECs primarily by abiotic media concentrations exceeding ecological risk-based thresholds. The RCBRA was a BERA that identified what were called COECs for the Columbia River through multiple lines of evidence but there was not a complete analysis of linkage to Hanford Site operations. Thus, for this BERA, the RCBRA COECs are referred to as COPECs, and are evaluated specifically with respect to Hanford Site operations associated with 100-K Area.

purposes of the following assessment, the RCBRA COECs are defined as COPECs because a link to the Hanford facility was not previously evaluated. In addition to re-examining these COPECs in this BERA, a multi-step evaluation process was used to identify final COCs from the dataset summarized in Table 7-12 that warrant additional consideration in the FS.

Table 7-12. Riparian, Nearshore, and Riverine COPECs from the RCBRA and CRC

COPEC	Receptors	Media	CRC COPEC (100-Area Sub-Area)	RCBRA COPEC (River Corridor)
Arsenic	Terrestrial Plants	Riparian Soil	--	X
Cadmium	Aquatic Plants and Invertebrates	Sediment	--	X
Cr(VI)	Fish	Pore Water	X	X
	Aquatic Plants and Invertebrates, Amphibians			
	Aquatic Plants and Invertebrates	Sediment	X	--
Chromium	Aquatic Plants and Invertebrates and the Bufflehead	Sediment	X	X
	Terrestrial Plants and Invertebrates	Riparian Soil	--	X
Lead	Terrestrial Plants	Riparian Soil	--	X
Manganese	Fish	Pore Water	X	
	Aquatic Plants and Invertebrates, Amphibians			X
	Aquatic Plants and Invertebrates	Sediment	--	X
Mercury	Terrestrial Invertebrates	Riparian Soil	--	X
TPH-Diesel	Terrestrial Invertebrates	Riparian Soil	--	X
Uranium	Aquatic Plants and Invertebrates	Groundwater/ Pore water	--	X
Zinc	Terrestrial Plants and Invertebrates and Kingbirds	Riparian Soil	--	X

References: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*.
DOE/RL-2010-117, *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment*.

-- = not applicable
COPEC = contaminant of potential ecological concern
CRC = Columbia River Component
Cr(VI) = hexavalent chromium
RCBRA = River Corridor Baseline Risk Assessment
TPH = total petroleum hydrocarbon

The CRC (DOE/RL-2010-117) did not identify any risks to terrestrial plants or invertebrates from exposure to island soil. Island soil samples were collected from island soil that may have been transported during high river levels during floods or other nonroutine events. A total of 84 soil samples (not including Reference samples) were collected to evaluate effects to terrestrial island receptors. None of these samples are relevant to 100-K because there are no islands directly adjacent to 100-K. The closest island, Coyote Island (visible in Figure 7-7), is upstream of 100-K, while the closest downstream islands are adjacent to 100-D. Individual sample chemical concentrations from island soil, were evaluated for risks to plants, invertebrates, and wildlife. All concentrations were below PRGs; thus, there was no risk to terrestrial plants, invertebrates, or wildlife inhabiting the islands. Given these findings, island soil data from the CRC are not presented or re-examined here in this BERA.

Exposure of avian receptors to sediments within mudflats surrounding the islands was also evaluated within the CRC. Evaluations of risk to avian wildlife were completed by using the shallow sediment data from exposure mudflat areas. The mudflats were also eliminated from further consideration in the CRC and are not presented or re-examined in this BERA.

7.7.2 Baseline Problem Formulation for Riparian and Nearshore/Riverine Habitats

The problem formulation for the area in and around the Columbia River within 100-K includes a summary of the site setting evaluated in the risk assessment and the CSM which provides an understanding of chemical sources, transport pathways, exposure media, exposure pathways and routes, and ecological receptors. Assessment endpoints are developed to identify receptors for which complete exposure pathways exist and summarize methods that will be used to evaluate potential risks to those receptors.

7.7.2.1 Site Setting

The Columbia River section along the 100-K Area defines a portion of the Hanford Reach, an important ecological, cultural, historical, and recreational feature. The Columbia River adjacent to the Hanford Site is within the Hanford Reach, which extends from Priest Rapids Dam downstream to the slack waters of Lake Wallula, created by McNary Dam.

As described in Section 7.2.1, the Hanford Reach contains three species listed as threatened or endangered under the *Endangered Species Act of 1973*, including Upper Columbia River spring-run Chinook salmon (*Oncorhynchus tshawytscha*), Upper Columbia River steelhead trout (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*). The occurrence of these species within the Hanford Reach is discussed in detail in Section 7.7.10.

The following environmental zones presented in the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) were included in the current evaluation of ecological risk in the Hanford Reach adjacent to the 100-K Area:

1. **Nearshore zone:** the nearshore aquatic zone includes the surface water of the Columbia River from the area that is permanently inundated by river water (i.e., represented by the low-water mark, commonly referred to as the “green line,” where the periphyton remain green year-round) up to the riparian zone.

2. **Riverine area:** the riverine area, known as the aquatic areas in the CRC (DOE/RL-2010-117), includes the surface water, sediment, pore water, and fish tissue data from the mid-channel zone of the Columbia River (i.e., between the low water mark on the Hanford side and ordinary high-water mark on the opposite bank). It also includes terrestrial soil data from the main channel islands and the opposite shore areas of the Columbia River (those areas beyond the near-shore area of the RCBRA) in the Hanford Reach. However, none of the islands are adjacent to or immediately downstream of 100-K.

3. **Riparian zone:** the riparian zone is a transition area between the aquatic environment in the nearshore zone and the upland zone. The riparian zone extends from the shoreline of the Columbia River to the point on the riverbank where upland vegetation becomes dominant. The riparian zone typically is narrow and varies in width depending on the slope of the riverbank.

4. **Upland zone:** the upland zone consists of land that extends inland from the riparian zone and is situated approximately 3 m (10 ft) above the river ordinary high-water mark. The upland zone generally is dry and not readily influenced by river flow. Recharge to groundwater in this zone occurs largely from precipitation. The upland zone includes operational areas in the 100-K Area decision areas and generally is where waste sites are located.

These environmental zones are depicted in Figures 7-8 and 7-9.

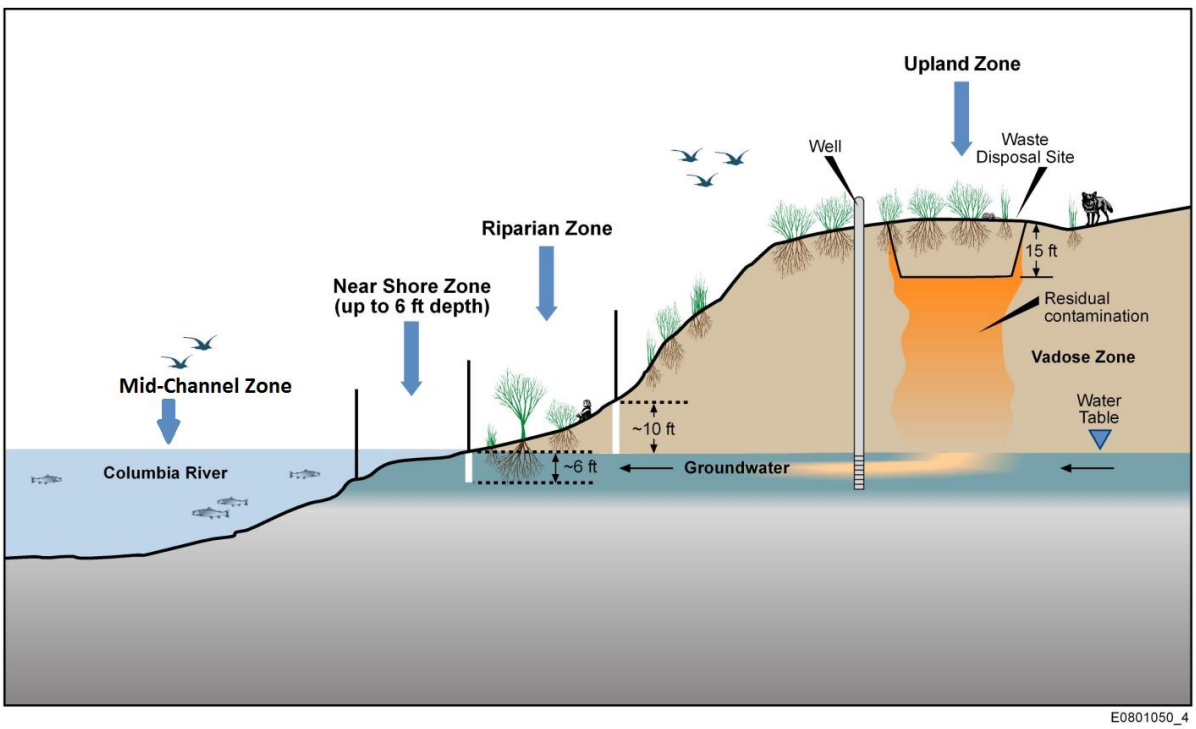

Figure 7-8. Environmental Zones in the Riparian/Nearshore Areas

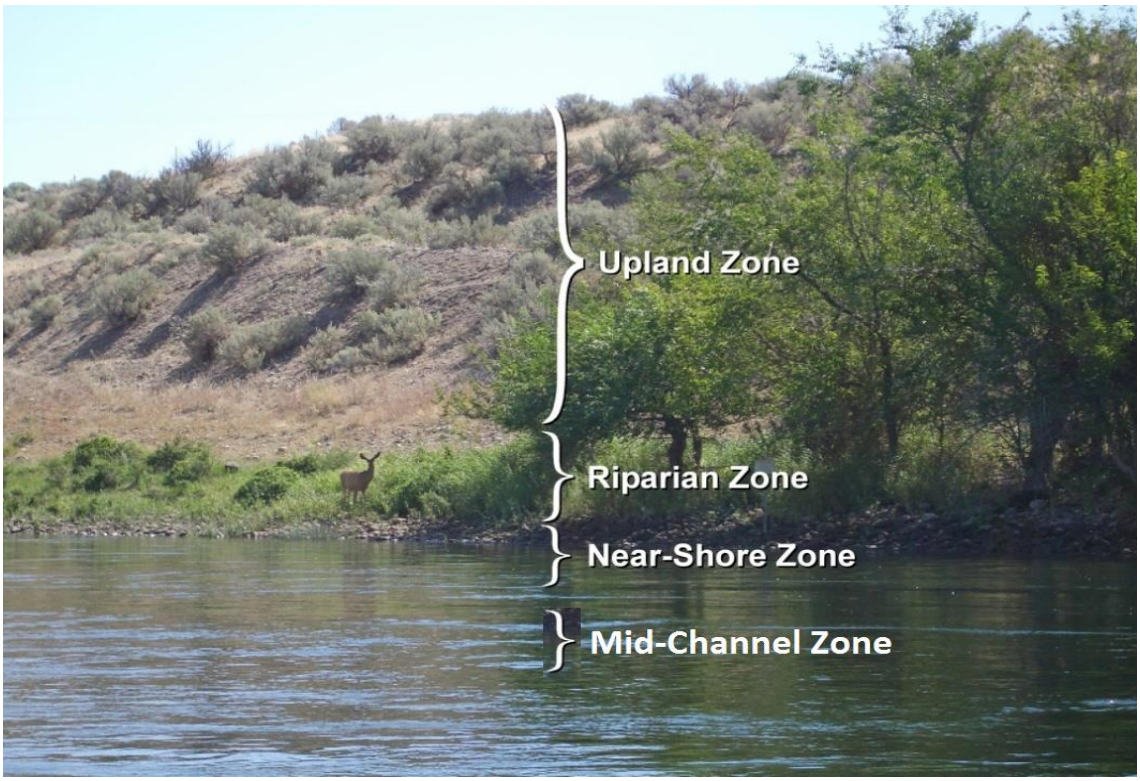

Figure 7-9. Photograph Depicting the Environmental Zones

7.7.2.2 Ecological Exposure Model Summary for Columbia River Environments

The objective for developing an exposure model is to provide a tool for evaluating the potential for contaminants in riparian, nearshore, and riverine media to be associated with releases from Hanford-related sources. As previously noted, full risk evaluations of the riparian area within the Columbia River are not presented because they were already completed for the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117); however, the same models and receptors were employed here as in those documents.

Potential exposure pathways from the 100-K Area and the 100-KR-4 OU groundwater may be linked to media in the riparian, mid channel, and nearshore zones. An exposure pathway can be described as the physical course that a contaminant takes from the point of release to a receptor. An exposure pathway is the means by which a contaminant comes into contact with a receptor. For an exposure pathway to be complete, all the following components must be present:

- Source (of contamination)
- Mechanism(s) of contaminant release and transport
- Environmental transport medium
- Exposure point (location)
- Exposure route (ingestion, etc.)
- Receptor or exposed population/community

In the absence of any one of these components, an exposure pathway is considered incomplete; therefore, cannot result in a risk or hazard to an individual receptor or population/community.

Sources are required to complete an exposure pathway, including sources that may be unrelated to Hanford Site operations and that have been transported and deposited via the river.

Once the sources, transport, potential exposure media and pathways, and receptors are identified and described, sampling and analytical data from various media are evaluated. The objectives for this evaluation include identifying the concentrations (data) measured in the various riparian and nearshore media and evaluating quality of the data. Environmental sampling media in the riparian and nearshore areas include groundwater, pore water, seeps/springs, surface water, sediments, biota tissue, and soil. The results from this data evaluation are combined with the exposure pathway and receptor information to determine whether contaminant concentrations located at exposure points are potentially associated with Hanford Site activities.

Contaminant Release and Transport Mechanisms

Release and transport mechanisms associated with the occurrence of Hanford Site contaminants in riparian and nearshore zones are overland transport from waste sites, and contaminant leaching from the vadose zone to underlying groundwater, followed by lateral transport in groundwater. Contaminants could have been transported to the riparian zone through the following:

- Overland flow from precipitation potentially results in the transport of hazardous and radioactive substances that are in surface materials from a waste site into other areas such as the riparian or nearshore environments. However, the Hanford Site is in a semiarid region and precipitation is more than balanced by evaporation and transpiration such that substantial overland flow from precipitation happens infrequently.
- Overland flow from past spills or releases from liquid waste disposal facilities.
- Historical releases from outfall structures of the reactors and retention basins.
- Landslides or slumping of contaminated soil from upland operational areas into the riparian zone are possible.
- Fugitive dust may be transported through wind or work activities on the waste sites.

Historical operations and release descriptions are presented in Section 1.2.2. The fate and transport of contaminants detected in vadose zone soil to groundwater is discussed in detail in Chapter 5. Figure 7-10 presents a conceptual model for groundwater-surface water interaction at 100-K.

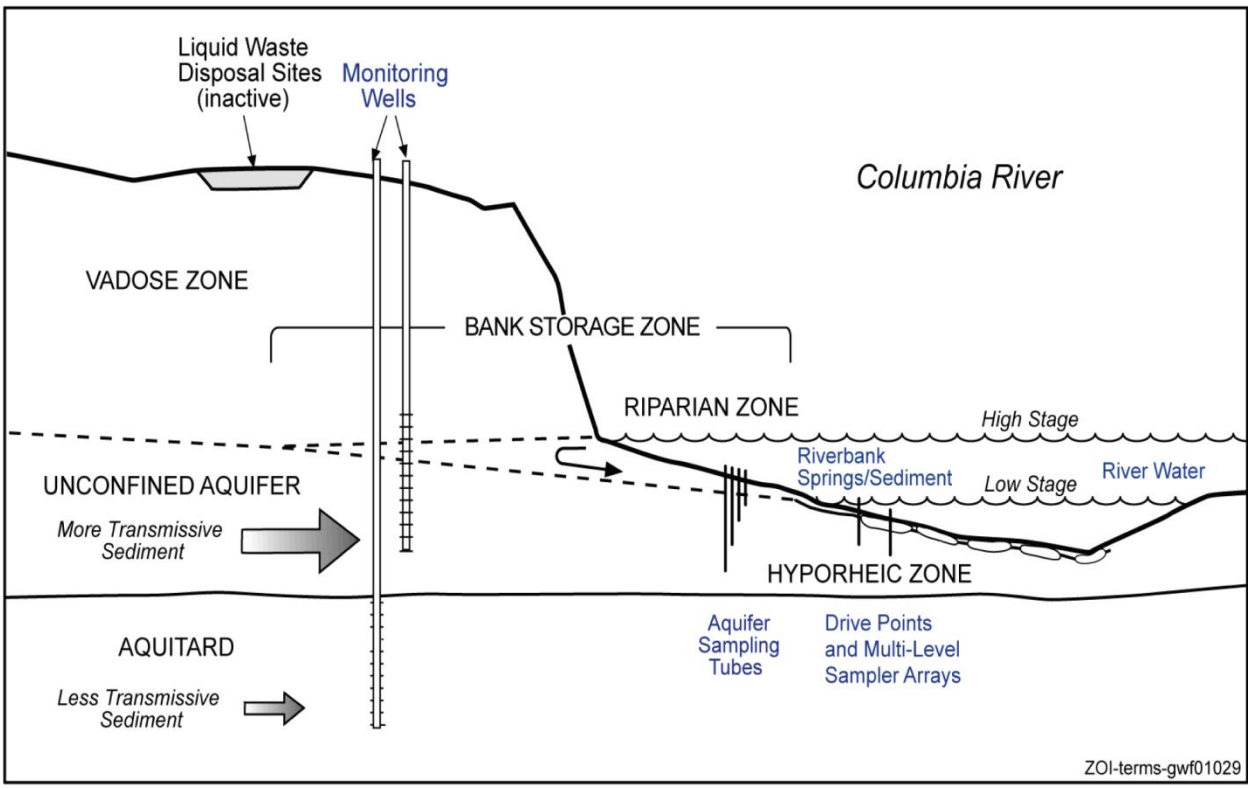

Figure 7-10. Conceptual Hydrologic Model of Groundwater-Surface Water Interaction at the Hanford Site

Groundwater may enter the riparian area through seeps/springs or enter the aquatic system through the hyporheic zone (Figure 7-10). In the studies of the Columbia River at the Hanford Site, the term hyporheic zone has been used as a general term to describe the zone of all groundwater and surface water mixing. The hyporheic zone may be found in Columbia River studies called nearshore aquatic, and aquatic areas, which change size over time given river stage changes. The thickness of the hyporheic zone also varies with physical conditions such as sediment type and hydraulic head. Within the hyporheic zone, more mixing with surface water occurs (dilution) as groundwater moves up through sediment toward the sediment surface (riverbed). Mechanisms of dilution and mixing of groundwater may not be as effective at greater depths.

Exposure Points in Abiotic Media Collected for the RCBRA

In the RCBRA (DOE/RL-2007-21), semi-aquatic and aquatic exposure points were defined within the riparian and nearshore aquatic zones. Of the 18 riparian study sites evaluated in the RCBRA, two (Riparian site 2c and Riparian #5) were located near the 100-K Area. Of the 20 nearshore study sites, three (Nearshore site 2c and Cr1 and Cr2) were located near the 100-K Area (DOE/RL-2007-21, Figures 5-3 and 6-3).

- **Riparian 2c**. This investigation area was located 100 m (328 ft) downstream of the old Hanford town site water intake (historic pump house) and just upstream of a major peninsula known as Coyote Rapids. Scattered metal debris was common throughout the site, and a small road that had been used extensively by Hanford Site personnel crossed a small portion of the upper end of the investigation area. This site's average dimensions were 30×200 m (98 x 656 ft), but the widths varied from 20 to 70 m (65 to 229 ft) and encompassed approximately 4,600 $m^{2`}$ (1.13 ac) of shoreline habitat. This site was also located in a relatively high depositional environment and widened substantially near the downriver end. The site consisted of sediment-covered cobbles and a moderate cover of reed canary

grass and other associated riparian taxa. Mulberry (*Morus spp.*) trees bounded the upper regions on nearly half of the investigation area. This site is located upstream of the 100-K Area.

- **Riparian #5 (RIP 5 in some maps and tables)**. This site is located 0.5 km (0.3 mi) downstream of the 100-K East water intake structure. The shoreline boundary consists of a series of small points and bays with lightly scattered vegetation consisting of largely of forbs and a few scattered short-statured mulberry (*Morus spp.*) trees. The substrate is predominantly large cobbles and boulders, with very little sediment/soil matrix visible on the ground surface. The average width of the site was 17 m (56 ft) and ranged from 9 to 26 m (30 to 85 ft) at each end and in the center of the 200 m (656 ft) transect. The site encompassed 4,500 m^2 (1.1 ac).

- **Nearshore Site 2c**. This investigation area was located about 100 m (328 ft) downstream of the old Hanford townsite water intake (historic pump house), and just upstream of a major peninsula known as Coyote Rapids. This site was also located in a highly depositional river environment. The substrate generally consisted of gravels that were heavily embedded. A small macrophyte population persisted near this area.

- **Nearshore Sites Cr1 and Cr2.** Chromium sites 1 through 4 were located between 100-K and 100-N in permanently inundated areas where groundwater upwelling was also known to persist. The river was relatively symmetric with no adjacent islands or backwater channels there. The substrate consisted of moderately embedded gravels and cobbles. All sites were located in areas with no current when flows were about 1,982 cms (70,000 cfs). Chromium site 3 was subjected to slightly more river flow than the other sites described in this area. The low water velocities at this site coupled with highly embedded substrates made it unsuitable as steelhead spawning habitat.

Soil samples were collected from riparian study sites and from reference sites using MULTI INCREMENT® sampling (MIS) methodology. This method was designed to obtain representative estimates of the average contaminant concentrations in the study site and control the sampling fundamental error and the grouping and segregation errors associated with measuring discrete soil sample concentrations. Soil MIS represents surface soil of the 0 to 15 cm (0 to 6 in.) depth interval using a systematic random design across a 200 m (656 ft) long riparian investigation area. Seep/spring data were also collected when present and is discussed in detail in Section 7.5.4. Assessment of ecological risks based on the riparian biota sampling is described further in Section 7.7.4.

In addition, data is available for riparian soil near 100-K from in process sampling. In process samples were part of a lines-of-evidence discussion to support the assessment of whether areas required remediation, but were not the final decision data as they did not have the same quality pedigree as validation data. In process pothole sampling was conducted at the 100-K-63 waste site. Twenty discrete samples were collected from the surface, 1.5, 3, and 4.6 m (5, 10, and 15 ft) bgs. A recent report summarized analytical results, field observations and protectiveness evaluations based on sampling and radiological surveys in the excavated area and potholing locations within the 100-K-63 waste site (RA-00287, *Recommended Path Forward for the 100-K-63 Waste Site*). Contaminants reflected in these soil samples include metals and radionuclides.

Sediment, pore water, and surface water samples were collected from the nearshore study sites in the RCBRA. The biologically active zone in sediment is the depth where the species critical to the function, diversity, and integrity of the benthic community are located (WAC 173-204, “Sediment Management Standards”). The upper end of the hyporheic zone (nearest the sediment surface) has a strong impact upon

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aquatic communities so, for the purpose of this study, it is defined as the portion of the streambed where aquatic communities may be present. This may be as little as 10 cm (4 in.) for some epibenthic species or as much as 0.5 m (1.6 ft) for benthic organisms and the redds of spawning salmonids (i.e., a redd is a depression in gravel where eggs are laid during the spawning season). Exposure at this depth is represented by pore water data, while the deeper hyporheic zone representing groundwater prior to mixing with surface water is represented by aquifer tube data (collected under a different sampling effort as described below). Assessment of ecological risks based on the biota sampling results is described in Sections 7.7.7 through 7.7.12.

Exposure Points in Abiotic Media Collected for the CRC

In the CRC (DOE/RL-2010-117), aquatic exposure points were defined within the aquatic zone. The aquatic areas of investigation were divided into Sub-Areas. The boundaries of the Sub-Areas downriver of Priest Rapids Dam were determined based on spatial distribution of contaminant concentrations observed in surface water and sediment with respect to the various sources of contamination from the Hanford Site. Surface water, sediment, and groundwater abiotic samples were collected in 2008 and 2010 from 100 Area Sub-Area (River mile [RM] 387 to RM 366) (WCH-398). Pore-water data were evaluated relative to CERCLA groundwater OUs on the Hanford Site, to facilitate the correlation of these data with groundwater contaminant plumes in OU areas; therefore, pore-water data were divided into and evaluated in the seven different groups. For pore water, the 100-KR-4 OU (RM 382 to 379.65) group was located near the 100-K Area (DOE/RL-2010-117).

Riverine surface water samples were collected at approximately two-thirds of the depth of the water column. Surface water was also collected as part of the groundwater upwelling investigation. For this evaluation, surface water was collected from within a 0.3 m (1 ft) of the sediment surface in areas of documented plume release. Sediment and pore water samples were collected at the same locations. A total of 44 surface water samples were collected and used to evaluate effects on aquatic biota in the screening-level ERA for the 100 Area Sub-Area (RM 387 to RM 366), not including Reference samples. Ten of these samples were collected near the 100-K Reactor Area (WCH-398, Table J-2). While samples were collected from a variety of aquatic environments, aquatic receptors were assumed to be exposed to all samples for the purposes of the screening assessment.

Pore water samples were collected as part of the groundwater upwelling study at specified locations associated with reactors and documented groundwater plumes. Thirty-seven groundwater upwelling samples for most analytes and 165 samples for Cr(VI) were collected and analyzed for the 100 Area Sub-Area (RM 387 to RM 365), not including reference samples. Twelve and 34 of these samples, respectively, were collected near the 100-K Reactor Area.

Sediment sampling consisted of the collection of shallow and deep sediment, shoreline sediment, and shallow and deep sediment cores. Sediment was also collected as part of the groundwater upwelling investigation. A total of 123 shallow sediment samples (not including Reference samples) and 10 sediment cores were collected as part of the RI and used for the ERA for the 100 Area Sub-Area (RM 387 to RM 366). Of these, five shallow sediment and two sediment cores were taken near the 100-K Reactor Area. A stratified random approach was used for the design of the sediment sampling program. Because most of the river bottom consists of coarse to medium gravel, a fine-grained sediment survey was conducted prior to selecting sample locations to identify depositional areas where fine-grained material is present in quantities sufficient for sampling. Shallow sampling depth was upper 10 cm (4 in.). All sediment samples, along with core sediment samples from the top 30 cm (12 in.) or less of sediment, were used to evaluate effects on aquatic biota in the ERA.

Additional Exposure Points in Abiotic Media considered for this BERA

Further sampling occurred after the completion of the RCBRA and CRC investigations. Additional data needs included the hyporheic zone where groundwater discharges to the Columbia River. Aquifer tube

data from the hyporheic zone generally represent groundwater prior to mixing with surface water. These investigations are described in Section 2.1.8. Additional groundwater monitoring is described in Section 2.1.11. Groundwater data from wells near the river were also evaluated in Appendix J. Samples used from these investigations are presented in Appendix J.

Routes of Potential Exposure and Receptors

A range of terrestrial and aquatic plant, invertebrate, and wildlife species were considered in the ERA conducted as part of the RCBRA and are discussed in detail in that ERA. Once contaminants move through the vadose zone and into groundwater, the groundwater will eventually migrate toward the river. Three initial contact media for contaminants at the shore are the groundwater, sediment, and soil. Groundwater/pore water will upwell in seeps along the riverbed and discharge into the Columbia River. Soil and sediments along the shoreline and riverbed will accumulate contaminants as the water ebbs and flows through the system; contaminants also will accumulate from airborne wet and dry deposition pathways. In the riparian and nearshore environments, biota living in those locations will be exposed through contact and uptake from soil, sediment, and water, and from consumption of exposed biota in the food chain (DOE/RL-2006-26, *Aquatic and Riparian Receptor Impact Information for the 100-NR-2 Groundwater Operable Unit*).

The river stage changes in response to seasonal river stage variations and release of water from the upstream Priest Rapids Dam, and the resulting water table fluctuations cause changes in contaminant water concentrations in nearshore wells. In the fall, the river is at its lowest flow rate, and the river stage becomes relatively stable. Contaminant concentrations in the groundwater near the shoreline also tend to stabilize during this time because of the stable river stage. This creates a time of maximum exposure to receptors in the nearshore area because the undiluted groundwater flowing into the river is more accessible than at other times during the year (DOE/RL-2006-26).

A conceptual model depicting the ecological receptor exposure pathways is provided in Figure 7-11, followed by a depiction in Figure 7-12 of the measurement endpoints used to evaluate those pathways to the receptors identified.

Riparian Zone Exposure Pathways

The boundaries of the riparian zone are defined as extending from the water line of the Columbia River to the upper edge of the riverbank where upland vegetation becomes dominant. The riparian zone along the shoreline of the Columbia River is typically narrow because of the steep riverbank. Development of the ecological CSM for this ERA involved characterizing the exposure pathways. Full risk evaluations of the riparian area within the Columbia River are not presented because they were already completed for the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117); however, the same models and receptors were employed here as in those documents. With consideration of the ecological setting, land use, and COPC release mechanisms and transport pathways, the ecological exposure pathways considered most plausible are graphically displayed in Figure 7-11.

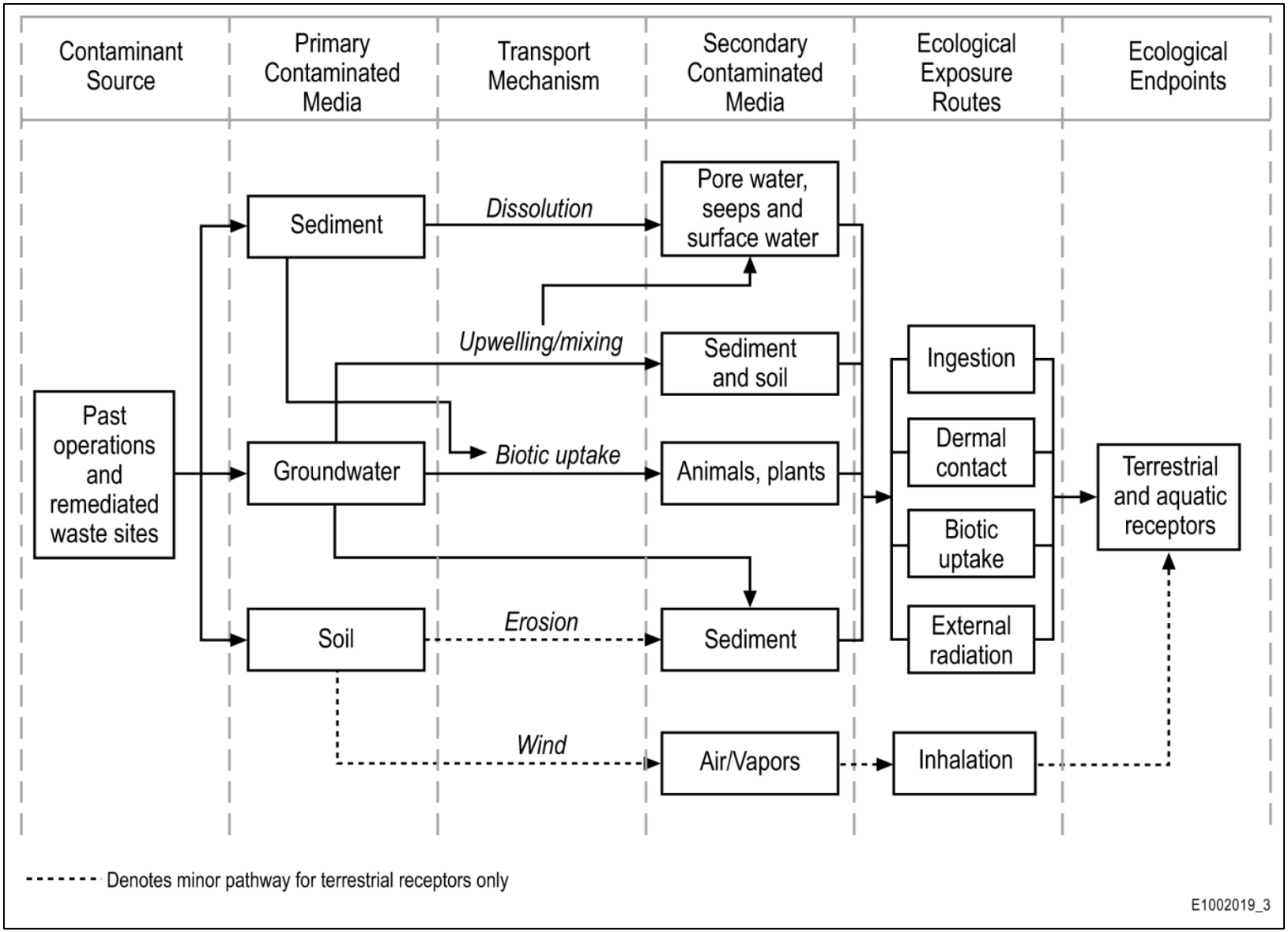

Figure 7-11. Ecological Conceptual Site Model for the Aquatic Environment (Riparian, Nearshore, and Riverine Zones)

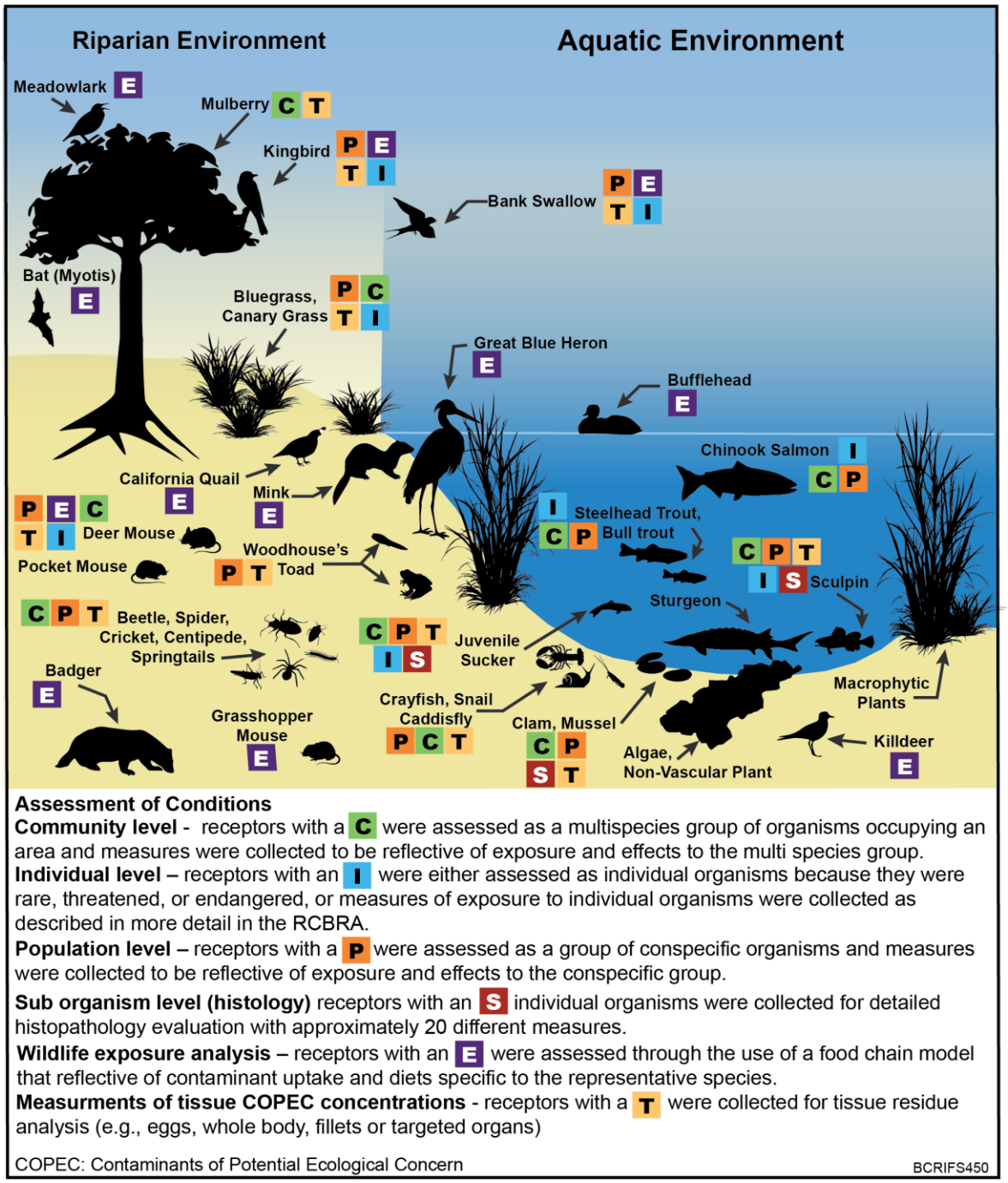

Figure 7-12. Summary of Measures of Exposures and Effects Evaluated in the Riparian, Nearshore, and Riverine Environments

Through transport pathways (e.g., upwelling of groundwater in a riverbank seep), secondary media (such as plants) may become contaminated through root uptake from soil or groundwater/seeps. These secondary contaminated media, in turn, may be consumed by receptor species contributing to exposure.

The following ecological exposure routes were identified for the riparian zone:

1. Incidental or intentional ingestion of contaminated soil, sediment, water, or food items (biota)
2. Dermal (skin) contact with contaminated soil, sediment, water, or biota
3. Exposure of terrestrial and aquatic vertebrates, invertebrates, and plants to external radiation emitted by contaminated soil or food items
4. Uptake (absorption) of the bioavailable contaminant fractions from soil, sediment, or water
5. Inhalation of contaminated dust or volatilized contaminants

The riparian ecological exposure pathways that were evaluated in this ERA include ingestion of contaminated soil, seep water, and food items (biota). Exposure from external radiation was considered by comparing soil radioactivity to radionuclide-specific biota concentration guidelines. Although there is a potentially complete exposure pathway via inhalation of fugitive dust and dermal contact with chemicals, these are generally considered minor exposure routes for ecological receptors (OSWER Directive 9285.7-55).

Sampling locations were selected near historical operating areas and in areas likely to have been affected by contaminated source media such as surface soil, shoreline seeps, or groundwater plumes. The sampling locations were generally selected to optimize the potential for detecting contaminants and effects.

Nearshore and Riverine Zones Exposure Pathways

The nearshore aquatic zone is defined as the area that is permanently inundated by river water, extending from the seasonal mean low-water mark (that is, a “green line” where the periphyton [sessile algae] remains green year-round) into the river to a water depth of about 2 m (6 ft). A nearshore study boundary depth of 2 m (6 ft) was selected to optimize the ability to measure potential influence of emergent groundwater and other potential Hanford Site contaminant sources within the Columbia River. Potential sources of contamination within the nearshore aquatic zone include contamination along the Columbia River shoreline at riverbank seeps/springs and submerged locations of Columbia River where upwelling groundwater mixes with the river water (sediment). Exposure pathways related to the primary contaminated media are presented in Figure 7-10.

Secondary media such as surface or pore water, or biota may become contaminated through transport pathways such as biotic uptake or upwelling of groundwater, as described in the Contaminant Release and Transport Mechanisms subsection. These secondary contaminated media, in turn, may be contacted or consumed by receptor species, contributing to exposure.

Ecological exposure routes identified for the nearshore and riverine zones are the same as those identified for the riparian zone (described above), with the exception of inhalation.

The nearshore and riverine ecological exposure pathways that were quantified in this BERA include ingestion of contaminated sediment, surface water, and biota. Exposure from external radiation was considered by comparing contaminated sediment and water to radionuclide-specific biota concentration guidelines. Although there is a potentially complete exposure pathway to wildlife via dermal contact with chemicals, this is generally considered a minor exposure route for ecological receptors (OSWER Directive 9285.7-55). For aquatic receptors such as benthic organisms that spent their entire life exposed to abiotic media, dermal contact is a key component and is a key element of direct toxicity.

Sampling locations were selected near historical operating areas and in areas likely to have been affected by contaminated source media such as surface soil, shoreline seeps, or groundwater plumes. The sampling locations were generally selected to optimize the potential for detecting contaminants and effects.

7.7.2.3 Assessment Endpoints

Section 7.2.3 presented the purpose and process for selecting assessment endpoints for a risk evaluation and defined the entities, represented by trophic guilds. The attribute selected for each entity was based on the organizational level of the entity and the primary criteria that were used to select it. Entities and attributes were selected for community and population levels of assessment. The following entities, and their associated organizational level, have been identified as assessment endpoints for evaluation:

- Aquatic plants—community level
- Aquatic invertebrates—community level
- Fish—community, population, and individual level (individual level was only evaluated for steelhead trout [*Oncorhynchus mykiss*], fall-run Chinook salmon[29] [*Oncorhynchus tshawytscha*], spring-run Chinook salmon [*Oncorhynchus tshawytscha*], and bull trout [*Salvelinus confluentus*][30])
- Riparian plants—community level
- Terrestrial (riparian) invertebrates—community level
- Shorebirds, riparian birds—population level
- Riparian mammals—population level
- Reptiles[31] and amphibians—community level

Endpoint representative species were selected for several entities identified above that could use the site. Unlike birds and mammals, methods to differentiate exposure and effects among different plant, invertebrate, or amphibian species are unavailable nor are they well developed and accepted. Therefore, individual species of plants, invertebrates, and amphibians were not selected to represent the plant, invertebrate, or amphibian populations and communities for evaluation. Consistent with ERAGS (EPA 540-R-97-006) and EPA/630/R-95/002F, endpoint species should preferably be ones that have ecological relevance, are of societal value, are susceptible to chemical stressors at the site, or allow risk managers to meet policy goals. These factors were used to select representative receptor species common to the Hanford Site riparian, nearshore and riverine environments that are within the bird and mammal trophic guilds identified above. Selected receptors are conservative indicators of the potential for risk to the trophic guilds identified for assessment.

The following are representative Hanford receptor species selected for those avian and mammalian assessment endpoints evaluated at the population level:

- Herbivorous birds—California quail (*Callipepla californica*)
- Herbivorous mammals—Great Basin pocket mouse (*Perognathus parvus*)
- Insectivorous birds—killdeer (*Charadrius vociferus*); western kingbird (*Tyrannus verticalis*); bank swallow (*Riparia riparia*)

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[29] Fall-run Chinook salmon are included in this evaluation because of their economic and cultural significance in the Hanford Reach.

[30] Spring-run Chinook salmon and bull trout do not spawn in the Hanford Reach of the Columbia River. Spring-run Chinook spawn primarily in headwater streams. The Hanford Reach only serves as a migration corridor for adult bull trout (PNNL-SA-75348, *Assessment of Apatite Injection at 100-NR-2 for Potential Impact on Threatened and Endangered Species*).

[31] Although part of the food web for the upland environment, effects data for reptiles are limited. Therefore, SSLs were not developed for this trophic guild.

- Insectivorous mammals—northern grasshopper mouse (*Onychomys leucogaster*); little brown bat (*Myotis lucifugus*)
- Omnivorous birds—western meadowlark (*Sturnella neglecta*); bufflehead (*Bucephala albeol*a)
- Omnivorous mammals—deer mouse (*Peromyscus maniculatus*)
- Carnivorous birds (raptors)—red-tailed hawk (*Buteo jamaicensis*)
- Carnivorous mammals—badger (*Taxidea taxus*)
- Piscivorous mammals—mink (*Mustela vison*)
- Piscivorous birds—Great blue heron (*Ardea herodias*)

For fish, methods to differentiate exposure and effects among different species are complex and are not widely used unless there is an identified concern with a specific species of societal or other importance. In most ERAs, fish are assessed at the community level. However, as described in greater detail in Sections 7.7.9 and 7.7.10, there are threatened and endangered species present within the Hanford Reach. As such, in addition to an evaluation of fish at the community level, the Upper Columbia River steelhead trout, fall-run Chinook salmon, spring-run Chinook salmon, and bull trout species were selected for evaluation at the population and individual level.

7.7.2.4 Measures of Exposure and Effects

Measures of exposure and effects are previously described for the upland environment in Section 7.2.4. Multiple site-specific measures of exposure and effects were identified for the BERA for the riparian, nearshore, and riverine environments. These are summarized in Table 7-13 to help answer risk questions from the RCBRA and in the CRC.

Table 7-13. Measurement Endpoints—Measures of Exposure and Effects

Aquatic Plants	Aquatic and Benthic Invertebrates	Fish	Amphibians	Terrestrial Plants, Invertebrates, and Wildlife
Surface Water Quality Criteria and Standards Sediment Quality Guidelines *Pak choi* bioassays	Sediment Quality Guidelines Surface Water Quality Criteria and Standards Tissue effect level Chronic *Hyalella azteca* *Ceriodaphnia dubia* bioassays Benthic community surveys using rock baskets *Corbicula fluminea* survival using clam tubes Mussel histopathology measures Mollusk surveys	Surface Water Quality Criteria and Standards Site-specific studies for the effects of Cr(VI) on salmonids Tissue effect levels Fish histopathology measures Fish population and community surveys	Surface Water Quality Criteria and Standards Tissue concentrations Xenopus bioassays	Chronic bioassays *(Poa secunda* and *Folsomia candida)* DOE's BCGs Site-specific SSLs and PRGs

BCG = biota concentration guide
Cr(VI) = hexavalent chromium
PRG = preliminary remediation goal
SSL = soil screening level

7.7.3 Baseline Effects and Exposure Assessment

Effects levels in this BERA were used for comparison with analytical results in water, soil, and sediment. At this point in the BERA process, effect levels were not identified as screening thresholds because, screening was previously conducted and presented in the RCBRA and CRC. The baseline effect levels were used, consistent with ERAGS, to identify COPECs that warrant further evaluation in the FS. The effect levels were derived from available sources of chemical-specific applicable relevant and appropriate requirements, readily available SSLs (organics and radionuclides in soil), or site-specific PRGs for plants and invertebrates or wildlife (inorganics in soil). A summary of effect levels for water are listed in Table 7-14. A summary of the lower and upper threshold sediment effect levels is provided in Table 7-15. The plant/invertebrate and wildlife effect levels were presented earlier in the Upland Habitat ERA (Sections 7.3 and 7.5). The specific effect level values used for comparisons in the aquatic BERA are shown in Appendix J, Table J-4.

7.7.3.1 Effect Levels for Water

The following represent the sources used to obtain water effect levels:

- Blindow, 1988, "Phosphorus Toxicity in *Chara*"
- BCMOE, 1995, *Ambient Water Quality Criteria for Fluoride*
- Camargo et al., 2005, "Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates"
- CRWQCB, 2007, *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater*
- DOE/EH-0676, *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1*
- DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*
- EPA 440-5-88-093, *Ambient Aquatic Life Water Quality Criteria for Antimony (III)*
- EPA, 2009, *National Recommended Water Quality Criteria*
- ES/ER/TM-96/R2, *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*
- MDEQ, 2011, "Water Quality Values," Rule 57
- Nautilus, 2013, *Evaluation of the Role of Hardness in Modifying the Toxicity of Nitrate to Freshwater Organisms*
- Neumann et al., 2001, "Detrimental Effects of Nitrite on the Development of Benthic Chironomus Larvae, in Relation to Their Settlement in Muddy Sediments"
- Sheppard et al., 2005, "Derivation of Ecotoxicity Thresholds for Uranium"
- WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"
- WHO, 2001, *Vanadium Pentoxide and Other Inorganic Vanadium Compounds*

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
4,4'-DDT (Dichlorodiphenyltrichloroethane)	50-29-3	µg/L	0.00100	WQC CCC	EPA, 2009	--
Acetone	67-64-1		1500	Tier II SCV	ES/ER/TM-96/R2	--
Aldrin	309-00-2		1900	WQS	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Alpha-Chlordane	5103-71-9		0.00430	WQC CCC	EPA, 2009	--
Aluminum	7429-90-5		87	WQC CCC	EPA, 2009	--
Antimony	7440-36-0		30	WQC CCC	EPA 440-5-88-093	Proposed continuous chronic criterion
Aroclor-1016	12674-11-2		0.0140	WQC CCC	EPA, 2009	--
Aroclor-1221	11104-28-2		0.0140	WQC CCC	EPA, 2009	--
Aroclor-1232	11141-16-5		0.0140	WQC CCC	EPA, 2009	--
Aroclor-1242	53469-21-9		0.0140	WQC CCC	EPA, 2009	--
Aroclor-1248	12672-29-6		0.0140	WQC CCC	EPA, 2009	--
Aroclor-1254	11097-69-1		0.0140	WQC CCC	EPA, 2009	--
Aroclor-1260	11096-82-5		0.0140	WQC CCC	EPA, 2009	--
Arsenic	7440-38-2		150	WQC CCC	EPA, 2009	--
Barium	7440-39-3		364	Tier II SCV	Michigan DEQ	Based on a 2005 hardness equation developed by the Michigan DEQ (MDEQ, 2011) and used by the Province of Quebec. An earlier (1996) version of the MDEQ, 2011 equation was previously used by Quebec and cited by MacDonald, 2000, and used by RCBRA to calculate a screening value. The proposed NOEC value of 0.364 mg/L reflects the use of the updated MDEQ, 2011 equation, which is now also used by Quebec. Value calculated at a hardness of 84 mg/L.

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
Cadmium	7440-43-9	µg/L	0.220	EPA, 2009	EPA, 2009	Hardness adjusted to 84 mg/L, average for Columbia River.
Calculated total uranium	calc_tot_U		5.0	PNEC	Sheppard et al., 2005	Sheppard aggregate value for invertebrates and plants. RCBRA receptor-specific value.
Chlordane	57-74-9		0.00430	WQC CCC	EPA, 2009	--
Chloride	16887-00-6		230000	WQC CCC	WAC 173-201A	--
Chloroform	67-66-3		28	Tier II SCV	ES/ER/TM-96/R2	--
Chromium	7440-47-3		64	WQC CCC	EPA, 2009	Hardness adjusted to 84 mg/L, average for Columbia River.
Cobalt	7440-48-4		23	Tier II SCV	ES/ER/TM-96/R2	--
Copper	7440-50-8		10	WQC CCC	WAC 173-201A	Hardness adjusted to 84 mg/L, average for Columbia River.
Cyanide	57-12-5		5.2	WQC CCC	EPA, 2009	--
Dieldrin	60-57-1		0.00190	WQC CCC	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Endosulfan I	959-98-8		0.0560	WQC CCC	EPA, 2009	--
Endosulfan II	33213-65-9		0.0560	WQC CCC	EPA, 2009	--
Endrin	72-20-8		0.00230	WQC CCC	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Fluoride	16984-48-8		300	AWQC	BCMOE, 1995	Tentative criterion; maximum where water hardness >/= 50 mg/L, – British Columbia
Gamma-BHC (Lindane)	58-89-9		0.0800	WQC CCC	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Heptachlor	76-44-8		0.00380	WQC CCC	EPA, 2009	--

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
Heptachlor epoxide	1024-57-3	µg/L	0.00380	WQC CCC	EPA, 2009	--
Hexavalent chromium	18540-29-9		10	WQC CCC	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Iron	7439-89-6		1000	WQC CCC	EPA, 2009	--
Lead	7439-92-1		2.1	WQC CCC	EPA, 2009	Hardness adjusted to 84 mg/L, average for Columbia River.
Manganese	7439-96-5		120	Tier II SCV	ES/ER/TM-96/R2	--
Mercury	7439-97-6		0.0120	WQC CCC	WAC 173-201A	Washington State Water Quality Standards for SW, Table 240(3) Toxic Substances Criteria. Note based on HH consumption of fish, not designed to be protective of aquatic life which yields a different value.
Methoxychlor	72-43-5		0.0300	WQC CCC	EPA, 2009	--
Nickel	7440-02-0		45	WQC CCC	EPA, 2009	Hardness adjusted to 84 mg/L, average for Columbia River.
Nitrate	14797-55-8		88600	IC-25 Ceriodaphnia dubia	Nautilus Environmental, 2013	Chronic NOEC for fish. In comparison, Camargo et al., 2005, suggest that 2,000 µg/L is protective of the most sensitive freshwater species
Nitrite	14797-65-0		493	--	Neuman et al., 2001	LOEC of 0.49 mg/L (0.15 mg/L NO2-N) for significant reduction in development.
Nitrogen in Nitrate	NO3-N		20000	IC-25 Ceriodaphnia dubia	Nautilus Environmental, 2013	Chronic NOEC for fish. In comparison, Camargo et al., 2005, suggest that 2,000 µg/L is protective of the most sensitive freshwater species
Pentachlorophenol	87-86-5		13	WQS	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Phosphate	14265-44-2		1000	Plant NOEC	Blindow, 1988	Plant value; no effect on growth. Phosphorous used as surrogate.

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
Phosphorus	7723-14-0	µg/L	1000	Plant NOEC	Blindow, 1988	Plant value; no effect on growth.
Selenium	7782-49-2		5.0	WQC CCC	WAC 173-201A	--
Silver	7440-22-4		2.6	WQS	WAC 173-201A	Hardness adjusted to 84 mg/L, average for Columbia River.
Total PCBs	TOTALPCB		0.140	Tier II SCV	ES/ER/TM-96/R2	--
Total Petroleum Hydrocarbons – diesel range	TPHDIESEL		500	--	CRWQCB, 2007	TPH value
Toxaphene	8001-35-2		0.0002	WQS	WAC 173-201A	Washington State Water Quality Standards for Surface Waters, Table 240(3) Toxic Substances Criteria
Trichloroethene	79-01-6		47	Tier II SVC	ES/ER/TM-96/R2	--
Uranium	7440-61-1		5.0	PNEC	Sheppard et al., 2005	Sheppard aggregate value for invertebrates and plants. RCBRA receptor-specific value.
Vanadium	7440-62-2		100	NOEC	WHO, 2001	World Health Organization gives range of LC50 values for freshwater fish, from 400 µg/L (144-hr exposure) to 118,000 µg/L (96-hr exposure). Given the uncertainty in such a broad concentration range for the same endpoint, a NOEC was considered based on using the lowest LC50 (400 µg/L; Knudtson, 1979). This study apparently lacked controls, had nominal concentrations, and measured non-native species (guppy). It is recommended that Stendahl and Sprague (1982) be used because of good study design (measured values, representative species and hardness [103 mg/L CaCO3], flow-through test) based on 11-d LC50 of 2,000 µg/L.
Zinc	7440-66-6		90	Washington chronic WQS	WAC 173-201A	Hardness adjusted to 84 mg/L, average for Columbia River.

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
Antimony-125	14234-35-6	pCi/L	367000	BCG	DOE-STD-1153-2002	Aquatic animal value
Barium-140	14798-08-4		94.6	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Riparian animal value
Carbon-14	14762-75-5		609	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Riparian animal value
Cerium/Praseodymium-144	CE/PR-144		1600	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Cerium-141	13967-74-3		8830	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Cerium-144	14762-78-8		1600	BCG	DOE-STD-1153-2002	Aquatic animal value
Cesium-134	13967-70-9		21.1	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Riparian animal value
Cesium-137	10045-97-3		42.6	BCG	DOE-STD-1153-2002	Riparian animal value
Chromium-51	14392-02-0		268000	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Cobalt-58	13981-38-9		9680	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Cobalt-60	10198-40-0		3760	BCG	DOE-STD-1153-2002	Aquatic animal value
Europium-152	14683-23-9		25500	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Europium-154	15585-10-1		21600	BCG	DOE-STD-1153-2002	Aquatic animal value
Europium-155	14391-16-3		26400	BCG	DOE-STD-1153-2002	Aquatic animal value
Iodine-129	15046-84-1		38400	BCG	DOE-STD-1153-2002	Riparian animal value
Iodine-131	10043-66-0		13700	BCG	DOE-STD-1153-2002	Riparian animal value
Neptunium-237	13994-20-2		68.5	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
Plutonium-238	13981-16-3	pCi/L	176	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Plutonium-239	15117-48-3		187	BCG	DOE-STD-1153-2002	Aquatic animal value
Plutonium-239/240	PU-239/240		187	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal; value for plutonium-239
Potassium-40	13966-00-2		250	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Riparian animal value
Radium-226	13982-63-3		4.1	BCG	DOE-STD-1153-2002	Riparian animal value
Radium-228	15262-20-1		3.4	BCG	DOE-STD-1153-2002	Riparian animal value
Selenium-75	14265-71-5		47800	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	--
Strontium-90	10098-97-2		278	BCG	DOE-STD-1153-2002	Riparian animal value
Technetium-99	14133-76-7		667000	BCG	DOE-STD-1153-2002	Riparian animal value
Thorium	7440-29-1		304	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	--
Thorium-230	14269-63-7		2570	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Thorium-232	TH-232		304	BCG	DOE-STD-1153-2002	Aquatic animal value
Thorium-234	15065-10-8		267000	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Aquatic animal value
Tritium	10028-17-8		265000000	BCG	RESRAD BIOTA v1.5 (DOE/EH-0676)	Riparian animal value
Uranium-233/234	U-233/234		202	BCG	DOE-STD-1153-2002	Value for uranium-234; same CAS no. Aquatic animal value.
Uranium-234	13966-29-5		202	BCG	DOE-STD-1153-2002	Aquatic animal value
Uranium-235	15117-96-1		217	BCG	DOE-STD-1153-2002	Aquatic animal value

Table 7-14. Surface Water Effect Levels for Aquatic Biota and Amphibians

Analyte Name	CAS#	Units	Surface Water Effect Level	Effect Level Basis	Effect Level Source	Notes
Uranium-238	U-238	pCi/L	223	BCG	DOE-STD-1153-2002	Aquatic animal value
Zinc-65	13982-39-3		13.2	BCG	DOE-STD-1153-2002	Riparian animal value
Zirconium/Niobium-95	ZR/NB-95		7330	BCG	DOE-STD-1153-2002	Aquatic animal value
Zirconium-95	13967-71-0		7330	BCG	DOE-STD-1153-2002	Aquatic animal value

Note: Complete reference citations are provided in Chapter 8 of this document.

AWQC = ambient water quality criteria
BCG = biota concentration guide
CAS = Chemical Abstract Service
CCC = criteria continuous concentration
DEQ = Department of Environmental Quality
LOEC = lowest observed effect concentration
MDEQ = Michigan Department of Environmental Quality
NOEC = no observed effect concentration
PCB = polychlorinated biphenyl
PNEC = probable no effect concentration
RCBRA = River Corridor Baseline Risk Assessment
SCV = secondary chronic value
TPH = total petroleum hydrocarbons
WQC = water quality criteria
WQS = water quality standard

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
1,2,4-Trichlorobenzene	120-82-1	µg/kg	9,600	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
2,4,5-Trichlorophenol	95-95-4	µg/kg	10	Dutch target	MHSPE, 2001	22,000	Dutch intervention	MHSPE, 2001
2,4,6-Trichlorophenol	88-06-2	µg/kg	10	Dutch target	MHSPE, 2001	110,000	Dutch intervention	MHSPE, 2001
2-Chlorophenol	95-57-8	µg/kg	55	Dutch target	MHSPE, 2001	7,800	MHSPE, 2001	MHSPE, 2001
2-Methylnaphthalene	91-57-6	µg/kg	470	SQS	Ecology Publication 03-09-088	560	CSL	Ecology Publication 03-09-088
2-Methylphenol [cresol, o-]	95-48-7	µg/kg	12	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	50,000	Dutch intervention	MHSPE, 2001
3+4 Methylphenol [cresol, m+p]	65794-96-9	µg/kg	260	SQS	Ecology Publication 11-09-054	2,000	CSL	Ecology Publication 03-09-088
Acenaphthene	83-32-9	µg/kg	1,060	SQS	Ecology Publication 03-09-088	1,320	CSL	Ecology Publication 03-09-088
Acenaphthylene	208-96-8	µg/kg	470	SQS	Ecology Publication 03-09-088	640	CSL	Ecology Publication 03-09-088
Acetone	67-64-1	µg/kg	8.7	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
Aldrin	309-00-2	µg/kg	2.0	LEL	Buchman, 2008	8.0	SEL – Concentration in µg/g organic carbon	Buchman, 2008
Alpha-BHC	319-84-6	µg/kg	6.0	LEL	Buchman, 2008	100	SEL – Concentration in µg/g organic carbon	Buchman, 2008
alpha-Chlordane	5103-71-9	µg/kg	0.030	Dutch target	MHSPE 2001	4,000	Dutch intervention	MHSPE, 2001
Aluminum	7429-90-5	µg/kg	1.40E+07	ERL	Buchman, 2008	2.50E+07	ARCS	Buchman, 2008
Anthracene	120-12-7	µg/kg	1,200	SQS	Ecology Publication 03-09-088	1,580	CSL	Ecology Publication 03-09-088
Antimony	7440-36-0	µg/kg	400	SQS	Ecology Publication 03-09-088	600	CSL	Ecology Publication 03-09-088

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Aroclor-1016	12674-11-2	µg/kg	7.0	LEL	Buchman, 2008	53,000	SEL – Concentration in µg/g organic carbon	Buchman, 2008
Aroclor-1248	12672-29-6	µg/kg	30	LEL	Buchman, 2008	150,000	SEL – Concentration in µg/g organic carbon	Buchman, 2008
Aroclor-1254	11097-69-1	µg/kg	60	LEL	Buchman, 2008	340,000	SEL – Concentration in µg/g organic carbon	Buchman, 2008
Aroclor-1260	11096-82-5	µg/kg	5.0	LEL	Buchman, 2008	240,000	SEL – Concentration in µg/g organic carbon	Buchman, 2008
Arsenic	7440-38-2	µg/kg	14,000	SQS	Ecology Publication 11-09-054	120,000	CSL	Ecology Publication 03-09-088
Barium	7440-39-3	µg/kg	300,000		Crommentuijn, 2000	--	--	--
Benzo[a]anthracene	56-55-3	µg/kg	4,260	SQS	Ecology Publication 03-09-088	5,800	CSL	Ecology Publication 03-09-088
Benzo[a]pyrene	50-32-8	µg/kg	3,300	SQS	Ecology Publication 03-09-088	4,810	CSL	Ecology Publication 03-09-088
Benzo[b]fluoranthene	205-99-2	µg/kg	11,000	SQS	Ecology Publication 03-09-088	14,000	CSL	Ecology Publication 03-09-088
Benzo[ghi]perylene	191-24-2	µg/kg	4,020	SQS	Ecology Publication 03-09-088	5,200	CSL	Ecology Publication 03-09-088
Benzo[k]fluoranthene	207-08-9	µg/kg	11,000	SQS	Ecology Publication 03-09-088	14,000	CSL	Ecology Publication 03-09-088
Beryllium	7440-41-7	µg/kg	--	--	--	--	--	--
beta-1,2,3,4,5,6-Hexachloro-cyclohexane	319-85-7	µg/kg	7.2	SQS	Ecology Publication 11-09-054	11	CSL	Ecology Publication 03-09-088

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Bis(2-ethylhexyl) phthalate	117-81-7	µg/kg	500	SQS	Ecology Publication 11-09-054	22,000	CSL	Ecology Publication 03-09-088
Butylbenzylphthalate	85-68-7	µg/kg	260	SQS	Ecology Publication 03-09-088	370	CSL	Ecology Publication 03-09-088
Cadmium	7440-43-9	µg/kg	2,100	SQS	Ecology Publication 11-09-054	5,400	CSL	Ecology Publication 11-09-054
Calculated Total Uranium	calc_tot_U	µg/kg	100,000	PNEC	Sheppard et al., 2005	--	--	--
Carbazole	86-74-8	µg/kg	900	SQS	Ecology Publication 11-09-054	1,100	CSL	Ecology Publication 11-09-054
Chloride	16887-00-6	µg/kg	--	--	--	--	--	--
Chromium	7440-47-3	µg/kg	72,000	SQS	Ecology Publication 11-09-054	88,000	CSL	Ecology Publication 11-09-054
Chrysene	218-01-9	µg/kg	5,940	SQS	Ecology Publication 03-09-088	6,400	CSL	Ecology Publication 03-09-088
Cobalt	7440-48-4	µg/kg	50,000	LEL	Buchman, 2008	--	--	--
Copper	7440-50-8	µg/kg	400,000	SQS	Ecology Publication 11-09-054	1.20E+06	CSL	Ecology Publication 11-09-054
Delta-BHC	319-86-8	µg/kg	12	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	2,000	Dutch intervention	MHSPE, 2001
Dibenz[a,h]anthracene	53-70-3	µg/kg	800	SQS	Ecology Publication 03-09-088	840	CSL	Ecology Publication 03-09-088
Dibenzofuran	132-64-9	µg/kg	200	SQS	Ecology Publication 11-09-054	680	CSL	Ecology Publication 11-09-054
Dichlorodiphenyldichloroethane	72-54-8	µg/kg	310	SQS	Ecology Publication 11-09-054	860	CSL	Ecology Publication 11-09-054
Dichlorodiphenyldichloroethylene	72-55-9	µg/kg	21	SQS	Ecology Publication 11-09-054	33	CSL	Ecology Publication 11-09-054
Dichlorodiphenyltrichloroethane	50-29-3	µg/kg	100	SQS	Ecology Publication 11-09-054	8,100	CSL	Ecology Publication 11-09-054

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Dieldrin	60-57-1	µg/kg	4.9	SQS	Ecology Publication 11-09-054	9.3	CSL	Ecology Publication 11-09-054
Diethylphthalate	84-66-2	µg/kg	530	Dutch target	MHSPE, 2001	53,000	Dutch intervention	MHSPE, 2001
Dimethyl phthalate	131-11-3	µg/kg	46	SQS	Ecology Publication 03-09-088	440	CSL	Ecology Publication 03-09-088
Di-n-butylphthalate	84-74-2	µg/kg	380	SQS	Ecology Publication 11-09-054	1,000	CSL	Ecology Publication 11-09-054
Di-n-octylphthalate	117-84-0	µg/kg	39	SQS	Ecology Publication 11-09-054	1,100	CSL	Ecology Publication 11-09-054
Endosulfan I	959-98-8	µg/kg	5.0	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	4,000	Dutch intervention	MHSPE, 2001
Endosulfan II	33213-65-9	µg/kg	5.0	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
Endosulfan sulfate	1031-07-8	µg/kg	5.0	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
Endrin	72-20-8	µg/kg	2.2	TEC	MacDonald et al., 2000	207	PEC	MacDonald et al., 2000
Endrin aldehyde	7421-93-4	µg/kg	2.2	TEC	MacDonald et al., 2000	207	PEC	MacDonald et al., 2000
Endrin ketone	53494-70-5	µg/kg	8,500	SQS	Ecology Publication 11-09-054	--	--	--
Fluoranthene	206-44-0	µg/kg	11,000	SQS	Ecology Publication 03-09-088	15,000	CSL	Ecology Publication 03-09-088
Fluorene	86-73-7	µg/kg	1,000	SQS	Ecology Publication 03-09-088	3,000	CSL	Ecology Publication 03-09-088
Gamma-BHC [Lindane]	58-89-9	µg/kg	2.4	TEC	MacDonald et al., 2000	5.0	PEC	MacDonald et al., 2000
gamma-Chlordane	5566-34-7	µg/kg	0.030	Dutch target	MHSPE, 2001	4,000	Dutch intervention	MHSPE, 2001
Heptachlor	76-44-8	µg/kg	68	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	4,000	Dutch intervention	MHSPE, 2001

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Heptachlor epoxide	1024-57-3	µg/kg	2.5	TEC	MacDonald et al., 2000	16	PEC	MacDonald et al., 2000
Hexachlorobenzene	118-74-1	µg/kg	20	LEL	Buchman, 2008	240	SEL – Concentration in µg/g organic carbon	Buchman, 2008
Hexachloroethane	67-72-1	µg/kg	1,000	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
Hexavalent Chromium	18540-29-9	µg/kg	--	--	--	--	--	--
Indeno[1,2,3-cd]pyrene	193-39-5	µg/kg	4,120	SQS	Ecology Publication 03-09-088	5,300	CSL	Ecology Publication 03-09-088
Iron	7439-89-6	µg/kg	2.00E+07	LEL	Buchman, 2008	--	--	--
Lead	7439-92-1	µg/kg	360,000	SQS	Ecology Publication 11-09-054	1.30E+06	CSL	Ecology Publication 11-09-054
Manganese	7439-96-5	µg/kg	460,000	LEL	Buchman, 2008	1.10E+06	SEL	Buchman, 2008
Mercury	7439-97-6	µg/kg	660	SQS	Ecology Publication 11-09-054	800	CSL	Ecology Publication 11-09-054
Methoxychlor	72-43-5	µg/kg	19	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
Molybdenum	7439-98-7	µg/kg	250,000	MPC	Crommentuijn, 2000	--	--	--
Naphthalene	91-20-3	µg/kg	500	SQS	Ecology Publication 03-09-088	1,310	CSL	Ecology Publication 03-09-088
Nickel	7440-02-0	µg/kg	26,000	SQS	Ecology Publication 11-09-054	110,000	CSL	Ecology Publication 11-09-054
Pentachlorophenol	87-86-5	µg/kg	1,200	SQS	Ecology Publication 11-09-054	1,200	CSL	Ecology Publication 11-09-054
Phenanthrene	85-01-8	µg/kg	6,100	SQS	Ecology Publication 03-09-088	7,600	CSL	Ecology Publication 03-09-088
Phenol	108-95-2	µg/kg	120	SQS	Ecology Publication 11-09-054	210	CSL	Ecology Publication 11-09-054

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Phosphorus	7723-14-0	µg/kg	600,000	LEL	Buchman, 2008	2.00E+06	SEL	Buchman, 2008
Potassium	7440-09-7	µg/kg	--	--	--	--	--	--
Pyrene	129-00-0	µg/kg	8,800	SQS	Ecology Publication 03-09-088	16,000	CSL	Ecology Publication 03-09-088
Selenium	7782-49-2	µg/kg	11,000	SQS	Ecology Publication 11-09-054	20,000	CSL	Ecology Publication 11-09-054
Silicon	7440-21-3	µg/kg	--	--	--	--	--	--
Silver	7440-22-4	µg/kg	570	SQS	Ecology Publication 11-09-054	1,700	CSL	Ecology Publication 11-09-054
Thallium	7440-28-0	µg/kg	2,600	--	Crommentuijn, 2000	--	--	--
Tin	7440-31-5	µg/kg	239,000	--	Crommentuijn, 2000	2.20E+07	--	Crommentuijn, 2000
Toluene		µg/kg	50	EqP at 1% TOC using SCV	ES/ER/TM-95/R4	--	--	--
Total PCB	TOTALPCB	µg/kg	110	SQS	Ecology Publication 11-09-054	2,500	CSL	Ecology Publication 11-09-054
Total petroleum hydrocarbons	TPH	µg/kg	17,000	SQS	Ecology Publication 11-09-054	30,000	CSL	Ecology Publication 11-09-054
Total petroleum hydrocarbons – diesel range	TPHDIESEL	µg/kg	340,000	SQS	Ecology Publication 11-09-054	510,000	CSL	Ecology Publication 11-09-054
Toxaphene	8001-35-2	µg/kg	0.10	TEL	MacDonald et al., 2000	--	--	--
Uranium [inorganic]	7440-61-1	µg/kg	100,000	PNEC	Sheppard et al., 2005	--	--	--
Vanadium	7440-62-2	µg/kg	90,000	PNEC	Environment Canada 2010	--	--	--
Zinc	7440-66-6	µg/kg	3.20E+06	SQS	Ecology Publication 11-09-054	4.20E+06	CSL	Ecology Publication 11-09-054
Americium-241	14596-10-2	pCi/g	5,150	BCG riparian animal	DOE-STD-1153-2002	--	--	--

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Antimony-124	14683-10-4	pCi/g	7,030	No BCG available; value for Sb-125 used. Riparian animal sediment	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Antimony-125	14234-35-6	pCi/g	7,030	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Barium-133	13981-41-4	pCi/g	230	No BCG available; value for Ba140 used. Riparian animal sediment	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Barium-140	14798-08-4	pCi/g	230	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Carbon-14	14762-75-5	pCi/g	59,000	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cerium/Praseodymium-144	CE/PR-144	pCi/g	2,900	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cerium-139	CE-139	pCi/g	2,900	No BCG available; value for Ce-144 used. Riparian animal sediment	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cerium-141	13967-74-3	pCi/g	15,900	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cerium-144	14762-78-8	pCi/g	2,900	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Cesium-134	13967-70-9	pCi/g	1,480	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cesium-136	CS-136	pCi/g	1,480	No BCG available; value for Cs-134 used. Riparian animal sediment	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Cesium-137	10045-97-3	pCi/g	3,120	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Chromium-51	14392-02-0	pCi/g	106,000	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cobalt-57	13981-50-5	pCi/g	1,460	No BCG available; value for Co-60 used. Riparian animal sediment	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cobalt-58	13981-38-9	pCi/g	3,800	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Cobalt-60	10198-40-0	pCi/g	1,460	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Europium-152	14683-23-9	pCi/g	3,040	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Europium-154	15585-10-1	pCi/g	2,570	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Europium-155	14391-16-3	pCi/g	31,600	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Iodine-131	10043-66-0	pCi/g	5,490	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Neptunium-237	13994-20-2	pCi/g	7,630	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Plutonium-238	13981-16-3	pCi/g	5,730	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Plutonium-239	15117-48-3	pCi/g	5,860	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Plutonium-239/240	PU-239/240	pCi/g	5,860	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Potassium-40	13966-00-2	pCi/g	4,430	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Radium-223	15623-45-7	pCi/g	88	No BCG available; value for Ra-228 used. Riparian animal sediment	DOE-STD-1153-2002	--	--	--
Radium-226	13982-63-3	pCi/g	101	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Radium-228	15262-20-1	pCi/g	88	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Selenium-75	SE-75	pCi/g	9,570	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Strontium-85	13967-73-2	pCi/g	582	No BCG available; value for Sr-90 used. Riparian animal sediment	DOE-STD-1153-2002	--	--	--
Strontium-90	10098-97-2	pCi/g	582	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Technetium-99	14133-76-7	pCi/g	42,200	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Thorium-228	14274-82-9	pCi/g	805	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Thorium-230	14269-63-7	pCi/g	10,400	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Thorium-232	TH-232	pCi/g	1,300	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Thorium-234	15065-10-8	pCi/g	4,330	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--
Tritium	10028-17-8	pCi/g	374,000	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Uranium [radionuclide]	U_rad	pCi/g	2,490	No BCG available; value for Ur-238 used. Riparian animal sediment	DOE-STD-1153-2002	--	--	--
Uranium-233/234	U-233/234	pCi/g	5,270	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Uranium-235	15117-96-1	pCi/g	3,730	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Uranium-236	13982-70-2	pCi/g	2,490	No BCG available; value for Ur-238 used. Riparian animal sediment	DOE-STD-1153-2002	--	--	--
Uranium-238	U-238	pCi/g	2,490	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Zinc-65	13982-39-3	pCi/g	1,430	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Zirconium/Niobium-95	ZR/NB-95	pCi/g	2,330	BCG riparian animal	DOE-STD-1153-2002	--	--	--

Table 7-15. Summary of Sediment Effect Levels

Analyte Name	CAS#	Units	Lower Threshold Effect Level	Lower Threshold Effect Level Basis	Lower Threshold Effect Level Source	Upper Threshold Effect Level	Upper Threshold Effect Level Basis	Upper Threshold Effect Level Source
Zirconium-95	13967-71-0	pCi/g	2,330	BCG riparian animal	DOE-STD-1153-2002	--	--	--
Tin-113	13966-06-8	pCi/g	N/A	BCG riparian animal	RESRAD BIOTA v1.5 (DOE/EH-0676)	--	--	--

Notes: Complete reference citations are provided in Chapter 8 of this report.

Lower threshold effect levels are the more conservative value used for screening purposes and generally (but not always) based on effects to 20% or less of test organisms below which significant effects are unlikely.

Upper threshold effect levels are the value used for defining for decision making based on effects to a greater number of individuals and above which effects are probable.

ARCS = Assessment and Remediation of Contaminated Sediments
BCG = biota concentration guide
CAS = Chemical Abstract Service
CSL = cleanup screening level
EqP = value based on the use of equilibrium partitioning principles to establish a value from a surface water criterion
ERL = effects range low
LEL = lower effect level
MPC = maximum permissible concentration
N/A = not applicable
PEC = probable effect concentration
PCB = polychlorinated biphenyl
PNEC = predicted no effect concentration
SCV = secondary chronic value
SEL = severe effect level
SQS = sediment quality standard
TEC = threshold effect concentration
TEL = threshold effect level
TOC = total organic carbon
TPH = total petroleum hydrocarbons

The water effect level that was used represented the lowest of the available values for protection of aquatic receptors. The lowest value was used to evaluate the potential for adverse effects to multiple classes of organisms at once with the premise that if the water concentrations are below the lowest value, then all organisms were assumed to be protected. The selected effect levels are summarized in Table 7-14 and Appendix J, Table J-2.

7.7.3.2 Ecological Effect Levels for Riparian Soil

Ecological effect levels used for the evaluation of riparian area soil were the same as those used for the uplands as described in Sections 7.3 and 7.5. Values included those in ECF-HANFORD-11-0158 and CHPRC-01311. Screening level evaluations of the riparian and island soil data have previously been conducted in the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2012-117), and lists of COPECS were identified. Thus, comparisons for this BERA were immediately made against soil PRGs (Section 7.5) when available. Plants and invertebrates were evaluated separately from wildlife and comparisons were made to either the lowest soil PRG for plants and invertebrates (Section 7.5, Table 7-6) or the lowest soil PRG for wildlife (Section 7.5, Table 7-6). The lowest SSLs from CHPRC-00784 were used for organic chemicals and radionuclides since PRGs were not available.

7.7.3.3 Effect Levels for Sediment

Sediment effect levels are summarized in Table 7-15 and Appendix J, Table J-4. Both lower threshold effects levels for screening and upper threshold effects levels for refined evaluation are presented. Effect levels for sediment are the same as those used in the RCBRA and in the CRC and come from a variety of published sources. When available, preference was given to values published in Ecology Publication 11-09-054, *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho*. In addition to the values summarized in Ecology Publication 11-09-054, the following additional sources were used (bulleted list below) when an effect level was not available, with preference specifically toward datasets from the Pacific Northwest.

- WAC 173-340, Table 749-3, "Ecological Indicator Soil Concentrations for Protection of Terrestrial Plants and Animals"
- ES/ER/TM-126/R2, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*
- ES/ER/TM-85/R3, *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*
- LA-UR-08-6673, *ECORISK Database*, Release 2.3
- Ecological Soil Screening Levels (SSLs), Office of Solid Waste and Emergency Response
- RESRAD BIOTA for Windows, Version 1.5 (http://web.ead.anl.gov/resrad/home2/) (radionuclides only)
- Sheppard et al., 2005, "Derivation of Ecotoxicity Thresholds for Uranium"
- Ecology Publication 03-09-088, 2003, *Development of Freshwater Sediment Quality Values for Use in Washington State. Phase II Report: Development and Recommendation of SQVs for Freshwater Sediments in Washington State*
- Ecology Publication 11-09-054, 2011, *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho*

- Environment Canada, 2010, *Screening Assessment for the Challenge, Vanadium oxide (Vanadium pentoxide) Chemical Abstracts Service Registry Number 1314-62-1*
- MHSPE, 2001, *Intervention Values and Target Values – Soil Quality Standards*
- Buchman, 2008, *NOAA Screening Quick Reference Tables*, NOAA OR&R Report 08-1
- Crommentuijn et al., 2000, "Evaluation of the Dutch Environmental Risk Limits for Metals by Application of the Added Risk Approach"
- MacDonald et al., 2000, "Development and Evaluation of Consensus-Based Sediment Effect Concentrations for Polychlorinated Biphenyls"
- DOE/EH-0676, 2004, *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation. User's Guide, Version 1*
- DOE-STD-1153-2002, 2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*
- ES/ER/TM-95/R4, 1997, *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Sediment Associated Biota: 1997 Revision*

7.7.3.4 Ecological Effect Levels for Tissue

A number of studies are available linking tissue concentrations with observed effects in fish and other aquatic life. Tissue-based effect data for epibenthic invertebrates were identified in the Environmental Residue Effects Database (USACE, 2016). Fish data are also available in compendiums such as Jarvinen and Ankley, 1999, *Linkage of Effects to Tissue residues: Development of a Comprehensive Database for Aquatic Organisms Exposed to Inorganic and organic Chemicals*; subsequent databases; and individual studies. The values used for evaluating tissue data were presented in the RCBRA (DOE/RL-2007-21) and represent the lowest applicable values. They are not repeated here because tissue data were only collected over one season and therefore only considered as a supplemental line of evidence.

7.7.3.5 Exposure Assessment for Aquatic Life

Aquatic plants and invertebrates, fish, and early life stages of amphibians all experience exposure primarily through the water and sediment in which they live. This exposure occurs when living in a contaminated medium (i.e., receptors are directly exposed to COPECs). Other exposure pathways (e.g., dietary exposure for invertebrates or foliar uptake for plants) may also contribute to total exposure for these receptors. For this BERA, estimates of exposure for aquatic plants and invertebrates are represented by the concentration of COPECs in the surface water, pore water, and sediment. Individual samples were evaluated. No central tendency estimates were considered in the BERA.

7.7.3.6 Exposure Assessment for Terrestrial Plants and Invertebrates

As previously discussed in Section 7.3.2.2, terrestrial plants and soil invertebrates experience exposure primarily through the soil in which they live. Consequently, estimates of exposure for terrestrial plants and soil invertebrates are represented by the concentration of COPCs in the Hanford-specific tissue data collected for the RCBRA and CRC, which were not used to establish effect levels. Individual samples were evaluated at the screening level and this exposure assumption was not changed for a refined assessment. No central tendency estimates were considered in the BERA.

7.7.3.7 Exposure Assessment for Wildlife (Birds and Mammals)

In contrast to plants and soil invertebrates, birds and mammals experience chemical exposure through multiple pathways, including the ingestion of surface water, sediment/soil, and biotic media (food), inhalation, and dermal contact. Modeling is often employed to assess exposure via these multiple exposure pathways. The end product, or exposure estimate, for birds and mammals, is a dose estimate that quantifies the amount of chemical in milligrams per kilogram receptor body weight per day (mg/kg/day). The processes for estimating exposure for the riparian area soil are the same as those presented in Sections 7.3.2 and 7.5.1 for the upland waste sites.

7.7.4 Riparian Soil Risk Characterization

The RCBRA evaluated ecological risks at representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (groundwater, seeps, soil, or sediment). The RCBRA concluded that six COPECs[32] identified for the riparian environment (arsenic, chromium, lead, mercury, zinc, and TPH-diesel) may present a risk to one or more of the assessment endpoint entities based on: (1) soil bioassays, (2) comparison of COPC concentrations to plant or terrestrial invertebrate toxicity benchmarks, or (3) the results of wildlife exposure analyses. Each of these six COPECs is discussed in one or more of the following subsections based upon the assessment endpoint entity for which the RCBRA concluded there was a risk.

Most concentrations detected in riparian soil at 100-K fell below plant, invertebrate, and wildlife effect levels described previously and presented in Appendix J, Table J-3. Data used in this evaluation are presented in Tables J-25 to J-31. Except for bis(2-ethylhexyl) phthalate, carbon-14, and vanadium, all other detections within 100-K were below effect levels (Appendix J, Tables J-27 through J-31). Bis(2-ethylhexyl) phthalate, carbon-14, and vanadium are discussed in Section 7.7.4.3.

7.7.4.1 Risks to Riparian Plants

Risk to terrestrial plants in the riparian area was evaluated in the RCBRA (DOE/RL-2007-21) using both field measures and comparison to effect levels. A separate comparison to effect levels was included in this BERA using the effects levels described for the upland habitats in Sections 7.3 and 7.5 (as presented in Appendix J, Table J-3). Results of all three of these analyses (RCBRA comparison to effect levels, this BERA, and field ecological measures) are described below. The results suggest that there is no risk to terrestrial plants in the riparian soil of the 100-K Area.

Within the RCBRA (DOE/RL-2007-21), ecological risk from exposure to riparian area soil was evaluated using effect levels (SSLs) developed for terrestrial exposure. As shown in Table 5-61 of the RCBRA (DOE/RL-2007-21), central tendency estimates (CTEs) of some COPECs in riparian soil collected across the Hanford Reach (i.e., estimate of central tendency across both 100 and 300 Areas[33]) exceeded literature-based plant SSL concentrations developed for the RCBRA, indicating that the potential for effects in plants warranted further evaluation. CTEs for arsenic, chromium, lead, vanadium, and zinc in riparian soil across the Hanford Site were greater than effect levels identified in the RCBRA. Lead and zinc at 100-K riparian soil locations were higher than terrestrial plant effect levels (SSLs) (DOE/RL-2007-21, Table 5-61). However, none of the concentrations of these five chemicals or any

[32] For the purposes of this assessment, the RCBRA COECs will be defined as COPECs because a link to Hanford operations was not previously evaluated.

[33] 95% UCLs from the EPA's ProUCL software were the target CTE; however, a significant number of decisions were included in deriving the UCLs as described in much greater detail in the RCBRA (DOE/RL-2007-21).

other COPCs were above the Hanford Site-specific terrestrial plant effect levels (NOECs) identified for the RCBRA or those identified for this BERA (Appendix J, Table J-29).

For this BERA, all concentrations detected in riparian soil within the 100-K Area fell below effect levels described earlier (SSLs from Tables 7-1 and PRGs from Table 7-7) and do not warrant further evaluation in the FS (Appendix J, Tables J-27 and J-29).

For riparian soil, field ecological measures of the terrestrial plant community were developed as qualitative information on the status of these communities. These findings are supported by the results of several biological measures collected as part of the RCBRA (DOE/RL-2007-21), including plant bioassays on Sandberg's bluegrass (*Poa secunda*) and plant tissue testing. Although these lines of evidence carry less weight given their more limited datasets and temporal variability (i.e., they were conducted just once), the results do support the same conclusion. Seven different measures in bioassay testing indicate that COPECs may not adversely affect plants at riparian sites. These results include measures observed in samples collected from locations along the Columbia River with rare plants that performed better in bioassays compared with reference soil. Bioassays showed no significant differences in plant seed germination, root length, stem height, root biomass, or shoot biomass between riparian study sites and reference sites. Some chemicals were detected in plant tissues, but the concentrations of the chemicals were statistically different between riparian study sites and reference site concentrations for only four chemicals: barium, copper, thallium, and zinc (RCBRA, Table 5-32). There were no significant correlations with chemicals and bioassay measures, and there were no significant correlations between soil chemistry and plant tissue measurements. Like the upland plant data, chemical concentrations found in riparian plant tissues did not correlate to those in riparian soil. Therefore, although soil concentrations are greater than plant SSLs across the Hanford Site as a whole, for some COPECs, the weight attributed to this line of evidence is low and comparisons to effect levels do not overwhelm the other lines of evidence, which do not indicate risks to plants in riparian soil. Although several analytes were detected in plant tissue during the RCBRA, and statistical differences between riparian study area sites and reference site concentrations were noted, there were no statistically significant relationships of chemical concentrations in plant tissue and soil. Therefore, no chemicals in the 100-K Area riparian soil warrant further evaluation in the FS based on risks to terrestrial plants.

7.7.4.2 Risks to Invertebrates in the Riparian Area

Risk to terrestrial invertebrates in the riparian area was evaluated in the RCBRA using both field measures and comparison to effect levels. A separate comparison to effect levels was included in this BERA using the effects levels described for the upland habitats in Sections 7.3 and 7.5 (as presented in Appendix J, Table J-3). Results of all three of these analyses (field ecological measures, RCBRA comparison to effect levels, and this BERA) are described below. The results suggest that there is no risk to terrestrial invertebrates in the riparian soil of the 100-K Area.

For riparian soil, field ecological measures of the terrestrial invertebrate community were developed as qualitative information on the status of these communities. Terrestrial invertebrate tissue concentrations, which provide an indication of contaminant uptake and bioavailability, were measured at River Corridor study sites and reference locations, and some, but not all, COPECs were detected in terrestrial invertebrates. Statistical differences were found between RCBRA terrestrial invertebrate tissue concentrations for some chemicals between study site and reference site soil. However, this line of evidence was ranked low in the RCBRA (DOE/RL-2007-21) because of the lack of detections in invertebrate tissue for riparian COPECs and the possibility of bias as a result of sample collection methods. Statistical differences in tissue concentrations of mercury and zinc in terrestrial invertebrates were noted between River Corridor and reference study sites; this relationship is based on data across the entire River Corridor and should not be inferred as a relationship that is specific for 100-K. However,

there is insufficient evidence for chemicals in general of a correlation between tissue concentrations in terrestrial invertebrates and concentrations in soil (RCBRA). Based on this analysis, no chemicals in riparian soil warrant further evaluation in the FS because of risks to terrestrial invertebrates.

Within the RCBRA, ecological risk from exposure to riparian area soil was evaluated using effect levels (SSLs) developed for terrestrial exposure. Concentrations of chromium, copper, mercury, TPH-diesel, and zinc in riparian soil exceeded benchmarks identified in the RCBRA that are protective of terrestrial invertebrates; however, the copper, mercury and TPH-diesel exceedances were not at the 100-K sample locations. In the 100-K riparian study areas, concentrations of zinc (the 2c and Rip 5 sampling locations) were higher than the terrestrial invertebrate effect levels (SSLs) (DOE/RL-2007-21, Tables 5-69 and 5-70). However, none of the concentrations of these five chemicals or any other COPCs were above the Hanford Site-specific terrestrial invertebrate effect levels (NOECs) for the RCBRA or those identified for this BERA (Appendix J, Table J-27 and J-29).

For this BERA, concentrations detected in riparian soil within the 100-K Area (Table J-29) fell below effect levels described earlier (SSLs from Tables 7-1 and PRGs from Table 7-7) and do not warrant further evaluation in the FS. Based on this analysis, no COPECs in riparian soil for terrestrial invertebrates warrant further evaluation in the FS.

7.7.4.3 Risk to Wildlife in the Riparian Area

Risk to wildlife that may forage in the riparian area was evaluated in the RCBRA using both field measures and desktop food web modeling using similar models to those described in this BERA for SSLs. A separate desktop food web evaluation was included in this BERA using the effects levels described for the upland habitats in Sections 7.3 and 7.5 (as presented in Appendix J, Table J-3). Results of all three of these analyses (field ecological measures, RCBRA desktop evaluation, this BERA) are described below. The results suggest that there is no risk to wildlife in the riparian soil of the 100-K Area.

For riparian soil, field ecological measures of the small mammal community were developed as qualitative information on the status of these populations. Estimated dietary contaminant exposures and biological concentrations in small mammal tissues are compared to ecological effects levels established for dietary ingestion or related to tissue residues. For selected COPECs (cadmium, chromium, lead, selenium, and PCBs), measured tissue concentrations in small mammals trapped in River Corridor study sites were not greater than reference areas (RCBRA, Table 5-48) and were less than available tissue effect levels (RCBRA, p. 5-91). Only tissue concentrations for barium showed correlation with soil concentrations.

Within the RCBRA, Section 8.4.1.3, dietary exposure to terrestrial birds and mammals using wildlife exposure models, estimated for riparian concentrations across the River Corridor, indicated potential exposure higher than LOAEL-based effect levels for copper, selenium, vanadium, and zinc. Only zinc was identified as a final COPEC for riparian soil exposure to birds and mammals. However, except for zinc, concentrations of these four metals in soil in the 100-K Area fall within Hanford Site-wide background and, therefore, do not warrant further evaluation in the FS. Zinc concentrations in 100-K Area riparian soil were compared to the Hanford Site-specific effect levels as shown in Appendix J, Table J-30. The results from this comparison show that all zinc concentrations fall below the effect level (wildlife PRG). Therefore, zinc concentrations in riparian soil do not warrant further evaluation in the FS based on risks to wildlife.

For this BERA, most concentrations detected in riparian soil within the 100-K Area fell below effect levels described earlier (SSLs from Tables 7-2 and 7-3 and PRGs from Table 7-6) and do not warrant further evaluation in the FS. Comparison to effect levels showed three chemicals within riparian soil had

concentrations above wildlife effect levels along the 100-K Area: carbon-14, bis(2-ethylhexyl) phthalate, and vanadium (Appendix J, Table J- 31). However, these analytes were not identified as COPECs in the RCBRA or the CRC and do not warrant further evaluation in the FS as explained below:

Carbon-14—One of ten samples (maximum detect of 112 pCi/g) exceeded the SSLs developed for carbon-14 for Hanford-specific wildlife, which ranged from 32 to 61 pCi/g except for the grasshopper mouse (132 pCi/g). One exceedance of the SSL, and only three detections, does not represent a population level risk to the various wildlife feeding guilds represented by these SSLs. Exposure estimates for riparian habitat have not been presented because, for the most part, concentrations are below effect levels. However, the EPC for carbon-14 is 37.3 pCi/g, just slightly above the conservative SSL for the badger (32 pCi/g), and below the SSLs for all the other wildlife. As shown in Table H 6 in Appendix H, the badger home range is 1,598,508 – 2,399,786 m^2 (395-593 acres; Kurta, 1995, *Mammals of the Great Lakes Region*, and Long, 1999, "American Badger: *Taxidea taxus*"), greater than thirty times the waste site area (100-K-111; 48,044 m^2 [11.9 ac]) with only slightly elevated carbon-14 concentrations. Thus, considering an AUF would yield a hazard quotient below 1 indicating population level adverse effects are not likely. There is no unacceptable risk to wildlife from carbon-14 in soil of the riparian area, and no further evaluation is warranted.

Bis(2-ethylhexyl) phthalate—Five of the ten samples (maximum detect of 800 µg/kg) analyzed for bis(2-ethylhexyl) phthalate exceeded the SSLs developed for Hanford-specific avian receptors, which ranged from 140 to 263 µg/kg. However, the effect level was derived using an unbound NOAEL. Thus, no effects were observed at the maximum concentration tested, and there were such limited data available that it is uncertain at what concentration effects in birds may be seen. Bis(2-ethylhexyl) phthalate is a common laboratory contaminant, and there is no significant site use warranting this chemical as a constituent of significant concern. Given the lack of site use and the fact that concentrations are below those estimated to pose a risk to other wildlife (mammals), toxic effects to avian wildlife at the concentrations measured are unlikely. There is no unacceptable risk to wildlife from bis(2-ethylhexyl) phthalate in soil of the riparian area, and no further evaluation is warranted.

Vanadium—The maximum detected concentration of 46.4 mg/kg for 100-K was less than the site background of 85 mg/kg. Although the effect level (range of 43 to 505 mg/kg for avian and 260 to 4,531 mg/kg for mammalian receptors) was developed with a model using site-specific tissue data, it still included uncertainties. Thus, with concentrations being below background, potential toxic effects to wildlife are unlikely. There is no unacceptable risk to wildlife from vanadium in soil of the riparian area, and no further evaluation is warranted.

7.7.5 100-K Area River Effluent Pipeline Risk Characterization

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, the two inactive 100-K effluent pipelines remain in their original locations in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F Areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines. The RCBRA provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

UNI-3262 discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F Reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected

included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The dose rates measured for direct contact with the interior of the pipe surfaces were <1 mrem/hr, and readings on the exterior were below the instrument's detection capability. Because the half-lives of these radionuclides are less than 30 years, the activity levels have declined by a factor of two to five and are no longer expected to be ecological risk drivers.

In 1994, a comprehensive geophysical survey (WHC-SD-EN-TI-278) located and mapped the reactor effluent pipelines. The study relied mainly on remote-sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground-penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (BHI-00538). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (UNI-3262) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR Reactors.

The analytical results from the 1984 and 1995 effluent pipeline characterization studies at the 105-B, 105-C, 105-D/DR, and 105-F Reactors may reasonably be applied to effluent pipelines in 100-K, because operations among these reactors were similar. Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (BHI-00538) and the 1998 risk assessment effort (BHI-01141, *100 Area River Effluent Pipelines Risk Assessment*) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (BHI-01141) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk, because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks and, therefore, no remediation requirements under CERCLA. This is supported by the following conditions:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations as a result of decay
- Inaccessible location
- Lack of significant contaminants to adversely affect ecological and human receptors

Accordingly, no further evaluation of these pipelines is needed within the FS.

7.7.6 Aquatic Invertebrate Risk Characterization

The primary lines of evidence used to evaluate risks to aquatic invertebrates are field surveys, results of bioassays, and comparison of sediment and water concentrations to literature effect levels identified in this BERA. These lines of evidence are discussed in the following sections.

7.7.6.1 Water Concentrations Compared to Effect Levels

The final COPECs[34] for pore water in the CRC within the 100-KR-4 OU were identified as Cr(VI) and manganese as noted in the Executive Summary of the CRC. COPECs in pore water identified in the RCBRA included Cr(VI), manganese, and uranium based on concentrations at study sites across the Hanford Reach that were greater than chronic water quality standards or criteria (RCBRA, Section 8.5.1.1). A more detailed discussion of each of the COPECs from the RCBRA and CRC is presented in the following paragraphs.

Dissolved (filtered) and total recoverable analytes (unfiltered) were analyzed separately for most aquatic media. Dissolved concentrations more closely approximate the bioavailable fraction in water than total recoverable concentration and, therefore, are more accurate measurements of effect (EPA 822-F-93-009, *Additional Material for the Water Quality Standards Handbook*). Water quality standards are developed from and measured in the dissolved form and thus are intended for evaluating measurements of the same dissolved form. Therefore, the dissolved concentrations of analytes are the preferred state for screening purposes.

Cr(VI)–Measurements in the 100-K Area were above the AWQC (64 µg/L) and state WQS (10 µg/L) in groundwater, aquifer tubes, pore water, and seeps. Within 100-K, nearshore samples exceeded the AWQC and WQS in groundwater wells (97 of 206 filtered samples), aquifer tubes (19 of 184 filtered samples), pore water (3 of 7 unfiltered samples), and seeps (1 of 9 unfiltered samples). Given the elevated groundwater and aquifer tube concentrations and exceedances in the direct exposure media (pore water), there is a complete pathway of Cr(VI) originating from the 100-KR-4 OU near 100-K. The 100-KR-4 OU is contributing to concentrations of Cr(VI) observed in pore water at locations within the reach of the Columbia River adjacent to or downstream from points of entry from the 100-K nearshore area.

An exceedance of an AWQC is not confirmation that adverse effects are occurring or even that there is an unacceptable risk to aquatic life. To further understand what classes of organisms may be at risk within the Columbia River, measured water concentrations were considered in relation to the specific effects data that were used to develop the AWQC by EPA, and any other more recent and relevant published toxicological data for aquatic life. Table 7-16 presents the toxicological data for all taxa (including invertebrates and fish) that were used by EPA for the calculation of the AWQC for Cr(VI) (EPA-820-B-96-001, *1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water*).

Cr(VI) was not detected in surface water near 100-K and the maximum detection in pore water samples was 42 µg/L. This value is below the representative (EPA AWQC, published literature) toxicity data for all classes of aquatic life tested except for planktonic crustaceans. Thus, pore water concentrations and the 100-KR-4 source OU indicate a potential for adverse effects only to planktonic crustaceans. There is no unacceptable risk to the other aquatic life in the Columbia River that have been the subject of published studies. However, there are other groups of aquatic organisms that have not been studied in the laboratory. As described in PB85-227049, *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, the data for taxa in Table 7-16 are a useful indication of the sensitivities of appropriate untested species. In this evaluation, the planktonic crustacean thresholds were considered representative of potentially more sensitive and yet untested benthic organisms (e.g., microscopic organisms, such as rotifers) living in the hyporheic zone and

[34] The potential for the RCBRA COECs in the nearshore environment to have originated from the 100-K Area was not previously evaluated, so for the purposes of the following assessment, the RCBRA COECs will be defined as COPECs.

exposed to Cr(VI) at levels above the AWQC. The ecological significance of these organisms is uncertain and because Cr(VI) effect levels are not available for all relevant aquatic taxa, the potential for some degree, likely low, of residual risk to aquatic biota cannot be overlooked. Thus, there could be additional organisms of significance that are at risk for adverse effects from Cr(VI) is pore water in the 100-K nearshore environment.

Table 7-16. Ranking of Cr(VI) Toxicity Values for Aquatic Taxa

Rank	Taxa	Species	Toxicity Value* µg/L Cr(VI)	Source
1	Planktonic Crustacean	Cladoceran (*D. magna*); Cladoceran (*D. pulex*)	28.94	EPA-820-B-96-001
2	Planktonic Crustacean	Cladoceran (*S. serrulatus*); Cladoceran (*S. vetulus*)	36.35	EPA-820-B-96-001
3	Planktonic Crustacean	Cladoceran (*C. reticulata*)	45.1	EPA-820-B-96-001
4	Benthic Crustacean	Amphipod (*G. pseudolimnaeus*)	67.1	EPA-820-B-96-001
5	Benthic Crustacean	Amphipod (*C. pseudogracilis*)	583	EPA-820-B-96-001
6	Benthic Crustacean	Amphipod (*H. azteca*)	630	EPA-820-B-96-001
7	Bryozoan	Bryozoan (*P. emarginata*)	650	EPA-820-B-96-001
8	Insect	Dipteran (*Culex quinquefasciatus*)	1,300	Sorenson et. Al., 2006
9	Bryozoan	Bryozoan (*P. magnifica*)	1,440	EPA-820-B-96-001
10	Bryozoan	Bryozoan (*L. carteri*)	1,560	EPA-820-B-96-001
11	Mollusk	Snail (*P. heterostropha*)	23,010	EPA-820-B-96-001
12	Fish	Guppy (*P. reticulata*)	30,000	EPA-820-B-96-001
13	Fish	Striped bass (*M. saxatilis*)	30,450	EPA-820-B-96-001
14	Fish	Yellow perch (*P. flavescens*)	36,300	EPA-820-B-96-001
15	Fish	Indian major carp (*Labeo rohita*)	39,400	Vutukuru, 2005
16	Fish	Johnny darter (*E. nigrum*)	46,000	EPA-820-B-96-001
17	Fish	Bluntnose minnow (*P. notatus*); Fathead minnow (*P. promelas*)	47,180	EPA-820-B-96-001
18	Fish	Silverjaw minnow *(E. buccata*)	49,600	EPA-820-B-96-001
19	Fish	Central stoneroller (*C. anomalum*)	51,250	EPA-820-B-96-001
20	Insect	Midge (*T. dissimilis*)	57,300	EPA-820-B-96-001
21	Fish	Brook trout (*S. fontinalis*)	59,000	EPA-820-B-96-001
22	Insect	Midge (*C. tentans*)	61,000	EPA-820-B-96-001

Table 7-16. Ranking of Cr(VI) Toxicity Values for Aquatic Taxa

Rank	Taxa	Species	Toxicity Value* µg/L Cr(VI)	Source
23	Fish	Emerald shiner (*N. atherinoides*); Striped shiner (*N. chrysocephalus*); Sand shiner (*N. stramineus*)	67,610	EPA-820-B-96-001
24	Fish	Rainbow trout (*O. mykiss*) Coho salmon (*O. kisutch*)	69,993	EPA-820-B-96-001, Buhl and Hamilton, 1991
25	Fish	White crappie (*P. annularis*)	72,600	EPA-820-B-96-001
26	Fish	Arctic grayling (*Thymallus arcticus*)	100,000	Buhl and Hamilton, 1991
27	Fish	Goldfish (*C. auratus*)	119,500	EPA-820-B-96-001
28	Fish	Green sunfish (*L. cyanellus*); Bluegill *(L. macrochirus*)	123,500	EPA-820-B-96-001
29	Fish	Pacu (*Piaractus mesopotamicus*)	124,200	Castro et al., 2014
30	Insect	Damselfly (*E. aspersum*)	140,000	EPA-820-B-96-001
31	Benthic Crustacean	Crayfish (*O. rusticus*)	176,000	EPA-820-B-96-001
32	Fish	Common carp (*Cyprinus carpio*)	191,000	Tayybah et al., 2005
33	Insect	Stonefly (*N. capitata*)	1,870,000	EPA-820-B-96-001

References: Buhl, K.J. and S.J. Hamilton, 1991, "Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics."

Castro et al., 2014, "Acute Toxicity by Water Containing Hexavalent or Trivalent Chromium in Native Brazilian Fish, *Piaractus mesopotamicus*: Anatomopathological Alterations and Mortality."

EPA-820-B-96-001, *1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water*.

Sorensen et al., 2005, "Acute and Chronic Activity of Perchlorate and Hexavalent Chromium Contamination on the Survival and Development of *Culex quinquefasciatus.*"

Tayybah et al., 2005, "Acute Toxicity Studies of Hexavalent Chromium in the Common Carp, *Cyprinus carpio.*"

Vutukuru, 2005, "Acute Effects of Hexavalent Chromium on Survival, Oxygen Consumption, Hematological Parameters and Some Biochemical Profiles of the Indian Major Carp, *Labeo rohita*."

*The toxicity value presented is the genus mean acute value, a statistical representation of the acute toxicity data for specific genus of organisms. The GMAV is a common statistic that is specified in guidance for AWQC development (EPA-820-B-96-001).

AWQC = Ambient Water Quality Criterion

Cr(VI) = hexavalent chromium

GMAV = genus mean acute value

The risk identified for planktonic crustaceans is for the potential of adverse effects due to measures of Cr(VI) in pore water, aquifer tubes, and groundwater, greater than the toxicity threshold. However, the measures of Cr(VI) in these media are not an actual observance of exposure or of adverse effects. Before concluding that risk to planktonic crustaceans is unacceptable, other factors should also be considered. These factors include an understanding of the life cycle of the planktonic organisms that affect their exposure and the concentrations in the media to which they are exposed. The life cycle of planktonic crustaceans is entirely free floating, meaning that their life cycle is entirely within the water column, not within the hyporheic zone at the groundwater sediment interface where the Cr(VI) measurements were collected. Monitoring of pore water and river water over the years has shown that there is nearly instant dissipation of the Cr(VI) detected in pore water within the surface water column. Cr(VI) was not detected in the surface water, the media to which planktonic crustaceans are exposed. Thus, there is an incomplete exposure pathway for Cr(VI) in pore water to planktonic crustaceans. When planktonic crustaceans are present near 100-K, the zooplankton community in the Hanford Reach is presumed to derive largely from upstream reservoirs (ISAB 2011-1, *Columbia River Food Webs: Developing a Broader Scientific Foundation for Fish and Wildlife Restoration*). Zooplankton production in backwater areas, such as the Hanford sloughs, although important downstream in the John Day reservoir, is limited in the Hanford Reach by daily fluctuations in water level (ISAB 2011-1). Planktonic crustacea are able to remain suspended by using their legs and antennae and live almost exclusively in the water column where their food source (phytoplankton, other zooplankton) is located. When present, planktonic crustaceans, such as *Daphnia sp.* are small and struggle to survive in a lotic system like the Columbia River with a strong current, which they are unable to swim against.

Total chromium–Total chromium was not identified as COPC in pore water in either the RCBRA or the CRC. However, it is considered in this BERA because of its link with Cr(VI). Measurements of total chromium for 100-K were above the AWQC (64 µg/L) in unfiltered groundwater samples (13 of 395 samples), filtered groundwater samples (12 of 398 samples), and a filtered seep sample (1 of 21 samples). For groundwater, the maximum unfiltered detection was 203 µg/L while the maximum filtered detection was 188 µg/L. The maximum unfiltered seep was 36.4 µg/L while the maximum filtered seep measurement was 72.1 µg/L. There were no exceedances in 124 aquifer tubes, 7 pore water samples, or the 5 surface water unfiltered samples. While there does appear to be a source of total chromium in groundwater, it does not appear to be reaching the river as there are no exceedances in aquifer tubes and no samples reporting detections in surface water. However, total chromium was identified as a groundwater COPC, including for ecological risk, in Chapter 6, thus the conclusion for this BERA is that total chromium is recommended for further evaluation in the FS.

Manganese–Concentrations of manganese were elevated in pore water samples presented in the RCBRA (DOE/RL-2007-21). Within 100-K, filtered samples exceeded the effect level (Tier II secondary chronic value [SCV] of 120 µg/L) in seep (1 of 14 samples) and groundwater (4 of 332 samples). Unfiltered samples also exceeded the effect level in seeps (2 of 14) and groundwater (4 of 329). Pore water samples were not filtered and exceeded the effect level in one of seven samples. There were no exceedances in 114 aquifer tubes or the 4 surface water samples. Manganese was not identified as a groundwater COPC, including for ecological risk, in Chapter 6. Groundwater exceedances appear to be anomalous and not indicative of an ongoing source. Therefore, the conclusion for this BERA is that there is no unacceptable risk to benthic organisms and further evaluation in the FS is not recommended.

Uranium–Uranium was identified as a COPEC in the RCBRA because some pore water concentrations were above the effect level (predicted no effect concentration [PNEC] of 5 µg/L). However, the RCBRA identified COPECs for the Hanford Reach as a whole, not for sub-reaches adjacent to or within the influence of individual OUs. Measurements for 100-K were above the predicted no effect concentration (PNEC) for 4 groundwater samples (3 of 140 unfiltered and 1 of 129 filtered samples) and 10 aquifer

tubes (5 of 55 filtered and 5 of 55 unfiltered samples) but measurements were below the effect level in all 12 seep, 7 pore water, and 4 surface water samples (filtered and unfiltered) within the 100-K Area. The maximum filtered detection was 5.54 µg/L for groundwater and 10.2 µg/L in aquifer tubes. There was one of 129 filtered groundwater and one of 55 unfiltered aquifer tube samples above site background of 9.9 µg/L. No filtered aquifer tube samples were above background. Since there is no pattern of concentrations above background, no detections in the direct exposure media (pore water and surface water), and it was not identified as a groundwater COPC, including for ecological risk, in Chapter 6. The conclusion for this BERA is that uranium does not present a risk to aquatic organisms and no further evaluation is needed.

7.7.6.2 Sediment Concentrations Compared to Literature Values

The RCBRA identified three COPECs[35] (cadmium, chromium, and manganese) in sediment for the River Corridor as a whole (RCBRA, Section 8.5.1.2). Total chromium and Cr(VI) in sediment were also identified as COPECs in the CRC (DOE/RL-2010-117)[36]. Concentrations of most Hanford Reach sediment COPECs are either below effect levels (sediment quality standards and cleanup screening levels from Ecology Publication 11-09-054 or other values when not available) or below reference area concentrations in the 100-K Area nearshore environment (explanations for the exceptions are described below). For sediment samples collected within the 100-K Area nearshore (Appendix J, Tables J-32 to J-36), just one sample of antimony was greater than the upper threshold effect levels. This suggests that sediments upstream from the Hanford Site potentially contribute to concentrations observed in the 100-K Area nearshore sediments. Riparian soil concentrations for most of the COPECs are lower than upstream sediment concentrations and Hanford Site reference soil concentrations, suggesting that the riparian soil in the 100-K Area is not a source of the observed sediment concentrations for the RCBRA COPECs identified.

Cadmium–Cadmium was detected in five of eleven samples within the 100-K nearshore sediment; however, all five detections were below the lower threshold effect level (SQS; Ecology Publication 11-09-054). Table 5-29 of the RCBRA (DOE/RL-2007-21) indicates that cadmium concentrations across the Hanford Site riparian soil are greater than riparian reference soil concentrations. For the 100-K Area riparian soil, detected concentrations of cadmium (1.7 to 2.5 mg/kg) were in the range of the maximum sediment reference area concentration (2.2 mg/kg) presented in Table 6-40 of the RCBRA. Cadmium pore water and seep samples were below the groundwater background. Table 6-40 of the RCBRA indicates that the detected nearshore sediment study site concentrations of cadmium are not greater than the reference site concentrations. The conclusion for this BERA is that there is no complete or significant pathway for observed cadmium concentrations in sediment from the 100-K riparian area.

Cr(VI)–Cr(VI) is a known site contaminant of concern and was detected in 31 of 117 sediment samples in the 100 Area Columbia River reach of the as part of the CRC (DOE/RL-2010-117), with a maximum of 7.38 mg/kg. It was also detected in nearshore sediment samples collected for the RCBRA at 0.76 mg/kg at 100-K (2 of 7 detects). With no substantial toxicological data available to evaluate the bulk sediment measurements, this contaminant was identified as a COPEC in both reports.

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[35] For the purposes of the following assessment, the RCBRA COECs will be defined as COPECs because a link to Hanford operations was not previously evaluated.

[36] The CRC made these determinations by comparison to sediment quality standards (SQS) from Ecology Publication 11-09-054. The RCBRA relied on other sources because Ecology Publication 11-09-054 was released while the RCBRA was in final production and administrative review. The effect thresholds in the RCBRA were more conservative (lower) than the SQS in Ecology Publication 11-09-054.

More detail regarding the Cr(VI) in sediment and the environment within the Columbia River and particularly at groundwater upwelling locations is found in WCH-398 and WCH-380.

It is important to understand that the measured concentrations of Cr(VI) in sediment were the results of alkaline digestion (SW-846, 2007, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, Method 3060A). All components of the sediment are subject to the digestion process, including the subcomponents (i.e., interstitial water, elutriate, solid), but it does not allow for quantitation of individual components. While Cr(VI) in sediment has been detected, EPA guidance (EPA-600-R-02-011, *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks [ESBs] for the Protection of Benthic Organisms: Metal Mixtures [Cadmium, Copper, Lead, Nickel, Silver, and Zinc]*) points to focusing on pore water as the primary exposure pathway for this chemical. As such, risk to aquatic invertebrates identified by Cr(VI) concentrations in pore water above the AWQC is discussed further in the FS.

Total Chromium–Total chromium was identified as a COPEC in the RCBRA (DOE/RL-2007-21) and for the 100 Sub-Areas in the CRC (DOE/RL-2010-117) because of concentrations above an LOEC in three samples. Chromium was detected in all 11 RCBRA sediment samples in the 100-K nearshore environment, with the maximum detect equal to the lower threshold effect level of 72 mg/kg (SQS; Ecology Publication 11-09-054), and one of those (96.3 mg/kg) is above the upper threshold effect level of 88 mg/kg in the same report (referred to as cleanup screening level in Ecology Publication 11-09-054). Chromium was detected in all 10 100-K riparian soil samples. The maximum detect from the 100-K riparian soil samples was 41.7 mg/kg. In the CRC, the three mid-channel sediment samples identified above the upper threshold effect level of 88 mg/kg (ranging from 122 to 275 mg/kg) were collected miles downstream near the 100-D, 100-H, and 100-F areas, while all samples near the 100-K Reactor Area were below effect levels; thus, the measured downstream sediment concentrations do not originate from the 100-K riparian soil or nearshore sediments where the maximum detect was 96.3 mg/kg.

Measured detections of total chromium and Cr(VI) in aqueous and solid media near 100-K are shown in Figures 7-13 to 7-17. As presented in the detailed analysis of aqueous media, total chromium in aquifer tubes and pore water was detected below the AWQC (64 µg/L), suggesting no potential source partitioning to sediments in the 100-K Area. Pore water concentrations this low would not result in the sediment concentrations that were measured miles downstream. There is no complete or significant pathway for observed total chromium concentrations in sediment from the 100-K riparian area. Ninety-seven of 206 filtered nearshore groundwater samples exceeded the AWQC and surface water quality standard (SWQS) for Cr(VI), which represents most of the total chromium, suggesting a potential ongoing source partitioning to sediments. However, the Cr(VI) concentrations in mid-channel sediment (0.26 to 7.38 mg/kg) were lower than the mid-channel total chromium concentrations (5.9 to 275 mg/kg). Likewise, the maximum nearshore Cr(VI) concentration (0.76 mg/kg) was far below the total chromium concentrations (5.5 to 72 mg/kg). Chromium concentrations in aquatic media are noted in Figures 7-13 to 7-17.

The conclusions of this BERA is that Cr(VI) in groundwater is not a significant source of total chromium sediment concentrations and the total chromium sediment concentrations are not a concern. The one exceedance of the total chromium bulk sediment cleanup level does not suggest a current community-level risk to benthic organisms and no further evaluation of chromium in sediment is warranted.

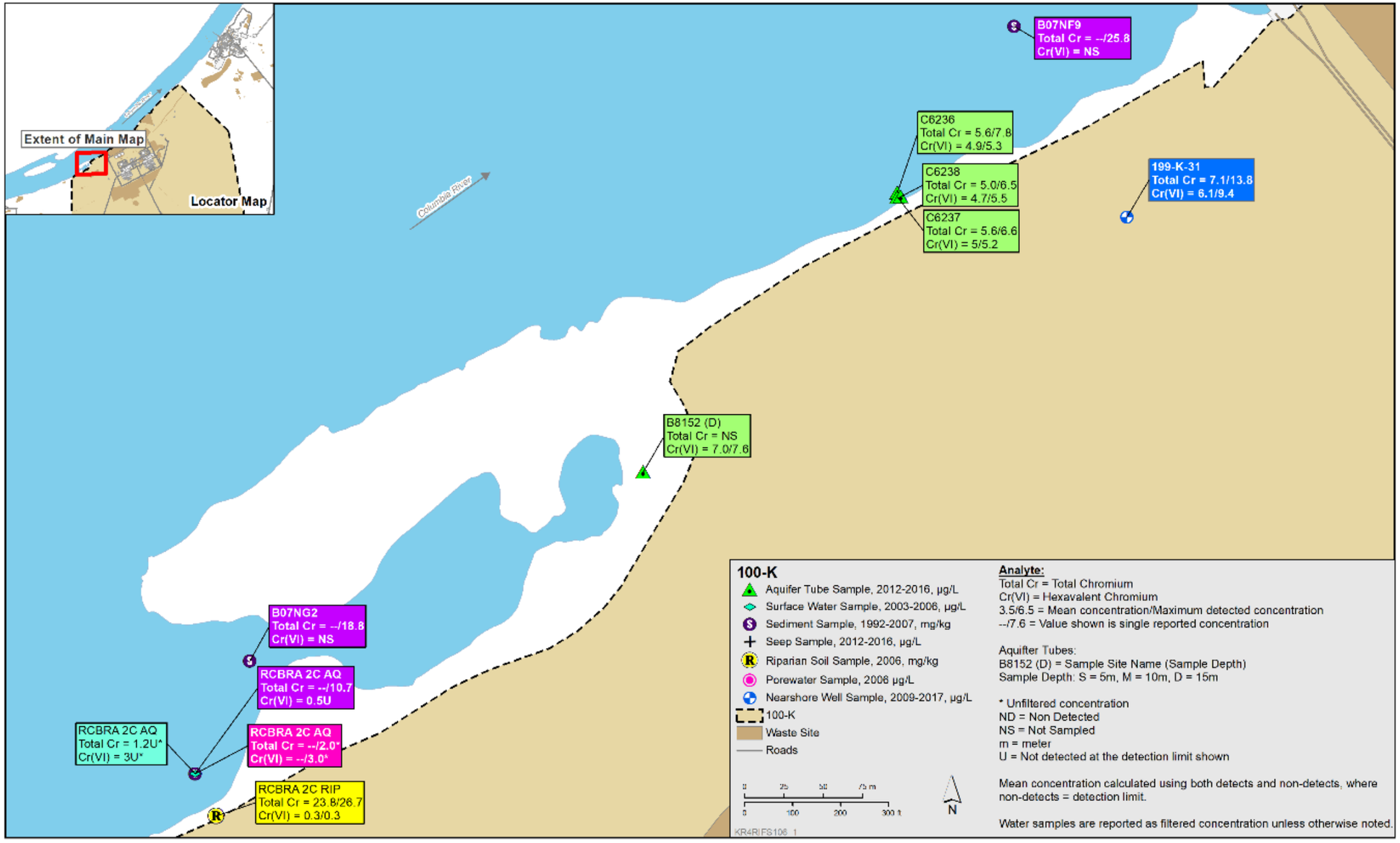

Figure 7-13. Cr(VI) and Total Chromium Concentrations in Riparian, Nearshore, and Aquatic Media at 100-BC Up-Central Locations

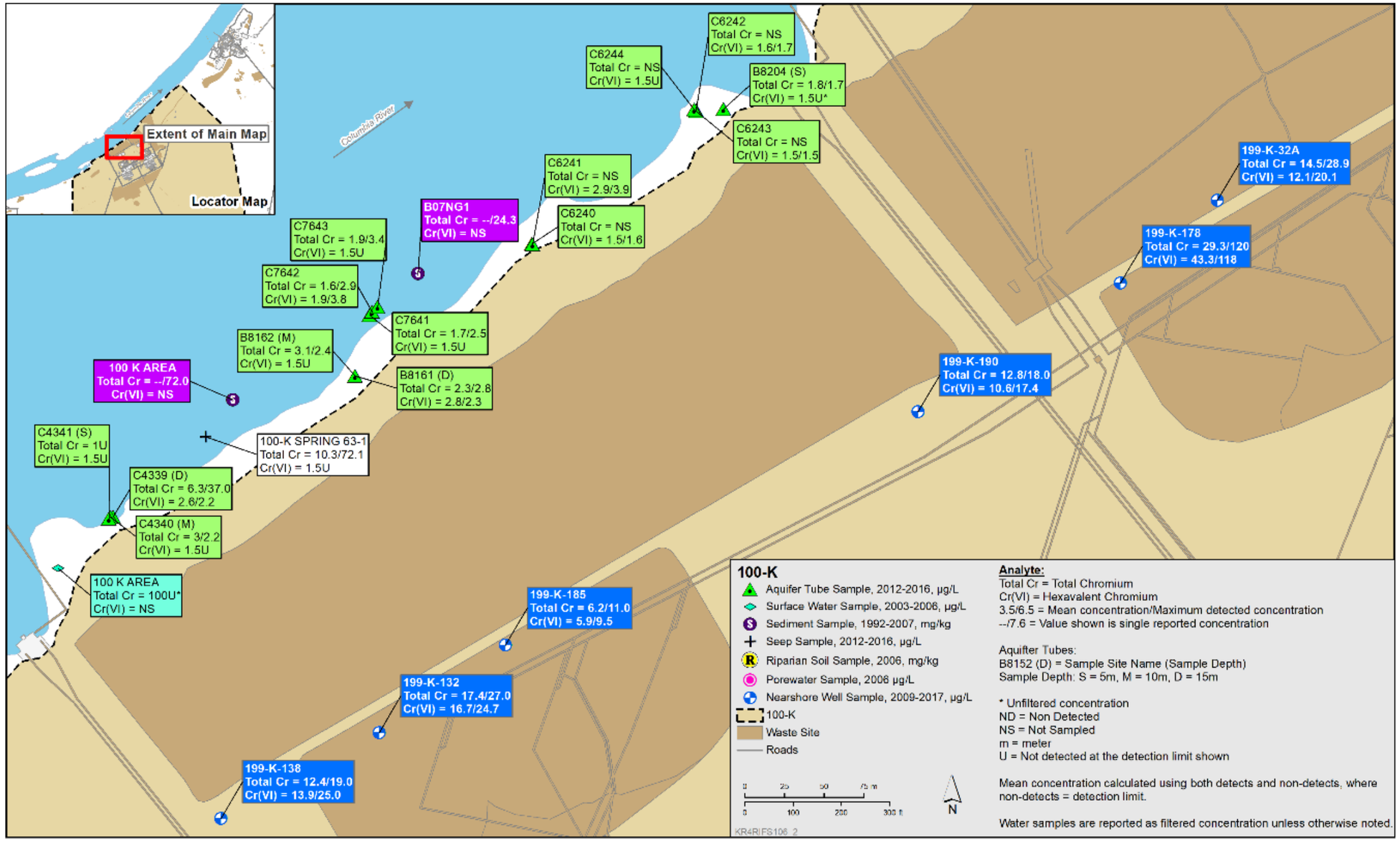

Figure 7-14. Cr(VI) and Total Chromium Concentrations in Riparian, Nearshore, and Aquatic Media at 100-K Central Locations

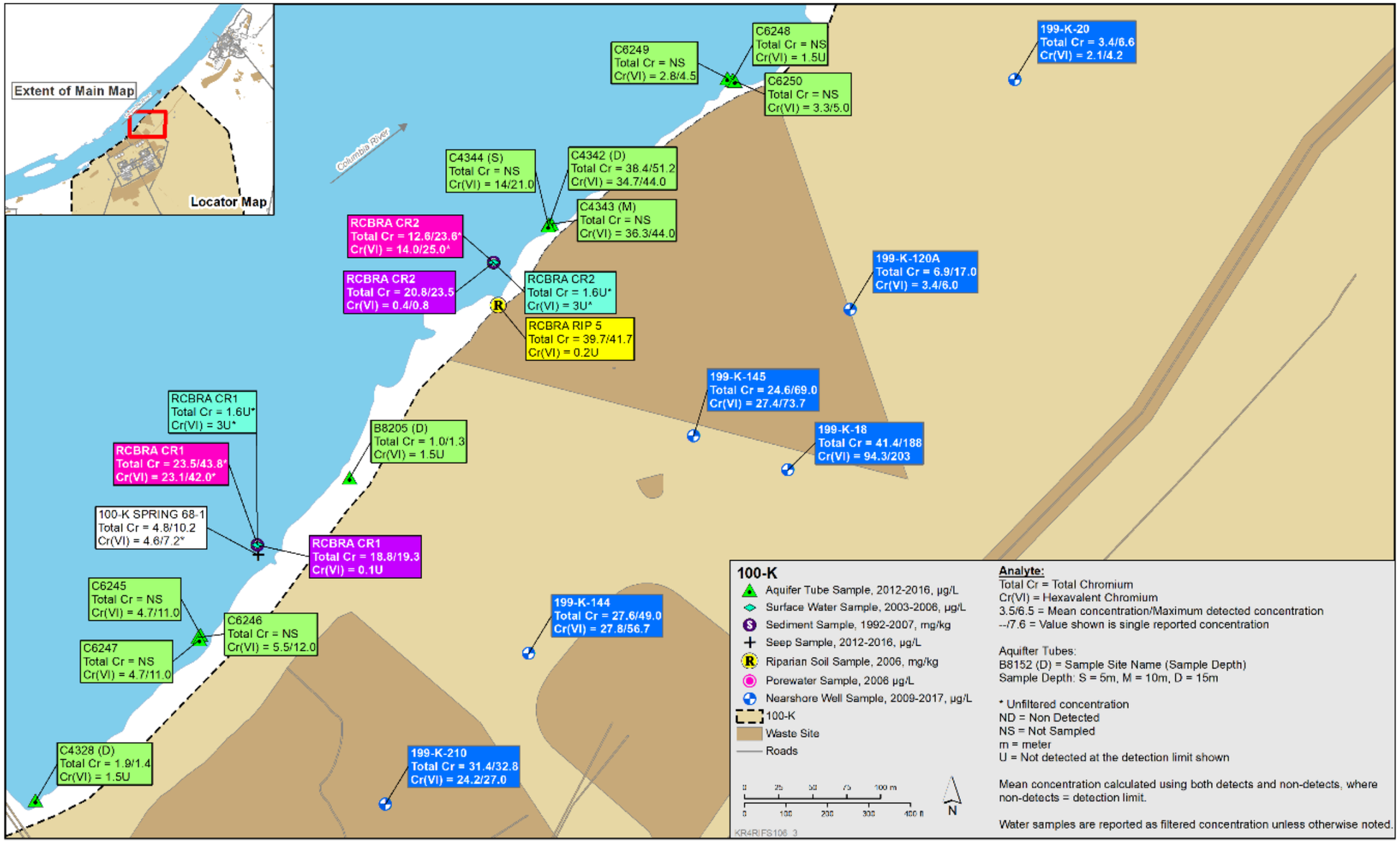

Figure 7-15. Cr(VI) and Total Chromium Concentrations in Riparian, Nearshore, and Aquatic Media at 100-K Down-Central Locations

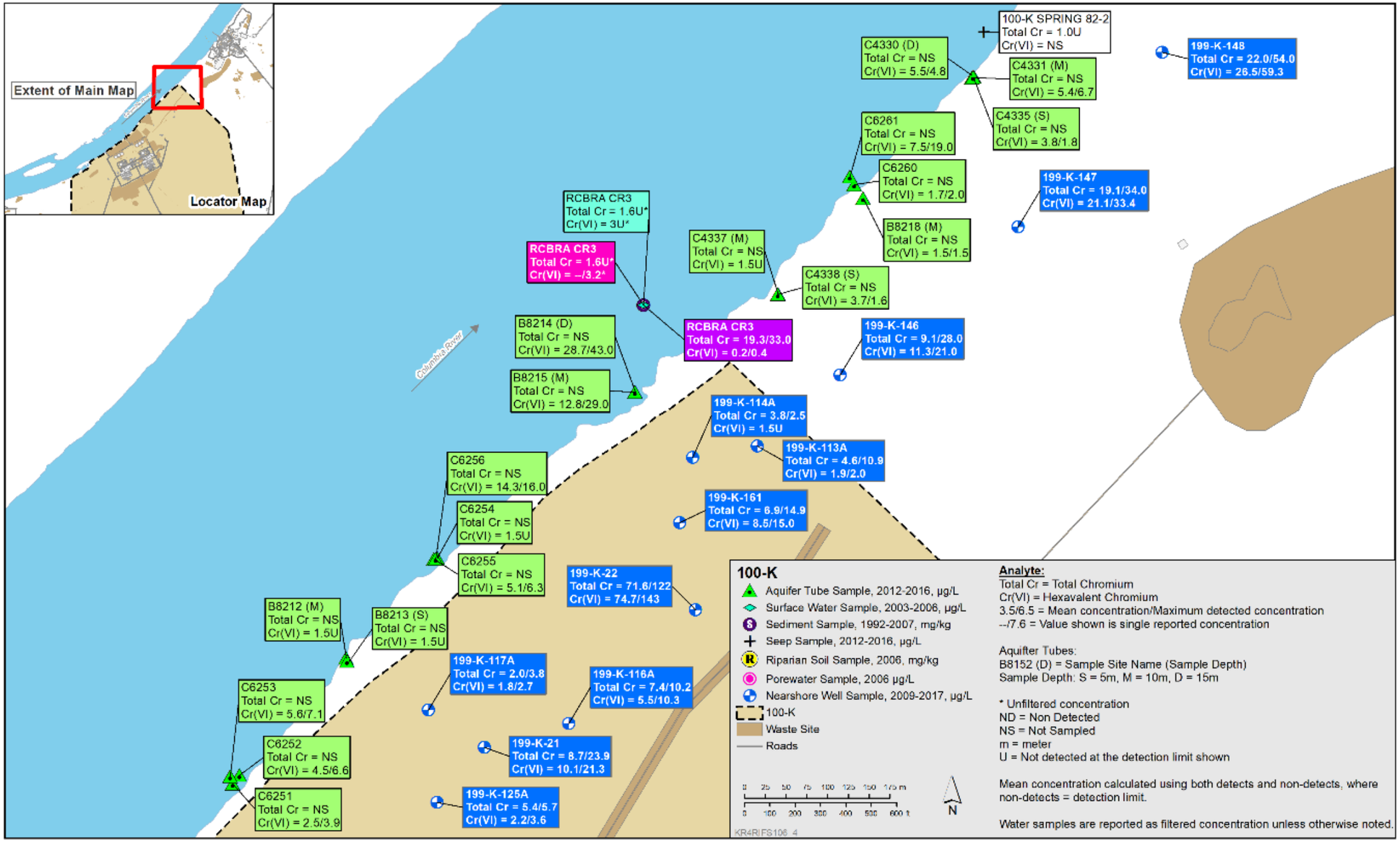

Figure 7-16. Cr(VI) and Total Chromium Concentrations in Riparian, Nearshore, and Aquatic Media at 100-K Downstream Locations

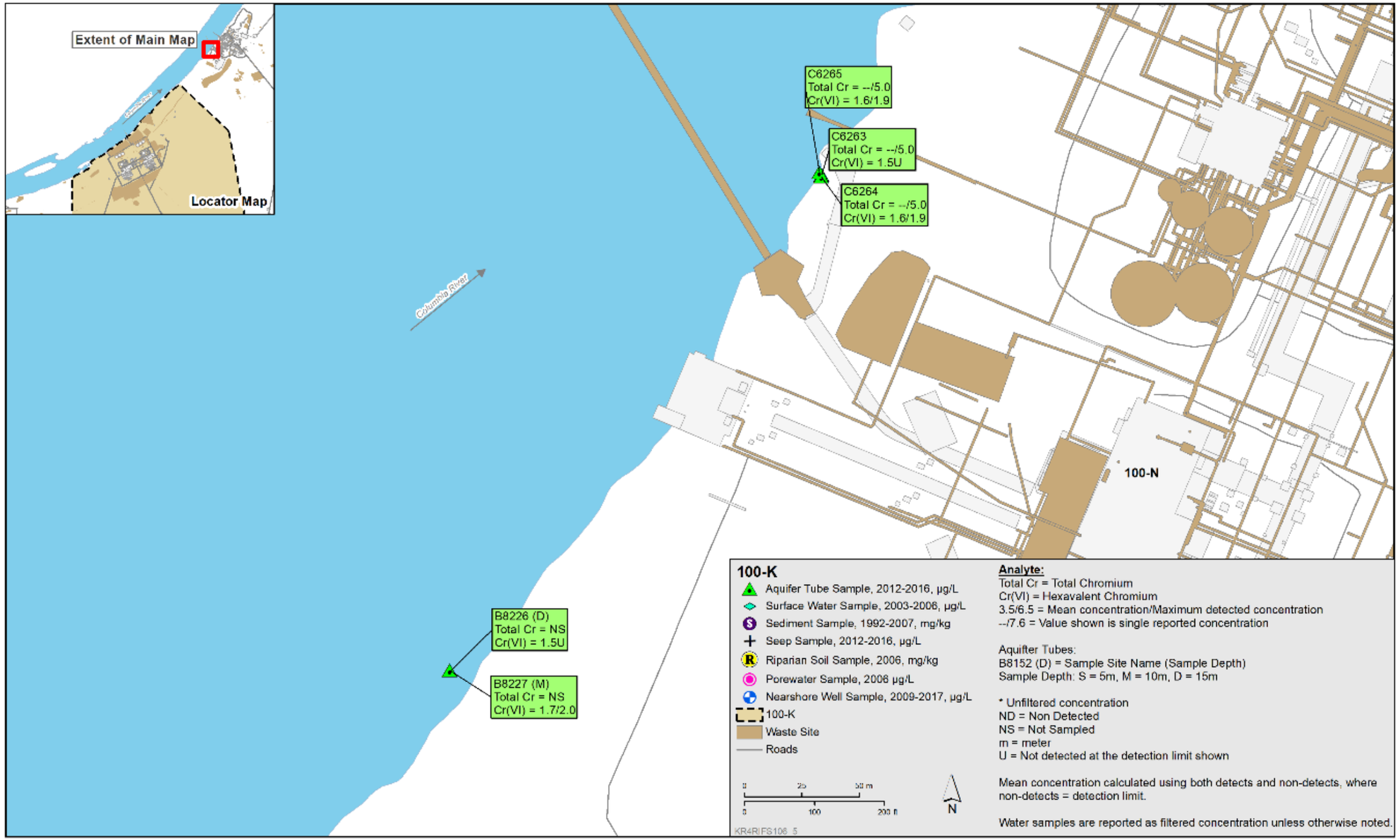

Figure 7-17. Cr(VI) and Total Chromium Concentrations in Riparian, Nearshore, and Aquatic Media Downstream from 100-K and Near 100-N

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Manganese–Manganese was identified as a COPEC for sediment along the River Corridor (RCBRA [DOE/RL-2007-21]). Manganese was detected in all eleven samples within the 100-K nearshore sediments at concentrations below the lower threshold effect level (460 mg/kg). The detected concentrations (148 to 329 mg/kg) are below the maximum reference site concentration (577 mg/kg). With concentrations in aquifer tubes not consistently exceeding the effect level (see Section 7.7.7.1discussion), concentrations in sediment were not likely from suspended solids in groundwater. Manganese was also detected below wildlife effect levels in all 10 riparian soil samples collected (Appendix J, Table J-31). Table 5-29 of the RCBRA (DOE/RL-2007-21) indicates that manganese concentrations across the Hanford Site riparian soil were not statistically different from riparian reference soil concentrations or background. The conclusion of this BERA is that there is no complete or significant pathway for observed manganese concentrations in sediment from the 100-K riparian area.

7.7.6.3 Histopathology Measures

Nineteen different histopathology measurements were recorded on samples of Asiatic clams (*Corbicula fluminea*) dispersed in clam tubes at study sites (including those adjacent to 100-K) and reference sites in the Columbia River (DOE/RL-2007-21). Nine measurements were also recorded in free-floating native clams found along the nearshore at low tide. Clam results are indicative of more fixed sessile exposure since they attach to river substrate while the mussel results are reflective of a much broader exposure since they are mobile in their behavior. Histopathology measures of Asiatic clams showed greater digestive epithelial cell shedding in study site samples compared to those from reference sites. Digestive epithelial cell shedding was significantly affected by riverbed substrate and could also be affected by key contaminants like chromium. Teh et al., 2000, “Sublethal effects of chromium-VI in the Asian clam (*Potamorcorbicula amurensis*),” evaluated the sublethal effects and toxicity of Cr(VI) in Asian clams under laboratory conditions. They noted that principal targets of Cr(VI) toxicity in Asian clams are the digestive gland, although evidence of digestive epithelial cell shedding was observed in RCBRA clam samples. Teh et al., 2000, showed that digestive epithelial cell shedding was indicative of chromium exposure. However, the laboratory test concentrations of chromium by Teh et al., 2000, were 0.92 mg/L or about two orders of magnitude higher than the maximum concentrations of dissolved chromium detected in pore water samples collected for this risk assessment. The number of clams having reproductive system follicle cysts was statistically greater than expected in reference site clam samples. The number of clam follicle cysts was significantly correlated with sediment particle size but not correlated with COPECs. There were no differences in the other 17 histopathology measures observed for Asiatic clams.

For native floater mussels (*Anodonta spp.*), incidences of digestive cell vacuolation, which could be a negative effect, varied in severity among study site and reference site samples; this measure was inversely correlated with aluminum in sediment. However, aluminum in the nearshore of 100-K was below the effect level in all eleven samples. There were no significant differences between study and reference locations for the presence/absence of vacuoles. Mantle condition was significantly degraded in study sites compared to reference, with greater than expected necrosis and loss of mantle tissue at study sites. Mantle condition was positively correlated with phosphorus in sediment. However, phosphorous in the nearshore sediment of 100-K was below the upper effect level. There are also relationships of confounding factors (i.e., non-chemical/geophysical properties) and mussel histopathology measures. There were no differences between study sites and reference sites for the remaining 18 mussel histopathology measurements taken on floater mussels.

7.7.6.4 Direct Toxicity Measures

Key community metrics in the RCBRA did not suggest contaminant-related impacts to benthic macroinvertebrates (such as insects, worms, clams, mussels, and snails) in aquatic study sites near 100-K. Risk to aquatic macroinvertebrates based on toxicity testing showed some relationships with confounding factors and some COPECs. Sediment bioassays for the 100-K Area showed lower growth in amphipod (*Hyalella azteca*) relative to reference sites, but no statistical difference in survival. Likewise, survival and reproduction tests on water fleas in pore water showed no difference at two sites representing the 100-K Area (Cr1 and Cr2), relative to reference sites. Correlation between abiotic media chemistry and any observed differences in measured effects from both bioassays was conducted across the entire Hanford Reach. Mercury was the only COPEC with a significant correlation that showed a potential negative effect with a significant regression (mercury with *Hyallella azteca* shown in Table 6-104 of the RCBRA and based on 3 outliers); however, mercury was below sediment effect levels at the 100-K Area study sites. Clams were also monitored for survival. There was a statistical decrease in survival at study sites compared to reference sites. There was no correlation of clam survival with COPECs, but there was significant negative correlation with clam survival and confounding factors (sand screen size, fraction of fine- and medium-grained sands and granules, substrate embeddedness class, and silicon). The effect of contaminant mixtures was not evaluated and, therefore, cannot be ruled out as a possible source for reduced survival. However, the collective evidence suggests these measures do not indicate substrate concentrations were toxic, but they do represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations. Actual effects from these fluctuations on aquatic invertebrates, particularly seasonal conditions where groundwater influence is greater, is uncertain. However, as the Cr(VI) data described in Chapter 4 suggests, these fluctuating conditions may not substantially influence contaminant concentrations, thus impact on adverse effects may not be substantial either[37].

7.7.6.5 Community Structure Measures

Key community metrics from the RCBRA (DOE/RL-2007-21) do not suggest that contaminant-related impacts to benthic macroinvertebrates are evident in aquatic study sites as a group, as indicated by the comparison of Ephemeroptera, Plecoptera, and Trichoptera data from study sites relative to reference sites. Most of the aquatic community measures did not differ between the study sites and reference sites. There were exceptions among the large number of aquatic community measures evaluated, but the agreement among measures was weak and the biological significance to populations is not evident.

7.7.6.6 Measures of Exposure in Tissue

Within the RCBRA, detected concentrations of COPECs (primarily inorganics) in invertebrate tissues, water, and sediment are clear measures of exposure (accumulation) in invertebrate communities. However, as shown in the RCBRA, there were no statistically significant correlations between COPEC concentrations in pore water or sediment with tissues of aquatic organisms, indicating a lack of significant COPEC bioaccumulation. With no pattern of uptake from pore water to tissue, there is no link between site contaminants in groundwater and detections in tissue. Further, no tissue effect levels for COPECs in invertebrate tissue were exceeded. Thus, invertebrate tissues concentrations indicate there is no unacceptable risk to aquatic invertebrate communities.

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[37] As illustrated in Figure 4-86, the ranges of observed concentrations in 0.15 m (6 in.), 0.5 m (20 in.), and 1 m (39 in.) hyporheic sampling points overlapped, and median concentrations were similar, indicating consistent upwelling in the shallow hyporheic zone.

Most histopathology measures of clams and mussels showed no significant differences between study sites and reference. Although some exceptions were noted (i.e. incidences of mussel digestive cell vacuolation correlated with aluminum in sediment and incidence of clam digestive system epithelial cell shedding correlated with chromium)[38], COPEC concentrations generally did not correlate with differences in histopathology measures.

7.7.6.7 Weight of Evidence

Both the abiotic and biotic measures collected for the RCBRA represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations. Abiotic measurements do exceed literature-based toxicity threshold values (effect levels) for some COPECs, and this line of evidence is generally given the lowest weight given the lack of site-specificity in the literature-based values. Biological measures such as amphipod bioassays, clam tubes, and community surveys from rock baskets show no clear indication of toxicity or correlation of response with COPEC concentrations. These measures support the analysis that Hanford Site operations at the 100-K Area are not adversely affecting aquatic and benthic invertebrates exposed to sediment in the 100-K nearshore environment. Although biological measures give a different perspective than abiotic media concentration data comparisons to effect levels, given the limited dataset and the uncertainty with full representation of seasonal measurements, the results of the abiotic media concentrations cannot be ignored. Of the key groundwater plume contaminants investigated, only Cr(VI) had concentrations of ecological relevance in the nearshore environment for the 100-K Area. Other chemicals above effect levels do not present an unacceptable risk associated with Hanford Operations for various reasons explained in Sections 7.7.7.1 and 7.7.7.2 (e.g., sporadic detections or detections below effect levels and AWQC in filtered groundwater, aquifer tube, and seep samples). Based on these findings, only Cr(VI) in groundwater in the 100-KR-4 OU, which represents a potential ongoing source for pore water concentrations that exceed water quality criteria, warrants further evaluation in the FS.

7.7.7 Aquatic Plants Risk Characterization

Potential effects on aquatic plants were evaluated through results of a bioassay in sediment and comparison of sediment and pore water concentrations to effect levels (RCBRA, Tables 6-88 through 6-91). Based on the combined pore water and sediment concentrations, the RCBRA identified cadmium, chromium, Cr(VI), manganese, and uranium as COPECs warranting further evaluation for potential effects on aquatic plants, as noted in RCBRA Section 8.5.1.1. The CRC (DOE/RL-2010-117) identified the final COPECs for pore water and sediment within the 100-KR-4 OU as Cr(VI), total chromium, and manganese. Looking at these RCBRA and CRC COPECs within 100-K Area nearshore sampling sites, Cr(VI) was greater than the chronic AWQC (Appendix J, Table J-24)[39]. Sediment COPECs are discussed in more detail with risks to aquatic invertebrates, with a conclusion that observed sediment concentrations do not warrant further evaluation.

Pore water COPECs from the 100-K Area nearshore sampling sites are also discussed above in detail and it was concluded that concentrations in the pore water, except for Cr(VI), were not at levels warranting additional evaluation. Of the key plume contaminants in the reach of the Columbia River adjacent to

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[38] Teh et al., 2000, evaluated the sublethal effects and toxicity of Cr(VI) in Asian clams under laboratory conditions. They noted that principle targets of Cr(VI) toxicity in Asian clams are the digestive gland. Although observations of digestive epithelial cell shedding in RCBRA clam samples could be indicative of chromium exposure, the laboratory test concentrations of chromium were 0.92 mg/L or about two orders of magnitude higher than the maximum concentrations of dissolved chromium detected in pore water samples collected for this risk assessment (DOE/RL-2007-21).

[39] Manganese also is included in Table J-24 but is not a source of elevated manganese (just 4 anomalous exceedances of the effect level out of 332 samples).

100-K, Cr(VI) had concentrations of ecological relevance in the nearshore environment. Only Cr(VI) represents a potential source for concentrations that exceeded water quality criteria at the point of exposure (pore water) warranting further evaluation in the FS. Notably, these pore water and sediment effect levels are derived for invertebrates/microbes and fish (e.g., *Chironomus sp.* and *Hyalella azteca*), not aquatic plants. Although the use of invertebrate and fish-based effect levels to evaluate potential threats to aquatic plants introduces some uncertainty into the assessment, doing so still errs toward conservatism in that invertebrates are typically more sensitive to contaminants than are rooted aquatic macrophytes. For example, comparison of threshold effect concentration values for metals in sediment from MacDonald et al., 2000, to EcoSSLs for plants (Table 7-17) indicates that, when plant EcoSSLs are available, they are consistently greater than sediment screening values. (Note that this comparison assumes equivalent sensitivity to metals for both terrestrial plants and rooted aquatic macrophytes.) Although invertebrates may be more sensitive to metals than terrestrial plants (and presumably aquatic macrophytes), it is unlikely for all chemicals (e.g., photosynthetic inhibitors). However, chemicals that adversely affect plants more severely than invertebrates may not be present in the study area. Because metals were the primary chemicals detected in bulk sediment, and with the absence of benchmarks for aquatic macrophytes, the risk characterization for aquatic invertebrates was applied to and considered representative of aquatic macrophytes.

Table 7-17. Comparison of Metals Threshold Effect Concentrations for Invertebrates to Metal SSLs for Plants

Analyte	Sediment Ecological Effect Level [a] (mg/kg)	Ecological Soil Effect Levels for Plants (mg/kg)
Arsenic	9.79	18
Cadmium	0.99	32
Chromium	43.4	--[b]
Copper	31.6	70
Lead	35.8	120
Mercury	0.18	--
Nickel	22.7	38
Zinc	121	160

a. Threshold effect concentrations are from MacDonald et al., 2000, "Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems."

b. -- indicates that ecological soil screening level for plants has not been developed.

Laboratory bioassays (i.e., toxicity tests) were conducted with Pak Choi exposed field-collected sediments (DOE/RL-2007-21). Although Pak Choi is not an aquatic vascular plant, this test was selected because it is a standard protocol for testing sediments and provides relevant phytotoxicity information. Some significant relationships were determined with observed response within aquatic plant toxicity tests in association with confounding factors and some chemicals. Additionally, clear measures of exposure (i.e., accumulation into plants), primarily for inorganic COPECs, were detected in pore water and sediment. However, of the significant relationships determined, none was with chemicals for which pore water concentrations were greater than aquatic plant benchmarks. Further, no risks to aquatic plants were noted based on toxicity testing. Detailed descriptions of these bioassay tests including study design, numbers, replicates, etc. are described in the approved planning documents for the RCBRA (e.g., DQO

[BHI-01757], DOE/RL-2004-37, and SAP [DOE/RL-2005-42]). Although the analysis represents only one season of sampling and analysis, the weight of the available data does not suggest risk to aquatic plants.

7.7.8 Community- and Population-Level Fish Risk Characterization

No COPECs in the RCBRA (DOE/RL-2007-21) or the CRC (DOE/RL-2010-117) were identified for surface water exposures to fish. This is supported by no surface water exceedance of effect levels; no histopathology issues; no fish tissue exceedances; limited evidence of bioaccumulation greater than the reference area; and finally, minimal pore water exceedances of effect levels[40], and pore water concentrations for Cr(VI) are less than fish effect values. These lines of evidence are presented in detail in the following paragraphs.

Groundwater contributions to the river are generally diluted quickly. All chemicals identified in Appendix J, Table J-24, as having at least one exceedance in groundwater, aquifer tubes, seeps, or pore water (i.e., evidence of 100-KR-4 as a potential source) were all below effect levels in surface water. No other chemicals exceeded effect levels in surface water either. Surface water monitoring for the Site Environmental Reports since the RCBRA and CRC were performed supports these conclusions (DOE-RL-2016-33, *Hanford Site Environmental Report for Calendar Year 2015*; DOE-RL-2014-52, *Hanford Site Environmental Report for Calendar Year 2014*; DOE-RL-2013-47, *Hanford Site Environmental Report for Calendar Year 2013;* DOE-RL-2013-18, *Hanford Site Environmental Report for Calendar Year 2012*). Surface water concentrations monitored and presented in the site environmental report, though not collected adjacent to the 100-K Area, have remained below the effect levels used to indicate risk to fish.

Cr(VI) in the 100-KR-4 groundwater OU, which represents a potential source for pore water concentrations that exceeded the AWQC and WQS for Cr(VI), warrants further evaluation in the FS. Cr(VI) concentrations in multiple nearshore wells, aquifer tubes, and pore water exceeded AWQC and WQS, suggesting an ongoing source. Chapter 6 also identified trichloroethene, nitrate, carbon-14, strontium-90, and tritium as COPCs in groundwater from 100-K sources. Concentrations of these chemicals were below their respective ecological screening values and therefore do not represent a risk to fish or other aquatic life. Other COPCs detected above AWQC do not appear to be issues in groundwater or aquifer tubes, suggesting that the 100-K Area and 100-KR-4 Groundwater OU are not the source of observed elevated concentrations. In general, exceedances of AWQC for other chemicals within various aquatic media (pore water, seeps, aquifer tubes, groundwater, surface water) were either anomalous (i.e., very low frequency), or a result of various laboratory reporting issues.

The CRC indicated exceedances of the Tier II SCV for manganese in pore water. The Cr(VI) exceedance has been discussed previously. However, as shown in Appendix J, Table J-20, manganese was not found above the Tier II SCV in nearshore groundwater except for a few anomalous occurrences (4 of 332 filtered samples) and it was not identified as a groundwater COPC for ecological risk in Chapter 6; therefore, there is no source for this COPEC from the 100-KR-4 OU.

[40] As shown in Table J-24, there was just one exceedance each of effect levels for aluminum, cadmium, manganese, and methoxychlor in pore water but none in surface water, the direct exposure medium for fish.

7.7.8.1 Cr(VI) Toxicity Evaluation

The RCBRA identified Cr(VI) pore water concentrations indicative of risk to fish and warranting additional consideration. The CRC also indicated exceedances of the AWQC for Cr(VI) in pore water. The Cr(VI) exceedance has been discussed previously.

Further, trends in fish histopathology for the RCBRA did not indicate adverse effects attributable to COPCs (RCBRA Appendix F-8). Statistically significant differences between study site and reference site fish were observed for four histopathological measurements: two histopathological attributes were more pronounced in reference area samples, and two attributes were more pronounced in study site samples. Measurements with higher scores in study site samples included the number of liver parasites and the number of muscle granulomas. However, no tissue COPECs were correlated with histopathological endpoints associated with adverse effects at study sites. The CRC histological evaluation suggested an exposure to contaminants through the diet but no stressor -response studies on potential Hanford Site contaminants was conducted and definitive conclusions about immune response were not possible. There were no exceedances of tissue effects levels for nearshore aquatic COPECs measured in fish tissue. In addition, evidence of greater contaminant uptake in fish from study sites was not apparent for most COPECs and tissues. Some mid-channel fish tissue samples collected for the CRC were elevated above effect levels. However, the CRC acknowledged that interpretation of the results of these comparisons were highly uncertain for a number of reasons and there was no correlation with the specific Hanford OUs. Finally, the CRC also included a fish condition factor but conclusions could not be drawn due to high variability in the data which led to a determination of no apparent correlation with the study area.

There are significant uncertainties relative to any of the conclusions based on pore water sampling. These abiotic measurements represent a single point measurement within a dynamic river system with daily and seasonal fluctuations and flow volumes that can shift the composition of the substrates that were sampled. Exceedances should not be ignored because they can be indicative of exposure at levels presenting a risk. But because of the uncertainty in the representativeness of the measurements due to the dynamic environment, the exceedances should be considered along with other data that identify whether there is, in fact, an ongoing source of the chemicals. The interpretation of pore water results as an indication of potential adverse effects to fish is the same as that for aquatic invertebrates and plants, given that the effect levels selected are intended to be protective of all aquatic organisms (e.g., they represent a conservative screening value). COPECs detected in pore water above effect levels do not appear to be issues in groundwater or aquifer tubes, except for Cr(VI), suggesting that the 100-KR-4 groundwater OU is not the source of observed elevated concentrations of these chemicals. 100-KR-4 is a source for Cr(VI).

Planktonic crustaceans are important as a source of food for larger organisms such as fish; however, one study suggests that though Daphnia are normally preferred by planktivorous fish over other planktonic crustaceans due to their larger size. Daphnia are in fact relatively uncommon in the mid-Columbia River, making up <10% of the total zooplankton (Neitzel et al., 1982b, “Mid-Columbia River Zooplankton”). In aggregate, Cladocerans in the Columbia River system do not exceed 750 organisms per cubic meter at the early summer peak density in most years (Neitzel et al., 1982b). More importantly, multiple studies suggest zooplankton are of low importance in the diets of some fishes inhabiting the Hanford Reach (Dauble, 1986, “Life History and Ecology of the Largescale Sucker (*Catostomus macrocheilus*) in the Columbia River;” Gray and Dauble, 2001, “Some life history characteristics of cyprinids in the Hanford Reach, mid-Columbia River”), including drift-feeding juvenile Chinook (Becker 1970; Rondorf et al., 1990, “Feeding Ecology of Subyearling Chinook Salmon in Riverine and Reservoir Habitats of the Columbia River”). And by mid-summer, when juvenile Chinook may feed on zooplankton including *Daphnia sp*., most juvenile salmon have migrated downstream and out of the Hanford Reach (Dauble et al., 1980, “Importance of Insects and Zooplankton in the Diet of 0-age Chinook Salmon (*Oncorhynchus*

tshawytscha) in the Central Columbia River"). Another important factor is that the area where Cr(VI) in pore water exceeds the AWQC is just a small portion of the area inhabited by the transitory free-floating planktonic community. At most, exposure to free-floating zooplankton is of short duration and not of sufficient duration to suggest a community-level risk that warrants further evaluation. However, available evidence suggests that even when planktonic crustaceans are present, they are not exposed to concentrations of Cr(VI) that would suggest an adverse effect because the Cr(VI) is not present in the surface water to which they are exposed (i.e., they are not exposed to pore water).

The weight of evidence leads to a conclusion that there is no unacceptable risk of adverse effects to zooplankton from exposure to Cr(VI), or any of the other tested organisms of ecological significance. While the concentration is above the toxic threshold for these organisms, exposure to these levels is incomplete given their life history and feeding strategy. Given the size of the affected area (zone of upwelling in excess of AWQC) relative to the larger pelagic zone within the Columbia River to which these free-floating organisms live and to which they and their fish predators are exposed, there is no unacceptable community level risk. Thus, impacts to fish from a decline in the planktonic crustaceans (and other untested organisms) fish consume is not an unacceptable risk.

7.7.8.2 Trichloroethene Toxicity Evaluation

The 100-K RI identified trichloroethene as a COPC based on its potential risk to human health, but it was not identified as a risk to aquatic organisms or wildlife along the Columbia River. The EPA has not identified a water quality criterion, nor has the State of Washington promulgated a surface water quality standard for trichloroethene. The effect levels used in the baseline ERA is a secondary chronic value published by ORNL (ES/ER/TM-96/R2) that employed methods established by EPA for water quality criteria development using published literature for several classes of aquatic organisms including fish. Though trichloroethene is a groundwater COPC for 100-K, all 101 nearshore well, 110 aquifer tube, and 9 seep samples reported a concentration below the effect level of 47 µg/L (ES/ER/TM-96/R2). The trichloroethene in groundwater has low mobility and currently does not exceed ecological thresholds for aquatic receptors throughout the groundwater plume. Predicted future groundwater concentrations continue to decrease in the aquifer over time as modeled through natural attenuation (CP-61711, Appendix F); therefore, concentrations going to the river will also continue to decrease. From these findings, there is no current or future threat to fish, including steelhead trout or fall-run Chinook salmon, in the Columbia River from the trichloroethene plume in the 100-KR-4 OU.

7.7.8.3 Nitrate Toxicity Evaluation

The 100-K RI identified nitrate in groundwater as a COC based on its potential risk to human health. In this BERA, the RCBRA, and the CRC, no risk to the aquatic community was identified, including fish, due to nitrate releases from 100-K. As identified below, there is no evidence of early life stage salmonids being exposed to contaminated groundwater from 100-K. Nevertheless, the potential toxicity to eggs and larvae of steelhead and Chinook salmon from nitrate are briefly identified below.

EPA has not identified a water quality criterion, nor has the State of Washington promulgated a surface water quality standard for nitrate. There are few studies of the effects of nitrate specifically on fish and even fewer on salmonids. Available data suggest that fish are relatively insensitive to acute exposures to nitrate. For chronic exposures, a study of lake trout by McGurk et al., 2006, "Acute and Chronic Toxicity of Nitrate to Early Life Stages of Lake Trout (*Salvelinus Namaycush*) and Lake Whitefish (*Coregonus Clupeaformis*)," identified a no effect level of 1.6 mg/L NO_3-N and a low effect threshold of 6.25 mg/L NO_3-N (lowest effect level used in the RCBRA). This work was the basis for effect levels in the RCBRA and CRC documents. More recent work published after those documents were in final production has shown this earlier study may not be fully indicative of nitrate toxicity within an aquatic environment

(Nautilus, 2013), as nitrate has been shown to be less toxic in water with higher hardness. A NOEC of 45 mg/L NO_3-N (199 mg/L NO_3) from the 92 mg/L hardness test group by Nautilus (2013) was selected as the effect level for steelhead in the Columbia River due to the higher level of hardness more representative of the river conditions. No detection in any aqueous media exceeds this threshold. As shown in Tables J-15 through J-19, concentrations of nitrate (NO_3) and nitrogen in nitrate (NO_3-N) were also below a much lower effect level for benthic organisms of 20 mg/L NO_3-N/88.6 mg/L NO_3 (Nautilus, 2013). Predicted future groundwater concentrations continue to decrease in the aquifer over time as modeled through natural attenuation (CP-61711, Appendix F); therefore, concentrations going to the river will also continue to decrease. From these findings, there is no current or future threat to fish, including steelhead trout or fall-run Chinook salmon, in the Columbia River from the groundwater nitrate plume in the 100-KR-4 OU.

7.7.8.4 Strontium-90, Carbon-14, and Tritium Toxicity Evaluation

The 100-K RI identified strontium-90, tritium, and carbon-14 as COPCs based on their potential risk to human health, but they were not identified as a risk to aquatic organisms or wildlife along the Columbia River. EPA has not identified a water quality criterion, nor has the State of Washington promulgated a surface water quality standard for carbon-14, strontium-90, or tritium. Toxicity thresholds for plants and wildlife found in aquatic, terrestrial, and riparian environments are represented by the DOE BCGs for radionuclides as presented in DOE-STD-1153-2002. As previously described in Section 7.3.1.1, the BCGs are based upon a radiation dose threshold of 0.1 rad/day for vertebrates (e.g., fish) based upon international consensus documents (ICRP Publication 60; IAEA STR-332; and UNSCEAR, 2000) adopted by DOE in 2002. The water BCG for aquatic animals (including fish) recommended for strontium-90 is 53,900 pCi/L, tritium is 4,990,000,000 pCi/L, and carbon-14 is 7,890 pCi/L. Lower values of 609 pCi/L for carbon-14, 278 pCi/L strontium-90, and 265,000,000 pCi/L tritium were published for riparian animals but are representative of drinking water exposure to wildlife species such as shorebirds and omnivorous mammals feeding on the edges of water bodies or in exposed mud flats, not for aquatic animals such as fish.

Strontium-90 concentrations detected at the point of exposure for fish (e.g., surface water and pore water) do not exceed the BCG. The maximum detected strontium 90 concentration value to date at nearshore groundwater wells (30 pCi/L) and aquifer tubes (8.8 pCi/L) is also well below the BCG. This strongly suggests that there is no current threat to fish in the Columbia River from the strontium-90 plume in the 100-KR-4 OU. Predicted future groundwater concentrations continue to decrease in the aquifer over time as modeled through natural attenuation (CP-61711, Appendix F); therefore, concentrations going to the river will also continue to decrease.

Tritium was not detected in surface water and did not exceed the BCG for riparian animals or aquatic animals (including fish) in pore water, aquifer tubes, seeps, or nearshore groundwater samples. This strongly suggests that there is no current or future threat to fish in the Columbia River from the tritium plumes in the 100-KR-4 OU. Predicted future groundwater concentrations continue to decrease in the aquifer over time as modeled through natural attenuation (CP-61711, Appendix F); therefore, concentrations going to the river will also continue to decrease.

Carbon-14 was detected above the aquatic life (e.g., fish) BCG (7,890 pCi/L) in nearshore groundwater, but not in other media. Concentrations in nearshore groundwater wells exceeded the aquatic life BCG in 2 of 286 nearshore well samples, both at well C4670 in 2015. Concentrations significantly decrease as the plume reaches the river where aquifer tube and seep samples are all below the aquatic life BCG and carbon-14 was not detected in pore water or surface water. This strongly suggests that there is no current threat to fish in the Columbia River from the carbon-14 plume in the 100-KR-4 OU. Predicted future groundwater concentrations continue to decrease in the aquifer over time as modeled through natural

attenuation (CP-61711, Appendix F); therefore, concentrations going to the river will also continue to decrease.

A number of Hanford Site studies have looked at the effects of total ionizing radiation or ionizing radiation specifically from strontium-90 on nonhuman biota. Some of the screening-level assessments using highly conservative exposure scenarios reported doses/risks for 100-N Area biota that approached or exceeded the dose criteria (PNL-8360, *Scoping Assessment of Radiological Doses to Aquatic Organisms and Wildlife – N Springs*; BHI-00055, *Qualitative Risk Assessment for the 100-NR-2 Operable Unit*; DOE/RL-93-81, *Limited Field Investigation Report for the 100-NR-2 Operable Unit, Hanford Site, Richland, Washington*; and PNNL-11933, *Survey of Radiological Contaminants in the Near-Shore Environment at the Hanford Site 100-N Reactor Area*). Site-specific studies (such as those just listed) carry more weight in a risk decision than an evaluation using data intended for broad application (such as the BCGs that have been described). Thus, these site-specific evaluations conducted at the Hanford Shoreline that include data for the species found in the Columbia River adjacent to Hanford or that include shoreline conditions or scenarios more closely aligned to what may occur at the Hanford site carry more weight than just comparing site measures to the BCGs. These Hanford-specific studies generally found that dose/risk levels were below the 0.1 rad/day dose threshold (PNNL-13127, 2000, *Strontium-90 at the Hanford Site and its Ecological Implications*; Poston et al., 2003, "Application of Biota Dose Assessment Committee Methodology to Assess Radiological Risk to Salmonids in the Hanford Reach of the Columbia River"; PNNL-20529, *Ecological Dose Modeling of Aquatic and Riparian Receptors to Strontium-90 with an Emphasis on Radiosensitive Organs*). Because site-specific results carry more weight, and confirmed that the 0.1 rad/day dose threshold was not exceeded, use of the PRG of 278 pCi/L (that is based on the 0.1 rad/day threshold) is supported. The maximum concentrations of strontium-90 in seeps (0.07pCi/L) and nearshore groundwater (30pCi/L) at 100-KR-4 are much lower than those at 100-NR-5 (33 pCi/L in seeps and 1,800 pCi/L in nearshore groundwater). The maximum concentrations of tritium in seeps (3,200 pCi/L) is also lower than 100-N (18,300 pCi/L) though nearshore groundwater (290,000 pCi/L) at 100-KR-4 is higher than 100-NR-5 (13,000 pCi/L). Other site-specific studies conducted for the RCBRA looked at the direct toxicity of pore water. Survival and reproduction tests on water fleas in pore water showed no difference at two sites representing the 100-K Area (Cr1 and Cr2), relative to reference sites. Correlation between abiotic media chemistry and any observed differences in measured effects was conducted across the entire Hanford Reach. There was no significant correlation with radionuclide concentrations and potential negative effects. Given the results of the site-specific studies at 100-N and for the RCBRA, the lower concentrations in the exposure medium (seeps), and the results of site-specific studies at an exposure area with greater concentrations of radionuclides, the use of the carbon-14, BCG of 609 pCi/L, strontium-90, BCG of 278 pCi/L, and tritium, BCG of 265,000,000 pCi/L, are sufficiently protective for use as PRGs for the 100-KR-4 OU.

7.7.9 Individual Level Risk Characterization for Threatened and Endangered Fish and Fish of Societal Importance

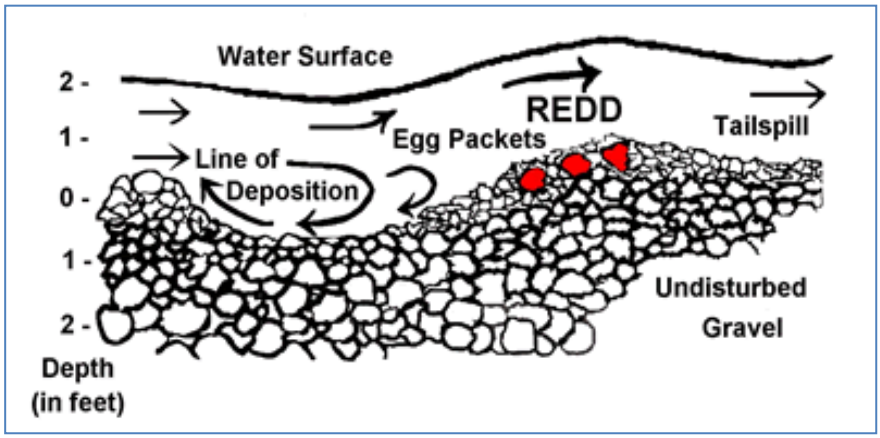
This section presents a qualitative evaluation of the potential for the exposure of threatened and endangered species to site-related chemicals within the Hanford Reach. The focus was to evaluate groundwater COPCs having the potential to reach the Columbia River. The evaluation considered current and future contaminant concentrations in the Columbia River water and gravels resulting from groundwater originating from the 100-K Area of the Hanford Site. The evaluation supports a conclusion of no effect on species listed as threatened or endangered under the *Endangered Species Act of 1973*. Further, the evaluation shows no evidence of effects of the proposed remedial action on the habitat for those species. This conclusion is based on several lines of evidence. First, the preferred remedy does not take an action in the Columbia River, so there will not be any direct physical effects on fish or their habitat. Second, there are no effects of contaminants on listed species of fish before, during, or after the

remedial actions. This second line of evidence is strengthened by data showing that contaminated groundwater does not flow to the river during moderate and high river stages when listed species have sensitive life stages in the river gravels.

7.7.9.1 Potential for Exposure of Threatened and Endangered Fish

The Hanford Reach of the Columbia River contains three ESA-listed species, including Upper Columbia River spring-run Chinook salmon (*Oncorhynchus tshawytscha*), Upper Columbia River steelhead trout (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*). Three runs (spring, summer, and fall) of Chinook salmon pass through the Hanford Reach; however, only the Upper Columbia River spring-run Chinook salmon is an ESA-listed species (PNL-5371, *Anadromous Salmonids of the Hanford Reach, Columbia River: 1984 Status*). Spring-run Chinook salmon and bull trout do not spawn in the Hanford Reach of the Columbia River. Spring-run Chinook spawn primarily in headwater streams. The Hanford Reach only serves as a migration corridor for adult bull trout (PNNL-SA-75348). The Hanford Reach supports a healthy population of spawning fall-run Chinook salmon. The fall-run Chinook salmon is not an ESA-listed species, but is an important regional resource.

The Columbia River rapidly dilutes groundwater contaminants entering the river to relatively low concentrations, so the primary concern for ESA-listed species is from exposure to pore water in sediments. Eggs and larvae (known as alevins) of salmonids are found in redds within these shallow sediments (Figure 7-18). Redds are formed by adults clearing the gravel area with their tails. Redd configurations cause a river flow pattern that continually flushes shallow sediments, providing oxygen and removing particulates.



Source: *http://wdfw.wa.gov/conservation/habitat/spawningbed_protection/redd.html*

Figure 7-18. Depiction of Redd Used by Salmonids for Egg Deposition and During Early Developmental Stages

Descriptions of the steelhead life cycle within DOE/RL-2000-27, *Threatened and Endangered Species Management Plan: Salmon, Steelhead, and Bull Trout*, support that exposure to groundwater after swim up would not be continuous. The report notes that newly hatched steelhead school near the margins of the river and over shallow-water gravel bars where vegetation and submerged cover provide protection and serve as feeding areas. As explained in Table 1 of DOE/RL-2000-27, after inter-gravel development (alevin stage), juvenile steelhead prefer the deep-water habitat such as the 100-D hole downstream of D Island. Later juvenile stages also prefer the deep water but feed in the margins. None of this suggests significant and consistent exposure to concentrations of groundwater COPCs found in pore water gravels.

Only one of the three ESA-listed species (i.e., steelhead) spawn within the Hanford Reach of the Columbia River. Spring-run Chinook salmon spawn primarily in headwater streams (PNNL-SA-75348). Steelhead are present in the surface waters of the Hanford Reach year-round, though most adults move into the Hanford Reach between August and November with migration into the area occurring in September (Watson, 1973, *Estimate of Steelhead Trout Spawning in the Hanford Reach of the Columbia River*; PNL-5371). Spawning occurs between February and June, with peak spawning occurring in mid-May (Eldred, 1970, *Steelhead Spawning in the Columbia River, Ringold to Priest Rapids Dam, September 1970 Progress Report*; Watson, 1973; PNL-5371). Egg stage occurs between early February and early July. Intra-gravel development occurs between early May and mid-July, after which fry move into the water column (DOE/RL-2000-27). The Columbia River stage is highest during the intra-gravel development period, as shown by the river gauge measurement data shown in Figure 7-19.

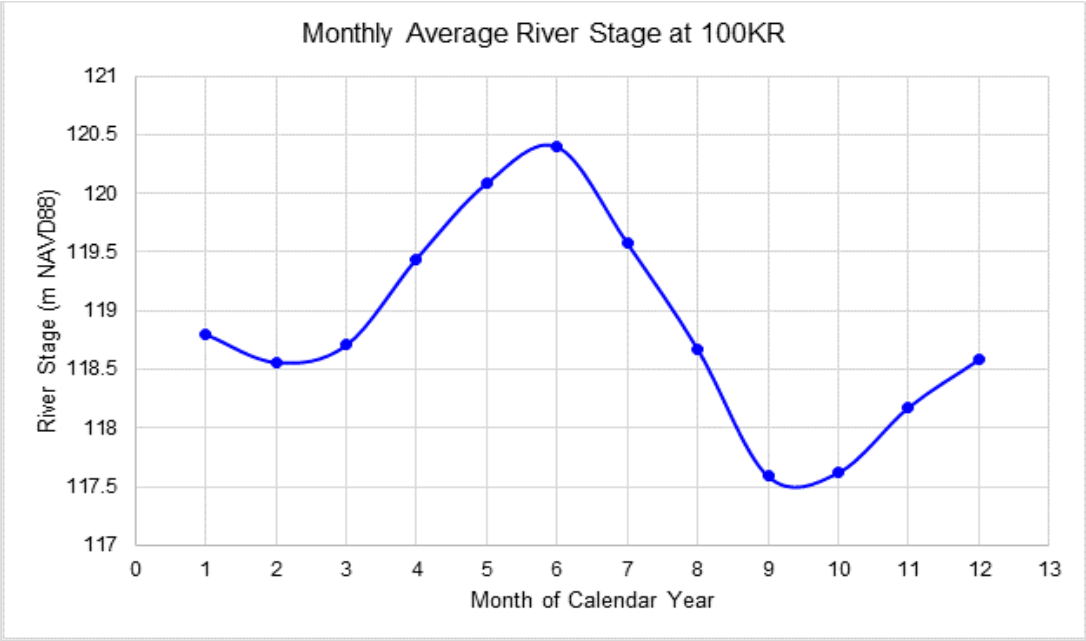


Figure 7-19. Monthly Average River Stage at 100-K (January 2006 through December 2017)

Although not listed under the Threatened and Endangered Species Act, the Hanford Reach supports a healthy population of fall-run Chinook salmon that spawn in the Hanford Reach (PNL-5371). This fall-run Chinook salmon population comprises the largest salmon run currently in the Pacific Northwest. This population is considered to have regional ecological and cultural significance and economic importance and is vital to preserving and restoring other Chinook stocks in the Columbia Basin (Dauble and Watson, 1997, "Status of Fall Chinook Salmon Populations in the Mid-Columbia River, 1948-1992"; Anglin et al., 2006, *Effects of Hydropower Operations on Spawning Habitat, Rearing Habitat, and Stranding/Entrapment Mortality of Fall Chinook Salmon in the Hanford Reach of the Columbia River Final Report*). Although steelhead are the primary focus of this evaluation based on their special status, fall-run Chinook salmon will also be considered in this evaluation based on their regional importance.

Ten general salmon spawning areas along the Hanford Reach of the Columbia River have been routinely monitored since 1948 (PNL-7289, *Spawning and Abundance of Fall Chinook Salmon (Oncorhynchus tshawytscha) in the Hanford Reach of the Columbia River, 1948-1988*, as cited in PNNL-14008, *Evaluation of the Effects of Chromium on Fall Chinook Salmon in the Hanford Reach of the Columbia River: Integration of Recent Toxicity Test Results*), while more intensive aerial fall-run Chinook salmon

redd surveys were conducted in the Hanford Reach during the fall seasons of 2011 to 2015 (HNF-52190, *Fall Chinook Redd Monitoring Report Calendar Year 2011*; HNF-54808, *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2012*; HNF-56707, *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2013*; HNF-58823, *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2014*; HNF-59813, *Hanford Reach Fall Chinook Redd Monitoring Report for Calendar Year 2015*). Detailed graphical display of the location of salmon redds was also provided in the CRC (DOE/RL-2010-117). These sources focus primarily on the location of fall-run Chinook salmon redds. Aerial mapping of steelhead redds is typically more difficult, if not impossible, due to high, turbid spring runoff that obscures visibility (DOE/RL-2000-27). However, a study of sympatric steelhead trout and Chinook salmon in the Crooked Fork and Johnson Creek of Idaho showed a similarity in spawning habitat (Everest and Chapman, 1972, "Habitat Selection and Spatial Interaction by Juvenile Chinook Salmon and Steelhead Trout in Two Idaho Streams"). PNNL-14008 reported the general characteristics of fall Chinook salmon in the Columbia River to include water depths of approximately 1 to 3 m (3.2 to 9.8 ft), velocities of 60 to 120 cm/sec (2.0 to 3.9 ft/sec), and dominant substrate size of 7.6 to 15.2 cm (0.25 to 0.50 ft). Orcutt et al., 1968, "Characteristics of Steelhead Trout Redds in Idaho Streams," reported similar conditions for steelhead trout redds studied on the Salmon River in Idaho: depth of 0.2 to 1.5 m (0.6 to 4.9 ft), velocity of 70 to 76 cm/sec (2.3 to 2.5 ft/sec), and substrate size of 1.3 to 10.2 cm (0.043 to 0.33 ft). More general mapping of steelhead redds in the Hanford Reach of the Columbia River was conducted in 1968 and 1970 during unusually low flow conditions (Figure 7-20).

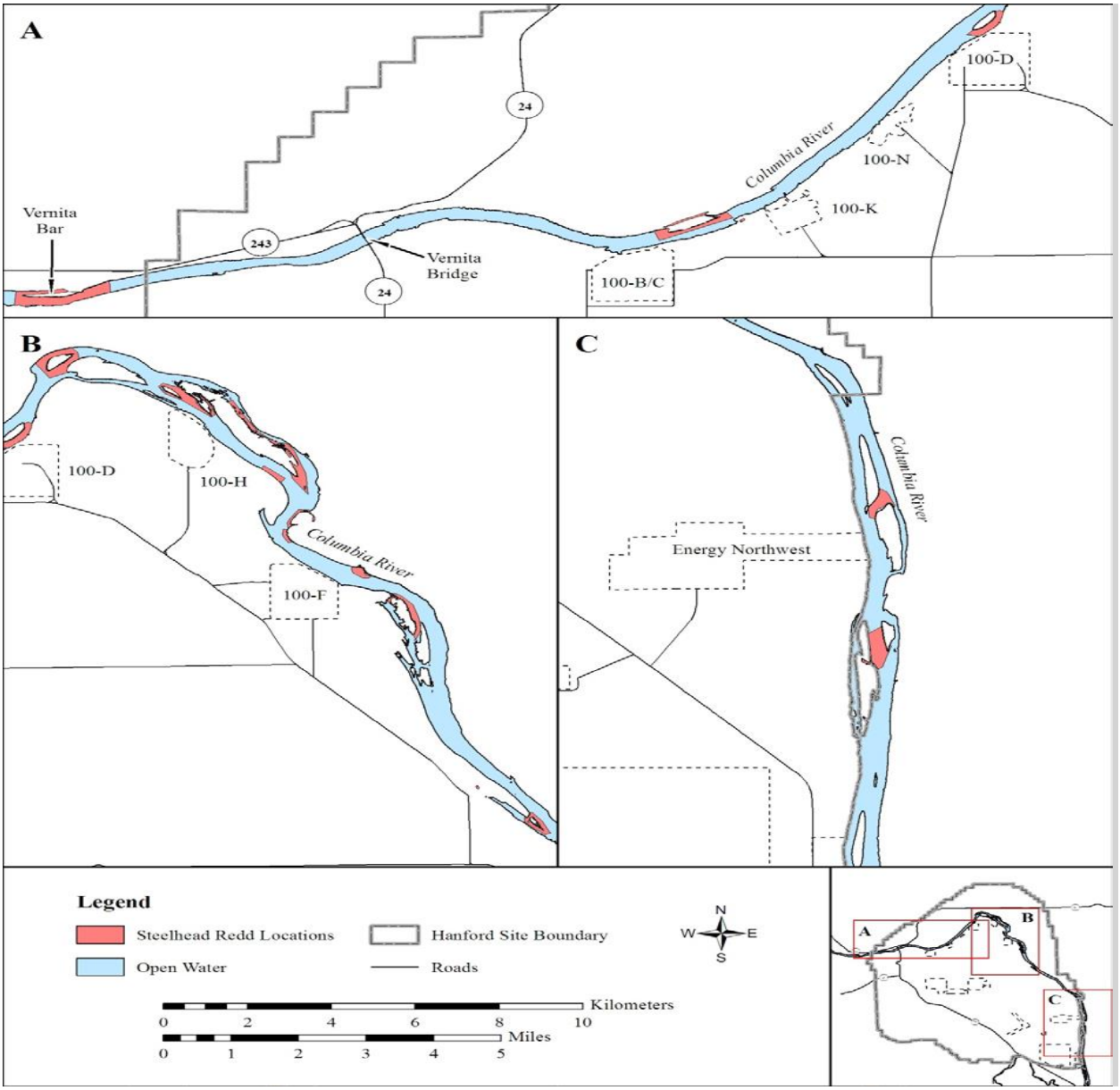
No steelhead redds were observed adjacent to the 100-K Area in the results of 1968 and 1970 surveys. Most redds were upstream and adjacent to Coyote Island, which is upstream from 100-K along the shoreline of the bank on the opposite side of the river from the Hanford Site. Results of recent 2011 through 2015 fall-run Chinook salmon redd aerial surveys (HNF-52190; HNF-54808; HNF-56707; HNF-58823; HNF-59813) show no fall Chinook redds near 100-K. Steelhead redd surveys conducted in 1968 did not identify any redds in areas of current groundwater upwelling on the 100-K Hanford shoreline of the Columbia River. More recent aerial surveys for steelhead redds in 2012 (HNF-53665, *Steelhead Redd Monitoring Report for Calendar Year 2012*) and 2013 (HNF-56705, *Hanford Site Steelhead Redd Monitoring Report for Calendar Year 2013*), and three aerial and one boat survey in 2015 (HNF-59116) identified redds for other areas but an absence of redds in the area immediately adjacent to 100-K. This provides strong evidence that steelhead and fall-run Chinook salmon do not spawn near the 100-K area. The absence of redds immediately adjacent to 100-K is likely the result of the deep channel adjacent to the 100-K Area, which is much deeper than the characteristic spawning habitats that were reported for Chinook salmon by Dauble et al., 2003, or steelhead trout by Orcutt et al., 1968.

The 100-K Area does not support steelhead nor do recent surveys show the area to support fall-run Chinook salmon spawning. Steelhead and fall-run Chinook salmon eggs and alevins in the river gravel would not be co-located with the groundwater COCs from 100-K. Since there is no exposure to steelhead or fall Chinook, there is no potential for effects from groundwater COCs.

7.7.9.2 Cr(VI) Toxicity Evaluation

The RI/FS identified total chromium and Cr(VI) in groundwater as a COPC/COPEC based on potential risk to human health and the environment. The eco risk assessment conclusion was based upon consistent detections of groundwater, aquifer tubes, and pore water at concentrations above the AWQC of 10 µg/L. An initial pore water investigation measured mid-channel pore water as high as 44 µg/L at one location. The Phase II(b) I investigation (WCH-380, Rev. 1) identified pore water above the AWQC and state WQS in 9 of 32 samples, with a range of 10-44 µg/L. Exceedance of the AWQC and state WQS were in both the nearshore environment and mid channel. The highest detect of 44 µg/L was mid channel and just downstream of the 181-K West River Pump Station (Figure 3-26 of WCH-380, Rev. 1 Part 2).

Because recent sampling of nearshore groundwater (2006 to 2015) included filtered detections of Cr(VI) at 203 µg/L, the potential for future Cr(VI) concentrations to present a risk was considered further.



Source: PNNL-14008, *Evaluation of the Effects of Chromium to Fall Chinook Salmon in the Hanford Reach of the Columbia River: Integration of Recent Toxicity Test Results*.

Figure 7-20. Locations of Steelhead Redds Observed During Aerial Surveys in 1968 and 1970 in the Upper Portion of the Hanford Reach

Total chromium is composed of trivalent chromium (Cr(III)) and Cr(VI) and, as indicated by the detected concentrations, Cr(VI) is the dominant form of chromium present in groundwater. Cr(VI) is significantly more toxic than Cr(III) for fish, primarily because Cr(VI) has markedly greater solubility, bioavailability, mobility, and toxicity than Cr(III) in the aquatic environment (EPA 440/5-84-029, *Ambient Water Quality Criteria for Chromium - 1984*; EPA-600-R-02-011; Eisler, 1986, *Chromium Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review*). Cr(III) has limited solubility based on its tendency to form stable complexes with organic ligands and sediment minerals and insoluble hydroxide and oxide complexes (Jardine et al., 2013, "Influence of Soil Geochemical and Physical Properties on Chromium (VI) Sorption and Bioaccessibility"). It has been demonstrated to have very low toxicity when present in the aquatic environment (Graham et al., 2008, "Chromium Occurrence and Speciation in Baltimore Harbor Sediments and Porewater, Baltimore, Maryland, USA;" EPA-600-R-02-011; Berry et al., 2004, "Predicting the Toxicity of Chromium in Sediments;" Becker et al., 2006, "Evaluation of Potential Toxicity and Bioavailability of Chromium in Sediments Associated with Chromite Ore Processing Residue;" Oshida, 1976, *Effects of Chromium on Reproduction in Polychaetes*; Oshida et al., 1981, "Effects of Hexavalent and Trivalent Chromium on the Reproduction of *Neanthes Arenaceodentata* (Polychaeta)"). Cr(VI) is the dominant form of chromium at this site and is, accordingly, the primary focus of this evaluation.

The most recent water quality criteria evaluation by EPA for Cr(VI) was in 1995 (EPA-820-B-96-001). This evaluation indicated there were not enough data to directly calculate a chronic criterion, so the evaluation relied on acute toxicity data and the use of an acute-to-chronic ratio. The most sensitive fish species in that evaluation was a guppy with an acute toxicity value of 30,000 µg/L. Rainbow trout were identified as having an acute toxicity value of 69,000 µg/L, with a species and study-specific acute to chronic ratio of 260.8, resulting in a chronic toxicity level at 265 µg/L.

Several investigations have been conducted over the years to evaluate the potential for adverse effects to salmonids because of Cr(VI) originating from the Hanford Site. Studies began with HW-44357, "Effect of Sodium Dichromate in Reactor Cooling Water on Young Chinook Salmon." More recently, Patton et al., 2007, "Evaluation of Early Life Stage Fall Chinook Salmon Exposed to Hexavalent Chromium from a Contaminated Groundwater Source," and PNNL-13471, *Chromium Toxicity Test for Fall Chinook Salmon (Oncorhynchus tshawytscha) Using Hanford Site Groundwater: Onsite Early Life-Stage Toxicity Evaluation*) studied the effect of Cr(VI) sampled from Hanford Site groundwater on early life-stage (eyed eggs to free swimming juveniles) fall Chinook salmon survival, development rate, and growth. PNNL-14008 discusses the results of several laboratory-based investigations that were completed to evaluate the effects of Cr(VI) on various life stages of fall Chinook salmon, including fertilization, egg, alevin, and parr, and toxicological endpoints of hatching, growth, survival, health, pathology, and avoidance of contamination behavior. Farag et al., 2000, *The Potential for Chromium to Adversely Affect Chinook Salmon (Oncorhynchus tshawytscha) in the Hanford Reach of the Columbia River, Washington, USA*, evaluated fertilization[41] success in cutthroat trout (*Oncorhynchus clarkii*) and Chinook salmon based on an evaluation of sperm and ovum viability and using exposure conditions (e.g., exposure period, temperature) that represent some of those present in the Columbia River adjacent to the Hanford Site. Farag et al., 2000, also conducted studies of exposure during the time period just after swimming up.

[41] Additional studies to post swim-up life stages were also conducted but a clear effects threshold was not established. Post swim-up fish would not be consistently exposed to elevated concentrations because of very high dilution rates as groundwater mixes with surface water. Chromium is not measured above water quality standards in surface water.

These studies on parr were a nonstandard 134-day exposure first to an initial concentration (24 or 54 µg/L for 105 days) and, when no effects were observed, to an increased concentration (120 or 266 µg/L for the final 20 days of the study). Endpoints included growth, survival, histology, and deoxyribonucleic acid alterations. However, the results of the studies on parr did not include consistent exposure concentrations and did not produce clear defensible thresholds[42]. Each of the studies conducted specifically for the Hanford Site (PNNL-13471; Patton et al., 2007; PNNL-14008; Farag et al., 2000) brings valuable insight to understanding the potential exposure and effects relationships in the Hanford Reach. However, with what is understood about the steelhead trout lifecycle and contaminant behavior in groundwater and surface water in the Hanford Reach, only a subset of these studies is applicable to assessing risk to the steelhead trout.

Table 7-18 summarizes potentially relevant toxicity data to evaluate Cr(VI) effects from releases from the Hanford Site. As noted by Everest and Chapman (1972), salmonids are only present in sediments during early developmental stages, which encompass egg laying and fertilization, egg development and hatching, and early alevin development (prior to swim up). Because Cr(VI) has not been detected in the overlying surface waters of the Columbia River adjacent to the 100-D/H, salmonids could only be exposed to Cr(VI) in pore water during these early life stages. Accordingly, only toxicity data for these early life stages are relevant to evaluating the potential for impacts to salmonids.

Effects of Cr(VI) on egg fertilization were best studied by Farag et al., 2000, who investigated a realistic sperm-egg Cr(VI) exposure period of 1 minute during fertilization studies. In the study, Chinook salmon and cutthroat trout eggs and sperm were exposed to Cr(VI) samples collected from groundwater wells at the Hanford Site. In this study, Farag et al., 2000, demonstrated that Cr(VI) concentrations of up to 266 µg/L would not adversely affect Chinook salmon or cutthroat trout egg fertilization. Since higher concentrations were not tested, the actual no effect concentration may be higher. Limited data are available about the sensitivity of salmonid eggs/embryos and early developmental stage alevins to chromium. EPA-600/3-76-105, *Effects of Exposure to Heavy Metals on Selected Freshwater Fish*, for example, reported a significant effect concentration of 6,100 µg/L for rainbow trout hatchability. PNNL-13471 reported no effect on the survival, development, and growth of Chinook salmon between eyed egg and swim-up stage when exposed to Hanford Site groundwater with up to 266 µg/L Cr(VI) (maximum concentration tested). Buhl and Hamilton, 1991, "Relative Sensitivity of Early Life Stages of Arctic Grayling, Coho Salmon, and Rainbow Trout to Nine Inorganics," meanwhile, reported a 96-hour LC50 concentration of 205,000 µg/L for Coho salmon and a 96-hour LC50 concentration of 600,000 µg/L for rainbow trout when exposed to Cr(VI) at the early alevin stage. Using the most conservative outcomes from the fertilization studies, a site-specific NOEC of 266 µg/L was identified as the threshold for the evaluation presented in this report. Historical and recent nearshore groundwater well, aquifer tubes, seep, pore water, and surface water data are all below this relevant screening level.

[42] 84.3% survival was not considered a biologically significant reduction, growth was reduced in the lower but not at the greater exposure concentration, no statistics were performed on the histopathology to determine significant differences, and deoxyribonucleic acid studies were inconclusive.

Table 7-18. Summary of Toxicity Data Available for Salmonid Early Life Stage Tests with Cr(VI)

Developmental Stage	Reference	Form Tested	Species	Component/ Stage Tested	Test Parameter	Endpoint	Endpoint Concentration (µg/L)
Fertilization	Farag et al., 2000	Cr(VI)	Cutthroat trout	Egg/sperm	Fertilization	NOEC (percent fertilization; multiple concentrations tested)	266
		Cr(VI)	Chinook salmon	Egg/sperm	Fertilization	NOEC (percent fertilization; multiple concentrations tested)	266
Egg/Embryo	PNNL-13471	Cr(VI)	Chinook salmon	Egg (eyed) to swim up stage	Egg survival, development, growth	NOEC (percent survival, development rate and length and weight; multiple concentrations tested)	266
Alevin	Buhl and Hamilton, 1991	Cr(VI)	Coho salmon	Alevin	Survival	96-hr LC50	205,000
		Cr(VI)	Rainbow trout	Alevin	Survival	96-hr LC50	600,000

Note: Complete reference citations are provided in Chapter 8 of this report.

Cr(VI) = hexavalent chromium

LOEC = lowest observed effects concentration

NOEC = no observed effects concentration

7.7.9.3 Conclusions for Threatened and Endangered Fish

Contaminated groundwater from the 100-KR-4 OU has no effect on ESA-listed species for the following reasons. No steelhead redds or fall Chinook salmon redds have been observed adjacent to 100-K or within the upwelling areas associated with the 100-KR-4 Groundwater OU. Even if redds were established, current and predicted conditions in groundwater still would not result in concentrations above risk thresholds at the point of exposure in pore water. Concentrations of Cr(VI) are below the most applicable no-effect thresholds. Further, the proposed remedial actions for the 100-KR-4 OU do not include physical actions in the river. That is, the remedial actions will not have effects on the aquatic habitat—habitat that to date has not been documented to support salmonid redds or egg and alevin life stages.

7.7.10 Amphibians Risk Characterization

Section 6.4.1.3 of the RCBRA (DOE/RL-2007-21) addressed the question "Do Contaminant Concentrations in Pore Water Decrease Amphibian Survival or Growth?" The results of frog embryo teratogenesis assay xenopus bioassays showed no survival or growth differences between study sites and reference sites. Comparison of unfiltered pore water results supported this conclusion with measured concentrations below amphibian aquatic benchmarks. The CRC (DOE/RL-2010-117) also identified amphibians as an assessment endpoint. Risk to aquatic life, including amphibians, was evaluated exclusively through the comparison of surface water concentrations to the lowest available benchmarks in Section 7.2.1 of the CRC. Since surface water concentrations were below benchmarks (subsequent Table 7-1 of the CRC), no risk to amphibians was identified. The use of surface water benchmarks for invertebrates and fish to evaluate amphibians is uncertain in the absence of amphibian specific benchmarks. However, as noted in RCBRA, Table 6-85, the amphibian thresholds identified were above those for fish and invertebrates. Assessments in the RCBRA and CRC simply addressed all three taxa at one time. Given the higher amphibian benchmarks, the conclusions of no risk to other aquatic life in the CRC and RCBRA apply to amphibians as well.

7.7.11 Aquatic-Dependent Wildlife Risk Characterization

The RCBRA evaluated risk to middle trophic-level wildlife including the kingbird, mink, and bufflehead. Risks to wildlife in the nearshore environment are primarily from ingestion of prey consisting of aquatic invertebrates, clams, and fish, and from incidental ingestion of sediment. Only chromium risk to the bufflehead represented a risk warranting further evaluation and the chromium was elevated at just one study site that is not located within the 100-K Area nearshore environment.

Risk to wildlife in the CRC focused on exposure to island and riparian soil, and shoreline sediment. Although a handful of chemicals exceeded thresholds based on no-effect levels, only killdeer exposure to lead in shoreline sediments was identified as a final COPEC. The maximum detected concentration was in shoreline sediment in the 300 Area at 111 mg/kg. The maximum detection of 10 samples (59.2 mg/kg) from 100-K is below the lowest avian PRG of 156 mg/kg; thus, risk to avian receptors is insignificant and does not warrant further evaluation.

7.8 Risk Conclusions and Scientific Management Decision Point for Riparian and Nearshore Habitats and the Columbia River

The results from the BERA showed that inorganic, organic, and radiological contaminants detected in near-river groundwater samples, collected from the 100-KR-4 OU, are not affecting the aquatic life

exposed to pore water, surface water, or sediment in the Columbia River near the 100-K Area[43]. Modeled future concentrations are also below effect levels (CP-61711, Appendix F). Numerous lines of evidence were considered as part of the evaluation. These included, but were not limited to, the comparison of aquatic media (aquifer tube, pore water, spring/seep, and surface water) in the riparian and nearshore areas to effect levels, data quality, temporal significance, and correlations or the lack thereof with chemistry and observed responses in the bioassays and reference data.

The results of pore water bioassays on aquatic invertebrates and amphibians also suggest little or no correlation between COPEC concentrations and observed responses in the bioassays and the responses were not different from those of upstream references. Benthic invertebrate community structure data also suggest no differences between reference sites and locations adjacent to the Hanford Site. The results from this analysis confirm the results from the evaluation presented in this aquatic BERA, that no COPECs are affecting aquatic life exposed to pore water or surface water in the Columbia River near the 100-K Area.

The results of the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) were re-examined in this BERA, along with additional data collected since the completion of those reports, to reach final conclusions about ecological risk in the 100-K Area, and to inform the ROD. A final summary of the evaluation of the RCBRA and CRC COPECs is presented below followed by the SMDP for the aquatic BERA.

7.8.1 Summary of Results and Conclusions of the RCBRA

The RCBRA evaluated ecological risks at 48 nearshore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia River and in areas between the plumes. Twenty-two COPECs were identified for the nearshore environment and sixteen of these (all inorganics) were further identified as COECs. The RCBRA concluded that across the Hanford Reach of the Columbia River (i.e., corridor-wide), five COECs (cadmium, chromium, Cr(VI), manganese, and uranium) in the nearshore environment may present an unacceptable level of risk for one or more of the assessment endpoint entities (aquatic plants, aquatic invertebrates, amphibians, fish, and wildlife). For the purposes of the following assessment, the COECs will be defined as COPECs because a link to the Hanford facility has yet to be determined. These results are based primarily on the comparison of COPEC concentrations to toxicity benchmarks, measures of exposure and effects in biota, or the results of wildlife exposure analyses (RCBRA).

The evaluation of these sediment COPECs is summarized as follows:

- **Cadmium** was detected in 5 of 11 nearshore sediment samples (Appendix J, Table J-34). However, none of the samples exceeded the lower or upper effects threshold (SQS and CSL from Ecology Publication 11-09-054); thus, cadmium was not carried forward to the FS.

- **Chromium** was detected in 11 of 11 nearshore sediment samples (Appendix J, Table J-34). However, the maximum concentration (72 mg/kg) was equal to the lower effects threshold (SQS from Ecology Publication 11-09-054). Riparian soil concentrations were detected at a maximum of only 41.7 mg/kg; therefore, are not the source of the observed sediment measurements. Likewise, filtered

[43] Both filtered and unfiltered water sample results were evaluated in the RCBRA (DOE/RL-2007-21). In some cases, the toxicity information or standards/criteria are based on dissolved metals concentrations (filtered samples). Therefore, exposure and the potential for risk from metals contaminants may be overestimated by using the unfiltered (or total metals) concentrations.

results for total chromium in aquifer tubes were measured below the effect level in all 124 samples. However, 97 of 206 filtered nearshore groundwater samples exceeded the effect level for Cr(VI), which represents the majority of the total chromium suggesting a potential source partitioning to sediments. The one measurement of total chromium at the bulk sediment lower effect level does not suggest a community level risk to benthic organisms. However, total chromium in groundwater was carried forward to the FS.

- **Manganese** was detected in 11 of 11 nearshore sediment samples (Appendix J, Table J-34). However, none of the samples exceeded the lower or upper effects threshold (SQS and CSL from Ecology Publication 11-09-054); thus, manganese was not carried forward to the FS.

The evaluation of pore water COPECs is summarized as follows:

- **Cr(VI)** within the 100-K Area nearshore filtered samples exceeded the AWQC and SWQS in aquifer tubes (19 of 184 samples) and riparian groundwater wells (97 of 206 samples) (Appendix J, Table J-24). The AWQC and SWQS were also exceeded in 3 of 7 unfiltered pore water samples. Therefore, there is a complete pathway for observed Cr(VI) concentrations in sediment and water from the 100-KR-4 OU, which warrants further discussion in the FS.

- **Manganese** was detected above the effect level in just 1 of 14 seep samples of the 100-K nearshore area (Appendix J, Table J-24). For filtered groundwater, 4 of 332 nearshore well samples exceeded the effect level. For aquifer tubes, none of the 114 filtered or unfiltered samples exceeded the effect level. Pore water samples in the 100-K nearshore area were not filtered but were below the effect level in 6 of 7 samples, which does not suggest the 100-K Area to be the source. Manganese was not detected above the effect level in 4 filtered nearshore surface water samples. Thus, with concentrations in nearshore groundwater or aquifer tubes not consistently exceeding the effect level, the 100-K Area is not contributing to concentrations of manganese observed in pore water in the Columbia River.

- **Uranium** concentrations within the 100-K riparian and nearshore aquatic media were above the PNEC for 4 groundwater samples (3 of 140 unfiltered and 1 of 129 filtered) and 10 aquifer tube samples (5 of 55 filtered and 5 of 55 unfiltered) but measurements were below the effect level in for all 12 seep, 7 pore water, and 4 surface water samples (the direct exposure media) within the 100-K Area. There is just one of 55 filtered groundwater and one of 140 unfiltered aquifer tube samples above site background of 9.9 µg/L. No filtered aquifer tube samples are above background. Since there is no pattern of concentrations above background, no detections in the direct exposure media (pore water and surface water), and it was not identified as a groundwater COPC for ecological risk in Chapter 6, the conclusion for this BERA is that uranium does not present a risk to benthic organisms and no further evaluation is needed.

The RCBRA (DOE/RL-2007-21) also evaluated ecological risks at 18 representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (i.e., groundwater seeps, soil, and sediment). As with the nearshore environment, 22 COPECs were identified for the riparian environment. The RCBRA identified 9 of the identified 22 COPECs (arsenic, chromium, copper, lead, mercury, selenium, TPH-diesel, vanadium, and zinc) as possibly presenting some level of risk for one or more of the assessment endpoint entities (terrestrial plants, invertebrates, and wildlife) (DOE/RL-2007-21). This is based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate benchmarks, or the results of wildlife exposure analyses. However, conclusions in the RCBRA were that on a River Corridor-wide basis, only six of these COPECs should be

considered further (arsenic, chromium, lead, mercury, TPH-diesel, and zinc). A summary of the evaluation of these COPECs is provided below.

As shown in Appendix J, Table J-29 (plants and invertebrates) and Table J-30 (wildlife), concentrations of arsenic, chromium, lead, mercury, TPH-diesel, and zinc in 100-K riparian soil were all below soil PRGs presented in Tables 7-5 and 7-6. Thus, none of these riparian soil COPECs were carried forward to the FS.

COPECs identified within the RCBRA are included in Table 7-19. These COPECs were determined for the River Corridor as a whole.

7.8.2 Summary of Results and Conclusions of the CRC

The purpose of the CRC SLERA was to evaluate the potential for Hanford Site-related contaminants to adversely affect the fish and wildlife of the Columbia River (DOE/RL-2010-117). The SLERA focused on the Columbia River itself including Hanford sources as well as upstream and non-Hanford Site sources. The SLERA included a statistical comparison of the detected concentrations in the Hanford Reach to offsite reference areas. This was the first step in distinguishing if potential effects in the Hanford Reach may be from other non-Hanford Site source areas. The SLERA then focused on the Hanford inclusion list chemicals and identified which sites were elevated relative to benchmarks. However, some of the COPECs identified in the CRC have no connection with Hanford sources. This BERA evaluated those COPECs further with respect to Hanford Sources.

The CRC (DOE/RL-2010-117) SLERA combined both screening and baseline elements. Abiotic media were compared to screening benchmarks for surface water, sediment, and pore water to identify COPECs. Soil concentrations were compared to plant and invertebrate benchmarks, and desktop food web models were used to evaluate risks to wildlife. A baseline assessment was also conducted to assess risk to fish using tissue residue data. The CRC concluded that there were nine COPECs within sediment, pore water, island soil, and shoreline sediment (aluminum, chromium, Cr(VI), lead, manganese, nickel, nitrate, selenium, and uranium) of the 100 and 300 Areas. The evaluation included distinct conclusions for the reach adjacent to the 100 Area versus those for the specific reach adjacent to 100-K. Cr(VI) and manganese were identified for pore water within the 100-K Area while chromium and Cr(VI) were identified for sediment within the 100 Areas as a whole. A summary of the evaluation of these COPECs is provided in the following subsections.

The evaluation of pore water COPECs is summarized as follows:

- **Cr(VI)** within the 100-K Area nearshore filtered samples exceeded the AWQC and SWQS in aquifer tubes (19 of 184 samples) and riparian groundwater wells (97 of 206 samples) (Appendix J, Table J-24). The AWQC and SWQS were also exceeded in 3 of 7 unfiltered pore water samples. Therefore, there is a complete pathway for observed Cr(VI) concentrations in sediment and water from the 100-KR-4 OU, which warrants further discussion in the FS.

- **Manganese** was detected above the effect level in just 1 of 14 seep samples of the 100-K nearshore area (Appendix J, Table J-24). For filtered groundwater, 4 of 332 riparian well samples exceeded the effect level. For aquifer tubes, none of the 114 filtered or unfiltered samples exceeded the ESL. Pore water samples in the 100-K nearshore area were not filtered but were below the effect level in 6 of 7 samples, which does not suggest the 100-K Area to be the source. Manganese was not detected above the effect level in 4 filtered nearshore surface water samples. Thus, with concentrations in nearshore groundwater or aquifer tubes not consistently exceeding the effect level, the 100-K Area is not contributing to concentrations of manganese observed in pore water in the Columbia River.

Table 7-19. Riparian, Nearshore, and Riverine COPECs from the RCBRA and CRC

COPEC	Receptors	Media	Is 100-KR-1 or 100-KR-2 a Potential Source?	Is 100-KR-4 a Potential Source?	Carried Forward to FS?	Rationale for Exclusion in 100-K Area
Arsenic [a]	Terrestrial Plants	Riparian Soil	No	No	No	All detections below the plant, invertebrate, and wildlife effect levels,
Cadmium [a]	Aquatic Plants and Invertebrates	Sediment	No	No	No	All detections were below effect levels.
Chromium [a,b]	Aquatic Plants and Invertebrates and the Bufflehead	Sediment	No	Yes	No	Total chromium in mid-channel sediment was not different from reference concentrations. Riparian soil concentrations were below the sediment concentrations and were not a source. While the risk in sediment is not a community level concern, nearshore groundwater, aquifer tube, and pore water samples suggest an ongoing source that should be evaluated further in the FS.
Chromium [a]	Terrestrial Plants and Invertebrates	Riparian Soil	No	No	No	All detections were below PRGs.
Cr(VI) [a,b]	Fish Aquatic Invertebrates Aquatic Plants	Pore Water	No	Yes	Yes	Nearshore groundwater, aquifer tube, and pore water samples suggest an ongoing source that should be evaluated further in the FS. However, the AWQC and SWQS exceedances is driven by planktonic crustaceans. Concentrations are below thresholds for other aquatic organisms, including threatened and endangered fish species.
Cr(VI) [b]	Aquatic Plants and Invertebrates	Sediment	No	Yes	No	EPA guidance (EPA-600-R-02-011) points to focusing on pore water as the primary exposure pathway for this chemical.
Lead [a]	Terrestrial Plants	Riparian Soil	No	No	No	All detections were below PRGs.
Manganese [a]	Aquatic Plants and Invertebrates	Sediment	No	No	No	No sediment samples exceeded the effect levels.

Table 7-19. Riparian, Nearshore, and Riverine COPECs from the RCBRA and CRC

COPEC	Receptors	Media	Is 100-KR-1 or 100-KR-2 a Potential Source?	Is 100-KR-4 a Potential Source?	Carried Forward to FS?	Rationale for Exclusion in 100-K Area
Manganese [a]	Fish, Amphibians, Aquatic Plants, and Invertebrates	Pore Water	No	No	No	Pore water concentrations in pore water (1 of 7) and nearshore groundwater (4 of 332) only sporadically exceeded the effect level. None of the 114 aquifer tube samples exceeded the effect level. Eliminated in the Chapter 4 groundwater evaluation.
Mercury [a]	Terrestrial Invertebrates	Riparian Soil	No	No	No	All detections were below PRGs.
TPH-Diesel [a]	Terrestrial Invertebrates	Riparian Soil	No	No	No	TPH was only measured in the 100-N Area, not within the 100-K Area.
Uranium [a]	Aquatic Plants and Invertebrates	Groundwater/ Pore Water	No	No	No	Concentrations in nearshore groundwater (1 of 129) and aquifer tubes (5 of 55) only sporadically exceeded the effect level. Only 2 samples were above background. Eliminated in the Chapter 4 groundwater evaluation.
Zinc [a]	Terrestrial Plants and Invertebrates and Kingbirds	Riparian Soil	No	No	No	All detections were below PRGs.

References: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*.

DOE/RL-2010-117, *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment*.

EPA-600-R-02-011, *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc*.

a. COECs presented in Sections 8.4 and 8.5 of DOE/RL-2007-21.

b. COECs presented in the executive summary of DOE/RL-2010-117.

AWQC = ambient water quality criteria
COEC = contaminant of ecological concern
COPEC = contaminant of potential ecological concern
Cr(VI) = hexavalent chromium
CRC = Columbia River Component
FS = feasibility study
OU = operable unit
PRG = preliminary remediation goal
RCBRA = River Corridor Baseline Risk Assessment
SWQS = surface water quality standard
TPH = total petroleum hydrocarbon

The evaluation of sediment COPECs is summarized as follows:

- **Total chromium** was detected in 11 of 11 nearshore sediment samples (Appendix J, Table J-34). However, and the maximum (72 mg/kg) was equal to the lower effects threshold (SQS from Ecology Publication 11-09-054). Riparian soil concentrations were detected at a maximum of only 41.7 mg/kg; therefore, are not the source of the observed sediment measurements. Likewise, filtered results for total chromium in aquifer tubes were measured below the effect level in all 124 samples. However, 97 of 206 filtered nearshore groundwater samples exceeded the effect level for Cr(VI), which represents the majority of the total chromium suggesting a potential source partitioning to sediments. The one measurement of total chromium at the bulk sediment lower effect level does not suggest a community level risk to benthic organisms. However, total chromium in groundwater was carried forward to the FS.

- **Cr(VI)** was detected in 31 of 117 sediment samples in the 100 Area reach of the Columbia River as part of the CRC, with a maximum of 7.38 mg/kg (RCBRA, DOE/RL-2010-117). It was also detected in nearshore sediment samples at 0.76 mg/kg at 100-K (2 of 7 detects) (DOE/RL-2007-21). With no substantial toxicological data available with which to evaluate the bulk sediment measurements, this contaminant was identified as a COPEC in both reports. Total chromium filtered results in nearshore groundwater wells were measured above the total (Cr(VIII)) AWQC in 12 of 398 samples. Of 206 filtered nearshore samples, 97 exceeded the AWQC and SWQS for Cr(VI). Thus, Cr(VI) in groundwater was carried forward to the FS. However, Cr(VI) in bulk sediment is not considered a final COC for the FS because EPA guidance (EPA-600-R-02-011) points to focusing on pore water as the primary exposure pathway for this chemical.

7.8.3 Summary of Results and Conclusions of the Groundwater COC Evaluation

Groundwater COCs were identified in Chapter 6. These COCs (Cr(VI), nitrate, trichloroethene, strontium-90, carbon-14, and tritium) were identified because existing groundwater and modeled future groundwater concentrations (CP-61711, Appendix F) are above human health risk-based values. However, existing data and future modeled concentrations of nitrate, trichloroethene, strontium-90, carbon-14, and tritium in the nearshore area are all below values protective of ecological risk. For carbon-14, strontium-90, and tritium, there have been several site-specific studies to support these conclusions and support that the DOE's BCGs are sufficiently protective of both riparian wildlife drinking from seeps along the River and aquatic life living in the River. Cr(VI) was also identified as a groundwater COC because measured and modeled future concentrations in the nearshore area exceed the AWQC (11 µg/L) and the state WQS (10 µg/L). Alternatives to address the ongoing potential adverse effects to aquatic life from Cr(VI) will be evaluated further in the FS.

7.8.4 Scientific Management Decision Point and Conclusions

The purpose of this aquatic habitats BERA was to evaluate, on a reactor decision area basis, the baseline risk and basis for action from current conditions. This BERA supplements the analysis of River Corridor-wide ecological risks presented in the ERA of the RCBRA. It also supplements the analysis of the 100-KR-4 OU ecological risks presented in the CRC SLERA (DOE/RL-2010-117). Multiple lines of evidence were considered as part of the evaluation in this current BERA, which included, but was not limited to, the comparison of aquatic media (aquifer tube, pore water, spring/seep, and surface water) in the riparian and nearshore areas to effect levels, data quality, temporal significance, results of bioassays performed on site media samples, correlations or the lack thereof with chemistry and observed responses in the bioassays, and comparison to reference data. Based on the results of the weight of evidence contained in this BERA, with the exception of Cr(VI), detected concentrations of contaminants in environmental media (riparian or nearshore groundwater, seeps/springs, aquifer tubes, pore water, and

riparian and island soil), do not indicate ecological risk that requires further evaluation in the FS or the risk is not associated with contaminated soil or groundwater resulting from Hanford Site operations.

Except for Cr(VI) in groundwater, there are no potential sources for the COPECs that are related to the Hanford Site. These sources are summarized in the RCBRA and CRC, as well as in Chapter 4. Only Cr(VI) from the 100-KR-4 Area groundwater OU was considered a source in the 100-K nearshore and riparian area. Measurements of Cr(VI) in nearshore wells and measurements in pore water demonstrate continued exceedance of the AWQC (11 µg/L) and SWQS (10 µg/L), indicating a continued complete pathway from 100-K groundwater to the Columbia River. Since Cr(VI) results in pore water are above the 11 µg/L AWQC, which is an ARAR, Cr(VI) in the 100-KR-4 OU requires consideration in the FS, but discussion specific to risk reduction need only focus on exposure to potentially sensitive benthic organisms in the hyporheic zone rather than risk for tested genera listed in Table 7-16 for which there was no identified population or community level risk. For the purpose of alternatives evaluation in the 100-K FS, Cr(VI) in the 100-KR-4 Groundwater OU should be considered the only COEC.

Chapter 7 Waste Site Summary

- Of the 58 waste sites evaluated in this RI/FS, 55 sites were evaluated for ecological risk. The remaining three sites were determined to be not applicable to the ERA. These sites were two deep waste sites (waste site 100-K-46 and waste site 100-K-47; 100-K-69, 100-K-70; 100-K-71) and one waste site that was 100% non-detect for all analytes (132-KE-1).
- Of the 55 sites evaluated in Chapter 7, there were no unacceptable risks to wildlife, plants, or invertebrates, and a conclusion of no further action was made for all the waste sites.

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Appendix A

Site Map

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A1 Introduction

This appendix provides a 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units map showing boundaries, waste sites, waste site remediation footprints, and waste site status as of April 31, 2017.

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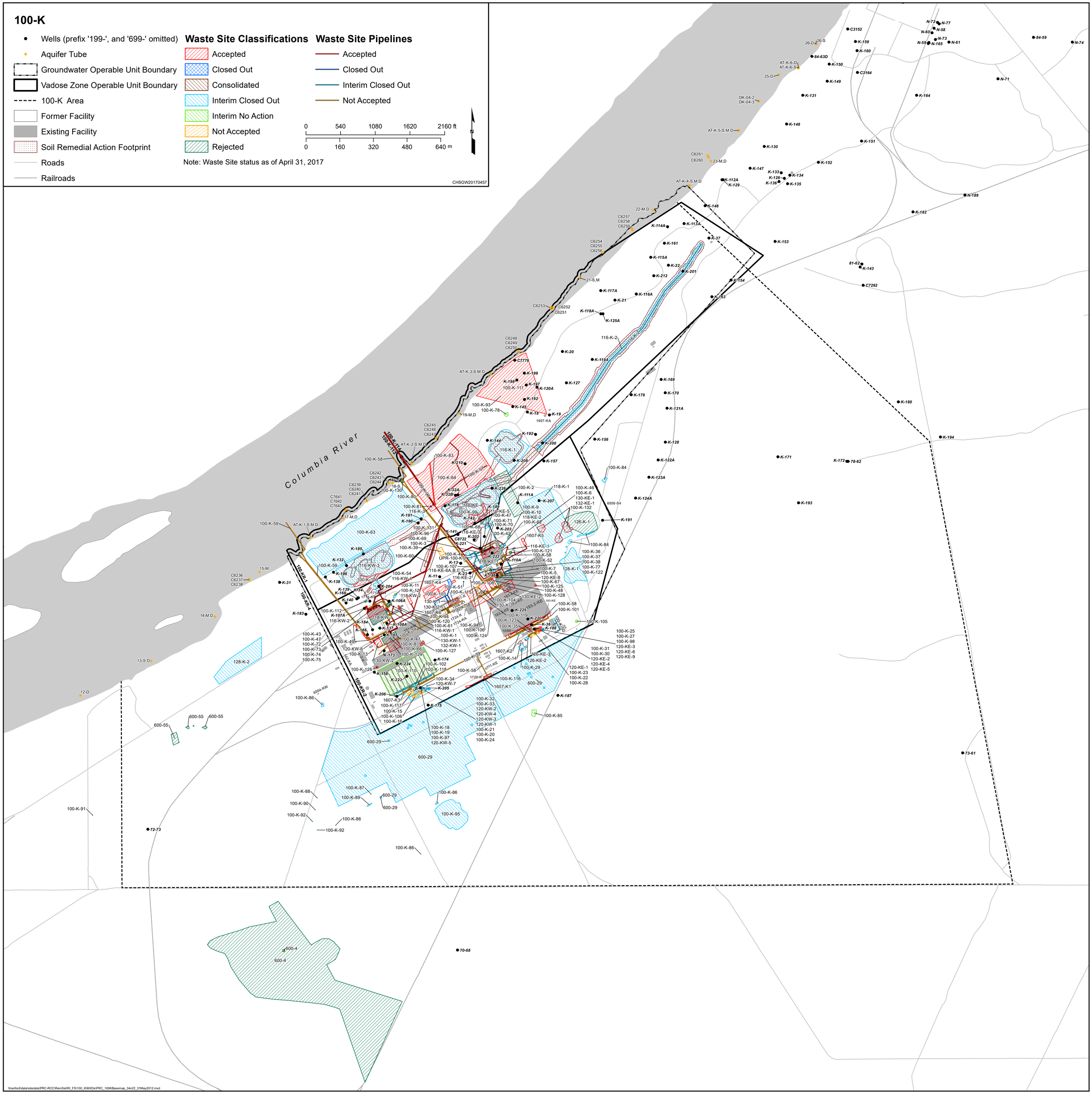
100-K
Wells (prefix '199-', and '699-' omitted)
Aquifer Tube
Groundwater Operable Unit Boundary
Vadose Zone Operable Unit Boundary
100-K Area
Former Facility
Existing Facility
Soil Remedial Action Footprint
Roads
Railroads
Waste Site Classifications
Accepted
Closed Out
Consolidated
Interim Closed Out
Interim No Action
Not Accepted
Rejected
Note: Waste Site status as of April 31, 2017
Waste Site Pipelines
Accepted
Closed Out
Interim Closed Out
Not Accepted
0 540 1080 1620 2160 ft
0 160 320 480 640 m
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CHSGW20170457
Columbia River
100-KR-1
100-KR-2
100-KR-3
100-KR-4
100-K-113
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116-KE-3
116-KE-4
116-KE-5
116-KE-6A,B,C,D
118-K-1
118-KW-1
118-KW-2
118-KE-1
118-KE-2
126-K-1
126-KE-1
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126-KE-3
128-K-1
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1607-K1
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1607-K4
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1724-KA
183.2-KE
6508-S4
6604-KW
600-4
600-29
600-55
UPR-100-K-3
AT-K-1-S,M,D
AT-K-2-S,M,D
AT-K-3-S,M,D
AT-K-4-S,M,D
AT-K-5-S,M,D
AT-K-6-D
AT-K-6-S
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N-189
15-M
14-M,D
13-S,D
12-D
17-M,D
18-S
19-M,D
21-S,M
22-M,D
23-M,D
25-D
26-D
26-S

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Appendix B

Annotated Bibliography and Previous Investigations Summary

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B1 Introduction

This appendix contains a bibliography of resources that were used to support the 100-K Remedial Investigation (RI) and Feasibility Study (FS). Table B-1 summarizes information sources that support various sections of the RI and FS.

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Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
--	--	2001	Hanford Site	*USDOE Hanford Site First Five Year Review Report*	The first five-year review for the 100 Area National Priorities List site identified the principal deficiency as a failure to achieve the required protectiveness for groundwater. The pump and treat systems showed insufficient plume capture and treatment of chromium-contaminated groundwater. The five-year review recommended optimizing and running the extraction/treatment system more reliably. For the 100-KR-4 operable unit (OU), recommendations included uptime improvement, decreased individual well downtime, and capture a higher percentage of the plume. Actions included: • Complete the design for system enhancements by September 2001 • Acquire an additional treatment skid and support systems • Build an annex or additional building to house the new treatment skid • Install an extraction well to bridge the gap between existing extraction wells K-120A and K-119A • Install a new injection well	D,S	Z,E	Y,S	--	No	No
--	--	2004 JUN	100 Area	*Determining flow, recharge, and vadose zone drainage in an unconfined aquifer from groundwater strontium isotope measurements, Pasco Basin, WA.*	This report presented results from strontium isotope compositions measured in groundwater samples from 273 wells in the Pasco Basin unconfined aquifer below the Hanford Site. These showed large and systematic variations that provided constraints on groundwater recharge, weathering rates of the aquifer host rocks, communication between unconfined and deeper confined aquifers, and vadose zone-groundwater interaction. The impact from discharge of millions of cubic meters of wastewater to the vadose zone (103 to 105 times higher than ambient drainage) was also reported.	D,H,P	G,Z, C,T	S,X, P	A	No	No
--	--	2009 AUG	100-HR-3 100-KR-4	*Explanation of Significant Differences for the 100-HR-3 and 100-KR-4 Operable Units Interim Action Record of Decision*	This explanation of significant differences identified two significant differences made to the Record of Decision (ROD): (1) Projected cost for the pump and treat operations were increased by more than 50% of the estimate in the ROD; and (2) Re-injection location requirements for treated water were revised to allow reinjection other than in upgradient locations to control migration of the plume and to prevent the 100-KR-4 chromium plume from converging with and interfering with remedial action of the strontium-90 plume at the 100-N Area.	D,H,P	Z	Y,S, X,P	--	No	No
0041053	--	1995 APR	100 Area	*Hanford Cleanup Costs in Perspective: Pump-and-Treat for Hexavalent Chromium*	This letter from U.S. Environmental Protection Agency (EPA) provided a perspective for 100 Area groundwater cleanup costs using pump and treat technology. The Boomsnub Site in Vancouver, Washington, provided an analog for pump and treat operations for chromium, including similar contaminant, media, and remedial process.	D	--	--	A	No	Yes
0042008	--	1995 SEP	100-HR-3 100-KR-4	*Focus on Hanford cleanup request for comments on 100-HR-3 and 100-KR-4 proposed plans*	This sheet was a request for comment regarding 100 Area ground water cleanups, protecting salmon spawning beds, and treatment options with alternatives (including the preferred one). Plans proposed cleanup actions near five reactors, the D, DR and H Reactors in an area designated the 100-HR-3 OU, and the K West and K East Reactors in the 100-KR-4 OU.	D	E	Y	--	Yes	Yes

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
0-043753	--	1996 APR	100-HR-3 100-KR-4	*Declaration of Record of Decision for USDOE Hanford 100 Area 100-HR-3 and 100-KR-4 Operable Units Hanford Site*	This ROD identified pump and treat as the selected interim remedial actions for 100-KR-4 and 100-HR-3. The pump and treat system was to remove hexavalent chromium (Cr(VI)) from groundwater and prevent contaminant discharges to the Columbia River.	D,H,P	G,Z,E	Y,S, X,P	A	Yes	Yes
0051443	--	1999 JUL	100 Area 200 Area	*Interim Action Record of Decision 100 Area Remaining Sites 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 OU Hanford Site, Benton County, Washington*	This ROD identified removal, treatment, and disposal (RTD) as the selected interim remedial actions for waste sites, including waste sites with known and unknown contaminant documentation, and sites associated with reactor debris.	D,H,P	G,Z,E	Y	--	Yes	Yes
0051819	--	1999 SEP	100-KR-2	*Declaration of Record of Decision for 100-KR-2 OU, USDOE, Hanford*	This ROD addressed the remediation for contents of the K Basins.	D,H,P	Z	Y,X		Yes	Yes
0053457	--	2000 AUG	100-KR-4	*Notice of Violation, Chromium-Contaminated Water Discharge at 100-KR-4*	This letter identified a violation of discharge standards for the period from July 25 to August 2, 2000. The violations were from release of contaminated water to the groundwater of the 100-K Area in excess of discharge standards.	D	--	Y,X	--	No	No
0053745	--	2000 OCT	100 Area	*Declaration of Record of Decision for 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, 100-KR-2, 100 Area Burial Grounds Hanford Site, Benton County, Washington*	This ROD selected interim remedial actions for 45 burial ground waste sites in the 100 Area. The response action selected was RTD.	D,H,P	G,Z,E	Y,S, X	M	Yes	Yes
0055226	--	2000 OCT	100-HR-3 100-KR-4	*The Potential for Chromium to Adversely Affect Chinook Salmon (Oncorhynchus tshawytscha) in the Hanford Reach of the Columbia River, Washington, USA*	The Hanford Natural Resource Trustee Council, in conjunction with the U.S. Fish and Wildlife Service and the U.S. Geological Survey, designed this study to assess the effects of chromium on Chinook salmon under exposure conditions similar to those of the Hanford Reach of the Columbia River.	D,P	Z,E	Y,X	A	Yes	No
0058507	--	2003 JAN	100-KR-4	*Clarification of CERCLA Risk Assessments for 100-KR-4*	Letter response to an EPA audit team, which concluded that sufficient data was not obtained to determine whether an interim remedial action was necessary for contaminated groundwater within the reactor section of the 100-K Area. The letter stated that EPA and U.S. Department of Energy (DOE) concluded, without completing a formal assessment, that an interim remedial action was unnecessary for the reactor section, as source remediation and pump and treat were already operative at 100-K.	D,P	--	Y	--	Yes	No
0058705	--	2003 FEB	100-HR-3 100-KR-4	*Chromium versus time plots for 199-D8-70 and 199-K-117a*	This presents the data files for wells 199-D8-70 and 199-K-117A. These two wells were sampled from 1997 to 2003 with a Kabis sampler per DOE/RL-96-90, the Interim Action Monitoring Plan. The wells were sampled monthly at 2 or 3 depths. The results did not show any stratification of chromium in these wells.	--	--	Y	--	--	--
0066954	--	2005 JUN	100-K	*U.S. Department of Energy 100-K Area K Basins Hanford Site — 100 Area, Benton County, Washington Amended Record of Decision, Decision Summary, and Responsiveness Summary*	The ROD directed removal of the spent nuclear fuel, sludge, water, and debris from the two K Basins in Hanford's 100-K Area. The amended remedy changed the sludge disposition and underwater debris retrieval, treatment, and disposal.	D,H,P	--	Y	--	Yes	Yes
0067599	--	2005 JUN	100-K	*Action Memorandum for the Non-Time-Critical Removal Action for the 100-K Area Ancillary Facilities*	This action memorandum documented approval of the non-time-critical removal action for 27 buildings and structures located in the northern section of the 100-K Area of the Hanford Site.	D,H,P	E	Y,S, X	--	No	No
0072067	--	2007 JAN	100-K	*Action Memorandum for the Non-Time-Critical Removal Action for the 105-KE and 105-KW Reactor Facilities and Ancillary Facilities*	This action memorandum implemented removal actions for the remaining buildings and structures in the 100-K Area.	D,H	E	Y,S, X	A	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
02-ERD-003	--	2001 OCT	100-HR-3 100-KR-4	*Transmittal of Design Documents for the 100-HR-3 and 100-KR-4 Pump and Treat System Upgrades*	These documents provided information for the completed design for the enhancements to the 100-HR-3 and 100-KR-4 pump and treat system, as specified in Action Item #100-1 of the Hanford Site First Five Year Review Report prepared by the EPA.	D	--	P	--	No	No
02-ERD-0112	--	2002 AUG	100-K	*Potential Effects to Bald Eagles Roosting in the Vicinity of the Hanford Site 100-K Reactor Area*	A series of chemical and radioactive waste sites were scheduled for remedial action within the 100-K Reactor Area facility boundaries. This action was scheduled to occur during the time when bald eagles are known to frequent the area (November to March). One of these waste sites, the 116-KW-3 Retention Basin, was located within 400 m (1,312 ft) of a known major roosting area for bald eagles. This letter served as informal consultation under Section 7 of the *Endangered Species Act of 1973* regarding potential effects from this effort.	D,H	C,E,T	--	A	Yes	No
02-SFO-019	--	2001 NOV	100-KR-2	*Revised Waste Management Plan for the K Basins Interim Remedial Action*	This revision expanded *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) waste staging areas at the 100-K Basins. A clarification was made to identify that the staged waste could also include waste generated from the demolition activities, external to the basins, covered under the 100 Area Remaining Sites ROD.	D,P	--	Y	--	No	No
114449	--	2004 FEB	100 Area	*Managers' Meeting: 100 Areas Remedial Action Unit/Source Operable Units, February 26, 2004*	These minutes provided the general status concerning the 100 Areas, including groundwater remediation and disposal activities. Remediation activities at 100-K included RTD at the 116-KE-4 Retention Basin and effluent pipelines. Overburden removal activities were initiated on the 116-K-2 “mile-long” Trench. Remediation activities were completed on the acid tank saddles, 128-K-1 Burn Site, and 100-K-29 sandblast sites. Excavation activities were completed on the 116-KE-1 and 116-KW-1 condensate cribs.	H,P	Z,T	Y,S, X,P	A,M	Yes	No
119468	--	2005 JAN	100 Area	*Managers' Meeting: 100 Areas Remedial Action Unit/Source Operable Units, June 24, 2004*	These minutes provided the status of the remediation and groundwater treatment at the 100-K Area.	D,P	Z,T	S,X, P	A	Yes	No
11-AMRC-0061	--	2011 JAN	100-KR-2	*Transmittal of Approved Waste Site Reclassification Form and Supporting Documentation for the 100-K-2 118-K-2 Sludge Burial Ground, Revision 0*	Two test trenches and one test pit were excavated at the 100-K-2, 118-K-2 Sludge Burial Ground waste site as part of an investigation to verify that sludge from the 107-KE and 107-KW retention basins was not disposed at the waste site. Field observations during excavation and soil sampling did not indicate the presence of any waste or sludge. Residual concentrations of contaminants of potential concern were all less than remedial action goals. Therefore, the 100-K-2 waste site was recommended for reclassification as a rejected waste site.	D,H	G	Y	--	No	No
2004-040	--	2004 JUN	100-KR-2	*Waste Site Reclassification Form 2004-040*	The 100-K-29, 183-KE Sandblasting site consisted of visible red/purple garnet sandblasting material on the surface, located most heavily in three general areas. Sampling was conducted to determine remediation requirements, with focused/judgmental sampling based on visual site evaluation. Sampling strategy was based on site photographs, historical sandblasting use information, and suspected waste materials. Confirmatory sampling detected Cr(VI) total chromium, lead and polychlorinated biphenyls (Aroclor-1254) at concentrations that exceeded action levels, indicating site remediation was required.	D,H,P	--	Y	A	Yes	No
2005-006	--	2005 JUN	100-KR-1	*Waste Site Reclassification Form 116-KE-4 Retention Basin*	This form documented agreement authorizing classification of the subject unit as interim closed out.	D	--	--	--	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
61 FR 10736	--	1996 MAR	100-K	*Record of Decision, Management of Spent Nuclear Fuel from 100-K Basin at Hanford Site Richland WA*	DOE's final Environmental Impact Statement (EIS) on the "Management of Spent Nuclear Fuel from the K Basins at the Hanford Site, Richland, Washington."	D	--	--	--	Yes	Yes
9208903	--	1992 DEC	100-K	*100-KE Fuel Rod Basin*	EPA letter to notify the DOE of its interest in the large quantity of contamination in the 100-KE fuel storage basin (FSB). High tritium concentrations in the basin and adjacent wells suggested a leak from the basin.	--	--	Y,X	A	No	No
9513332.0558	--	1995 JAN	Hanford Site	*Record of Decision, U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*	This ROD presents the selected remedial action for the Environmental Restoration Disposal Facility (ERDF), chosen in accordance with CERCLA. It includes site background and a list of alternative actions.	D,H,P	G,Z,E	Y,S, X	M	Yes	Yes
97-007	--	1997 OCT	100-KR-2	*Waste Site Reclassification Form 100-KR-2 600-55*	This form documented agreement authorizing classification of the 600-55 site as rejected.	D	--	--	--	No	No
97-012	--	1997 OCT	100-KR-2	*Waste Site Reclassification Form 100-KR-2 600-4*	This form documented agreement authorizing classification of the 600-4 site as rejected.	D	--	--	--	No	No
BHI-00403	Rev. 0	1995 APR	100-KR-4	*Data Validation Summary Report for 100-KR-4 Round 7 Groundwater Sampling Task*	This report presents the data validation summary for groundwater samples collected for the 100-KR-4 Round 7 Groundwater Sampling task. The analyses included metals, general chemistry, and radiochemistry.	--	--	Y	A	No	No
BHI-00620	Rev. 0	1995 OCT	100-HR-3 100-KR-4	*Description of Work and Sampling and Analysis Plan for Pore Water Sampling at Groundwater-River Interface Adjacent to 100-D/DR, -K, and -H Reactor Areas*	Report describing how the environmental restoration contractor underwater divers will obtain interstitial pore water samples at a 45.7 cm (18 in.) depth from the Columbia River substrate adjacent to the 100-D, 100-K, and 100-H Reactor Areas. Pore water samples were analyzed in the laboratory for hexavalent and total chromium. Pore water, seep, and water column samples were also analyzed for Cr(VI), nitrate, temperature, dissolved oxygen, pH, hardness, turbidity, and specific conductance using field analysis techniques.	D	Z,E	Y,X, P	M	No	Yes
BHI-00764	Rev. 0	1996 MAY	100-HR-3 100-KR-4	*100-HR-3 and 100-KR-4 Interim Remedial Measures Pump-and-Treat Acquisition and Design Strategy Plan*	This document describes a plan for acquisition/design of the 100-HR-3 and 100-KR-4 groundwater pump and treat systems as the interim remedial measure (IRM).	D	--	--	--	No	No
BHI-00765	Draft A	1996 JUN	100-KR-4 100-HR-3	*Remedial Design Report and Remedial Action Work Plan for 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*	This is the remedial design report and remedial action work plan for the 100-HR-3 and 100-KR-4 OUs IRM. This document was prepared per the interim ROD, and describes the design basis, description of the interim action, and identifies how interim ROD requirements are met.	D,P	G,Z,T	Y,S, X,P	A,M	Yes	Yes
BHI-00772	Rev. 1	1996 JUN	100-HR-3 100-KR-4	*Design Criteria and Design Basis for the 100-HR-3 and 100-KR-4 Pump-and-Treat Projects*	This document describes the project objectives and design criteria for the 100-HR-3 and 100-KR-4 groundwater pump and treat design. This document provided early documentation and approval of project objectives and design criteria while the detailed design work progresses concurrently.	D,P	G,Z	Y	M	No	No
BHI-00874	Draft A	1996 AUG	100-HR-3 100-KR-4	*Mitigation Action Plan for the 100-HR-3 and 100-KR-4 Pump and Treat*	The IRM pump and treat project involved drilling 22 wells, improving access roads to existing and new wells, laying connecting pipes, and constructing groundwater treatment facilities in the 100-KR-4 and 100-HR-3 OUs. This mitigation plan provided a series of prioritized actions designed to minimize or lessen potential project impacts on cultural and natural resources.	D,H	E	--	A	Yes	Yes

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
BHI-00917	Rev. 0	1996 SEP	100-BC-5 100-KR-4 100-HR-3 100-FR-3	*Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units*	This document presented technical information on groundwater contamination in the 100-BC-5, 100-FR-3, 100-HR-3, and 100-KR-4 OUs. In this document, site information was assembled into conceptual site models. The objective was to assemble and evaluate the best information available to support a better understanding of the nature, extent, and transport of contamination in each groundwater OU.	D,P	G,Z	Y,S, X,P	A,M	Yes	No
BHI-01494	Rev. 0	2001 JUN	100 Area	*Aquifer Sampling Tubes Data Summary, Fall 2000*	This report summarized aquifer sampling tube results for samples collected in the fall of 2000. The focus was to identify tubes which best represented groundwater quality as compared to those affected by the groundwater/river water mixing zone.	D,H,P	Z	Y,X, P	M	No	No
BHI-01737	Rev. 0	2004 JUL	100-KR-2	*Cleanup Status Report for the 116-KE-1 and 116-KW-1 Cribs*	This report summarized the status of the incomplete remediation of these two cribs, which were considered to be the source of carbon-14 and tritium in groundwater at wells 199-K-106A, 199-K-132A, and 199-K-33.The summary included analytical results of contaminated soils at the bottom of the 9.1 m (30 ft) excavations. Work stopped due to excavation layback requirements affecting adjacent 115- KE/KW and 117-KE/KW facilities.	D,H,P	G	Y,S, X,P	A,M	Yes	Yes
BNWL-1515	--	1970 OCT	Hanford Site	*Fall Chinook Salmon Spawning in Columbia River Near Hanford 1947-1969*	Description of fall Chinook salmon spawning and the connection from its population to Hanford Site operations.	D,H,P	E		A	No	No
CHPRC-0900289	Rev. 11	2010 MAY	100-K	*100K Project Managers' Meeting Minutes May 13, 2010*	Meeting minutes for work and project progress in the 100-K Area, including changes to work plans, and a summary presentation on the 100-K West Bio-infiltration Treatability Test Update	D,P	G	Y		No	No
CVP-2003-00024	--	2004 MAY	100-KR-1	*Waste Site Reclassification Form 100-KR-1 116-L-1 Crib*	This waste site reclassification form (WSRF) documented that the 116-K-1 Crib was remediated by RTD and reclassified as interim closed out.	D,H,P	G,Z,T	Y,S, X	A	Yes	No
CVP-2005-00006	Rev. 0	2005 SEP	100-KR-2	*Cleanup Verification Package for 100-K-55:1 and 100-K-56:1 Pipelines and the 116-KW-4 and 116-KE-5 Heat Recovery Stations*	This cleanup verification package documented remediation for the 100-K-55:1 and 100-K-56:1 pipelines, and the 116-KW-4 and 116-KE-5 heat recovery stations. WSRFs showing a status of interim closed out were included for each of the four sites.	D	--	Y	A,M	Yes	No
CVP-2006-00001	Rev. 0	2006 MAR	100-KR-1	*Cleanup Verification Package for 116-K-2 Effluent Trench*	This cleanup verification package documented completion of remedial action for the 116-K-2 Trench. The interim action RTD was completed and the WSRF shows a site status of interim closed out.	D,P	Z,T	Y,X	A,M	Yes	No
DOE/EIS-0119F	--	1992 DEC	Hanford Site	*Addendum (Final Environmental Impact Statement): Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*	This EIS presented analyses of potential environmental impacts from decommissioning eight surplus production reactors at the Hanford Site.	D,H,P	G,Z,E, C,T	Y,S, X	M	Yes	Yes
DOE/RL-2000-01	Rev. 0	2000 JUN	100-HR-3 100-KR-4 100-NR-2	*Annual Summary Report Calendar Year 1999 for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and Operable Units*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,H,P	Z	Y,X	A,M	No	No
DOE/RL-2000-59	Rev. 0	2000 OCT	100 Area	*Sampling and Analysis Plan for Aquifer Sampling Tubes*	This sampling and analysis plan (SAP) presented the overall rationale, strategy, and methods for aquifer tube sampling and analyses.	D,H,P	Z	Y,X	M	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2001-04	Rev. 0	2001 AUG	100-HR-3 100-KR-4 100-NR-2	*Annual Summary Report Calendar Year 2000 for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Units and Pump-and-Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,H,P	Z	Y,X	A,M	No	No
DOE/RL-2002-05	Rev. 0	2002 SEP	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2001 Annual Summary Report for the 100-HR-3, 100-KR-4 and 100-NR-2 Operable Unit Pump and Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,H,P	Z	Y,X	A,M	No	No
DOE/RL-2003-09	Rev. 0	2003 MAY	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2002 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,P	Z	Y,X, P	--	No	Yes
DOE/RL-2004-21	Rev. 0	2004 MAY	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump &Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,H,P	G,Z,T	Y,S, X,P	A,M	Yes	Yes
DOE/RL-2004-43	Rev. 0	2004 JUN	100-K	*Engineering Evaluation/Cost Analysis for the 100-K Area Ancillary Facilities*	This document presented the results of an engineering evaluation/cost analysis (EE/CA) that was conducted to evaluate alternatives and recommend an approach for disposition of 27 buildings (subsequently referred to as facilities) located in the 100-K Area. Hazardous substances in these facilities present a potential threat to human health and the environment to the extent that action is warranted for the facilities. EPA determined that removal action is appropriate to mitigate the potential hazards. An action memorandum developed from this EE/CA will document and authorize implementation of the removal action.	D,H,P	E	Y,S, X	A	Yes	Yes
DOE/RL-2004-48	Rev. 1	2005 JAN	100-KR-2	*Proposed Plan for an Amendment to the K Basins Interim Remedial Action Record of Decision*	This proposed plan recommended changes to the K Basins ROD. The recommended changes affected sludge disposition, and underwater debris retrieval, treatment, and disposal from the 105-K East and 105-K West Spent Nuclear Fuel Basins. The proposed changes result in increased protection to human health and the environment.	D,H,P	T	--	--	Yes	Yes
DOE/RL-2005-05	Rev. 0	2005 FEB	100-KR-4	*Treatability Test Plan for Fixation of Chromium in the Groundwater at 100-K*	The test plan described the theory, process, data quality objectives and approach to testing the efficacy of calcium polysulfide and an organic substrate (corn syrup) in immobilizing Cr(VI) in the aquifer.	D,P	--	Y,S	--	No	Yes
DOE/RL-2005-18	Rev. 0	2005, MAY	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2004 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,H	--	Y	A	No	No
DOE/RL-2005-26	Rev. 0	2005 JUL	100-KR-1 100-KR-2	*Removal Action Work Plan for 100-K Area Ancillary Facilities*	This removal action work plan was for 27 facilities (buildings and structures) in the 100-K Area. The ancillary facilities supported the 105-KE and 105-KW Reactors.	D	--	Y, S	--	Yes	No
DOE/RL-2005-33	Rev. 1	2006 NOV	100-KR-1 100-KR-2 100-KR-4	*100-K Area Interim Safe Storage and D4 Project Waste Sampling and Analysis Plan*	This SAP presented the strategy, requirements, and procedures for sampling and analysis activities that supported waste management decisions associated with interim safe storage of the 100-K reactors and deactivation, decontamination, decommissioning, and demolition (D4) of associated 100-K Area facilities.	D,P	--	Y	M	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2005-45	Rev. 0	2005 AUG	100 Area	*Surplus Reactor Final Disposition Engineering Evaluation*	This engineering evaluation assessed the decommissioning and final disposition options for the Hanford Site surplus production reactors. The evaluation considered whether changes had occurred regarding technical innovations, environmental values, regulatory requirements, or other information documented in the final EIS that might lead to a different decision.	D,H,P	--	Y	M	No	Yes
DOE/RL-2005-86	Rev. 0	2006 MAY	100-K	*Engineering Evaluation/Cost Analysis for 105-KE and 105-KW Reactor Facilities and Ancillary Facilities*	This EE/CA presented results of an evaluation of three removal action alternatives for the disposition of approximately 85 facilities (buildings or structures) in the 100-K Area, plus the 105-KE and 105-KW Reactor buildings.	D,H,P	Z,E	Y,S, X	M	No	Yes
DOE/RL-2006-08	Rev. 0	2006 MAY	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2005 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	H,P	--	Y	--	No	No
DOE/RL-2006-17	Rev. 0	2006 MAR	100-KR-4	*Treatability Test Report for Calcium Polysulfide in 100-K Area*	This report presented the results of a 2005 treatability test performed in the 100-K Area. The test used calcium polysulfide to remediate chromium in groundwater. This treatment also chemically reduced a portion of the aquifer materials to form a permeable reactive barrier to continue treatment. The test evaluated the practicality and cost-effectiveness of using calcium polysulfide remediation, and to gain operational experience. The test also determined aquifer hydrologic information and provided design and implementation experience.	D,P	Z	Y,S, X,P	A	No	No
DOE/RL-2006-20	Rev. 1	2006 NOV	Hanford Site	*The Second CERCLA Five-Year Review Report for the Hanford Site*	The five-year review was conducted to determine whether the remedies at the site are protective of human health and the environment, and to document the findings. The five-year review identified issues and actions to address them. For the 100-KR-4 OU, three issues were identified: 1. The southeastern (inland) extent of the chromium groundwater plume from the 116-K-2 trench, northeast of the injection wells had not been delineated 2. The small chromium plume at the KW Reactor site had reached the river, as evidenced by near-shore aquifer tubes, and there was no active remediation system in place. 3. Groundwater monitoring indicated that the expansion of the 100-K Area pump and treat extraction system has not yet achieved the remedial action objective. These findings led to installation of new wells to delineate the plume, construction of the KW pump and treat facility, and expansion of the pump and treat system with addition of KX.	D,H,P	E,P	S,X, Y	A	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2006-52	Rev. 0 Rev. 2	2006 SEP 2010 JAN	100-KR-4	*The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to 100-KR-4 Groundwater Operable Unit Interim Action*	This supplement to the remedial design report and remedial action work plan (RDR/RAWP) was prepared to include remediation of the chromium plume in the area of the 105-KW Reactor, including construction of the KW pump and treat system. Revision 2 provided additional hydrogeologic data and engineering design requirements to support a 100-gallon-per-minute expansion to the system.	D,P	G,Z,E, T	Y,X, P	A	Yes	No
DOE/RL-2006-75	Rev. 1 REISSUE	2008 OCT	100-KR-4	*Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Work Plan for the Expansion of the 100-KR-4 Pump and Treat System*	This supplement to the RDR/RAWP supported expansion of the pump and treat system remediating the Cr(VI) plume associated with the former 116-K-2 Trench. The supplement included an updated quality assurance project plan (Appendix A) and a numerical modeling discussion (Appendix B).	D,H,P	G,Z,E	Y,S, P	M	Yes	No
DOE/RL-2006-76	Rev. 0	2007 MAY	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*	This report discussed the interim remedial actions at the 100-KR-4 OU. The report evaluated pump and treat system performance, compliance, and cost.	D,H,P	Z	Y,S, X,P	M	Yes	No
DOE/RL-2007-48	Rev. 0	2008 JAN	100-KR-2	*Remedial Design Report and Remedial Action Work Plan for the 100 Area Remaining Sites Interim Remedial Action: 105-K East Basin Demolition,*	This RDR/RAWP described the remedial design, design basis, and the remedial actions to decontaminate and decommission the 105-K East Basin. The 105-K East Basin included both abovegrade and belowgrade structures.	D, H	G	S, Y	--	No	No
DOE/RL-2008-05	Rev. 0	2008 JUN	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operation*	This annual summary report discussed the groundwater remedial actions in the 100 Areas, including the pump and treat remedial action at the 100-KR-4 OU.	D,P	Z	Y	M	No	No
DOE/RL-2008-33	Rev. 0	2008 JUL	100-KR-4	*Sampling and Analysis Plan for Investigating Chromium Groundwater Contamination Near the 105-KW Reactor*	This SAP described the proposed drilling and construction of four wells in the 100-K West Area. The purpose of these wells was to investigate the extent of high chromium concentrations measured in groundwater at well 199-K-137 and to provide additional data to evaluate changes to the pump and treat facility treating the localized chromium plume near the 105-KW Reactor.	D,H,P	G,Z,T	Y,P	M	Yes	No
DOE/RL-2008-46	Rev. 0	2010 MAR	100 Area	*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*	This work plan presented the scope and procedures for a remedial investigation/feasibility study (RI/FS) to support remedy selection under CERCLA for the 100 Area National Priorities List site at the Hanford Site. This document explained the RI/FS project background and rationale, and presented detailed plans for investigation of the 100 Area. The 100 Area OUs included in the work plan were in the 100-BC Area, 100-K Area, 100-D/H Area, 100-N Area, and the 100-F/IU-2/IU-6 Area.	D,H,P	G,Z,C, E,T	Y,S, X,P	A,M	Yes	Yes
DOE/RL-2008-46-ADD2	Rev. 0	2010 JAN	100-KR-1 100-KR-2 100-KR-4	*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*	Addendum 2 to the work plan provided RI/FS requirements for the 100-K Area OUs.	D	C,D,G,	Y	S	No	No
DOE/RL-2008-66	Rev. 0	2009 MAR	Hanford Site	*Hanford Site Groundwater Monitoring Report for Fiscal Year 2008*	This report presented results of groundwater monitoring and summarized results of groundwater remediation and vadose zone studies for fiscal year 2008 on the Hanford Site.	H,P	Z,E	Y,S, P	A	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2009-108	Rev. 0	2009 DEC	100-K	*Ambient Air Monitoring Relocation Request for the 100-K Area Near-Facility Monitoring Network*	This document identified changes to the diffuse and fugitive environmental monitoring network of near-facility ambient air monitors located in the 100-K Area of the Hanford Site. DOE requested Washington State Department of Health approval to change the ambient air monitoring network for minor, diffuse, and fugitive sources at the 100-K Area.	D,P	G	Y,S, X	A,M	No	No
DOE/RL-2009-15	Rev. 1	2009 SEP	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2008 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operation*	This report discussed the groundwater remedial actions in the 100 Areas, including interim remedial actions at the 100-KR-4 OU. Summaries of pump and treat effectiveness and efficiency, aquifer effects, and general aquifer conditions in response to ongoing remedial actions are presented.	D,P	Z	Y	A	No	No
DOE/RL-2009-41	Rev. 0	2009 OCT	100-KR-1 100-KR-2 100-KR-4	*Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*	The SAP provided the RI/FS field investigation sampling and analysis requirements for the 100-K Area OUs	D,P	Z	Y	--	No	No
DOE/RL-2010-11	Rev. 1	2010 AUG	Hanford Site	*Hanford Site Groundwater Monitoring and Performance Report for 2009 Volumes 1 & 2*	This report presented the combined groundwater remedial actions for the Hanford Site at the 100-HR-3, 100-KR-4, 100-NR-2, 200-UP-1 and 200-ZP-1 OUs, with a presentation of groundwater monitoring results for calendar year 2009.	D,P	Z	Y	A	No	No
DOE/RL-2010-42	Rev. 0	2010 JUL	100-KR-2	*Remaining Sites Verification Package for the 100-KR-2 Operable Unit Waste Sites: 116-KE-6A, 116-KE-6B, 116-KE-6C, and 116-KE-6D, Documentation for Waste Site Reclassification Forms 2010-029, 2010-030, 2010-031, and 2010-032*	This remaining sites verification package (RSVP) summarized the completion or the remedial action performed on four waste sites in the 100-KR-2 OU. RTD of waste sites 116-KE-6A, 116-KE-6B3, 116-KE-6C, and 116-KE-6D, all components of the 1706-KE Waste Treatment System, was completed as a CERCLA action. The status of the four sites was changed to interim closed out.	D,H	G,C, E,T	Y	--	No	No
DOE/RL-2010-43	Rev. 1	2010 SEP	100-KR-2	*Remaining Sites Verification Package for the 100-KR-2 Operable Unit Waste Site: 100-K-4 Documentation for Waste Site Reclassification Form 2010-041*	This RSVP summarized the completion of the remedial action for the 100-K-4, 1706-KE Wet Fish Studies Ponds and Valve Pit. Completion of this remedial action provided the basis to change the status of the waste site to interim closed out.	D,H	G,C, E,T	Y	--	No	No
DOE/RL-2010-44	Rev. 0	2010 JUL	100-KR-2	*Remaining Sites Verification Package for the 100-KR-2 Operable Unit Waste Sites: 100-K-37 and 100-K-38 Documentation for Waste Site Reclassification Forms 2010-038 and 2010-039*	This RSVP summarized the completion of RTD for the 100-K-37, 1706-KE Sulfuric Acid Tank, 100-K-38, and the 1706-KE Caustic Soda Tank waste sites. Completion of this remedial action provided the basis to change the status of the waste sites to interim closed out.	D,H	G,C, E,T	Y		No	No
DOE/RL-2010-73	Draft B	2010 AUG	--	*100-K West Vadose Zone In Situ Bio-Infiltration Treatability Test Plan*	This document presented a treatability test plan for evaluating in situ bioremediation in the vadose zone at the 100-K West Area. The test was designed to determine if chemically reducing conditions suitable for remediating Cr(VI) contamination can be established by stimulating anaerobic microbes via infiltration of an organic nutrient solution from the ground surface.	D,P	G,Z,T	Y,S, X,P	A	No	No
DOE/RL-2011-25	Rev. 1	2011 JUN	100-HR-3 100-KR-4 100-NR-2	*Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*	This report discussed interim remedial actions at the 100-HR-3, 100-KR-4, and 100-NR-2 OUs. It included performance and compliance monitoring results.	D,P	Z	Y	A	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-89-12	Rev. 2	1995 JUL	Hanford Site	*Hanford Site Ground Water Protection Management Plan*	This report documented groundwater issues at the Hanford Site. It presented background information and groundwater status, and plans in place for water protection. It presented alternatives and goals to further this process and maintain standards.	D,H,P	G,Z,C	Y,S, X,P	M	No	Yes
DOE/RL-89-15	--	1990 JAN	Hanford Site	*Hanford Site Development Plan*	This plan was intended to guide short- and long-range development and use. All acquisition, development, and permanent facility use was to conform to the plan. The plan also served as the base document for subsequent facility use studies. The five major topics covered in the plan included general site information, existing conditions, planning analysis, the Master Plan, and the Five-Year Plan.	D,H,P	G,Z, C,T	S,X, P	A,M	Yes	Yes
DOE/RL-90-20	Rev. 0	1992 JUL	100-KR-1	*Remedial Investigation/Feasibility Study Work Plan for the 100-KR-1 Operable Unit, Hanford Site, Richland, Washington*	This work plan established the objectives, procedures, tasks, and schedule for conducting a CERCLA RI/FS for the 100-KR-1 OU. Groundwater, surface water, river sediment, and aquatic biota investigations for the 100-KR-1 OU were to be carried out per the 100-KR-1 work plan.	D,H,P	G,Z,E, C,T	Y,S, X	M	Yes	Yes
DOE/RL-90-21	Rev. 0	1992 SEP	100-KR-4	*Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington*	This work plan established the objectives, procedures, tasks, and schedule for conducting a CERCLA RI/FS for the 100-KR-4 OU. Groundwater, surface water, river sediment, and aquatic biota investigations for the 100-KR-4 OU were to be carried out per the 100-KR-4 work plan.	D,H,P	G,Z,E, C,T	Y,S, X	M	Yes	Yes
DOE/RL-92-12	Rev. 1	1992 MAY	100 Area	*Sampling and Analysis of 100 Area Springs*	This study was initiated in fulfillment of Tri-Party Agreement Milestone M-30-01 to evaluate impacts to the Columbia River from contaminated springs and seeps. This was done by confirming the concentrations of chemical and radiological constituents discharged through springs into the Columbia River. The 100 Area sites are included.	D,H	G,Z	Y,S, X	A,M	No	No
DOE/RL-92-28	Rev. 1	1994 MAR	100 Area	*Columbia River Impact Evaluation Plan*	The purpose of this plan was to satisfy Milestone M-30-02, which is to "Submit a plan (primary document) to EPA and the Washington State Department of Ecology to determine cumulative health and environmental impacts to the Columbia River, incorporating results obtained under M-30-01." The plan provided procedures and data quality objectives for the evaluation.	D,P	Z	Y,X	--	No	No
DOE/RL-93-19	--	1993 MAY	Hanford Site	*Hanford Site Development Plan*	The plan provided an overview of land use, infrastructure, and facility requirements to support DOE programs. The primary purpose was to inform senior managers and interested parties of development activities and issues that require a commitment of resources.	D, H	T	--	M	No	No
DOE/RL-93-78	Rev. 0	1994 AUG	100-KR-1	*Limited Field Investigation Report for the 100-KR-1 Operable Unit*	This report summarized the data collection and analysis activities conducted during the 100-KR-1 limited field investigation and the associated qualitative risk assessment (QRA). The report evaluated available information and provided the rationale to select sites for implementation of IRMs.	D,H,P	G,Z,E, T	Y,S, X	A,M	Yes	No
DOE/RL-93-79	Rev. 0	1994 JUL	100-KR-4	*Limited Field Investigation Report for 100-KR-4 Operable Unit*	This report summarized the data collection and analysis activities conducted during the 100-KR-4 limited field investigation. The report included a human health and ecological QRA. The report recommended continuation of IRM.	D,H,P	G,Z,E, T	Y,S, X	A	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-93-88	Rev. 0	1994 FEB	Hanford Site	*Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*	This report presented the annual hydrogeologic evaluation of 20 *Resource Conservation and Recovery Act of 1976* groundwater monitoring projects and one nonhazardous waste facility. It included an interpretation of groundwater data. Groundwater quality was also described for the 100, 200, 300, and 600 Areas and the Hanford Site. Contaminants included nitrate, chromium, carbon tetrachloride, tritium, and other radionuclides.	D,P	G,Z	Y,X, P	A	No	No
DOE/RL-94-113	Rev. 1	1995 SEP	100-KR-4	*Proposed Plan for Interim Remedial Measure at the 100-KR-4 Operable Unit*	This proposed plan introduced the preferred alternative for interim remedial action to address groundwater contamination at the 100-KR-4 OU. The plan also included a summary of other interim remedial alternatives analyzed for the 100-KR-4 OU.	D,H,P	Z,E	Y,S, X,P	--	Yes	Yes
DOE/RL-94-119	Rev. 1	1995 SEP	100-KR-1	*Proposed Plan for Interim Remedial Measure at 100-KR-1 Operable Unit*	This proposed plan identifies the preferred alternative for IRMs for remedial action of radioactive liquid waste disposal sites that include contaminated soils and structures at the 100-KR-1 OU. It also summarizes other remedial alternatives evaluated for IRMs.	D,P	Z,E	Y,S, X	--	Yes	Yes
DOE/RL-94-150	Rev. 0	1994 DEC	Hanford Site	*Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington*	The habitat used by the bald eagle and Peregrine falcon on the Hanford Site includes perch sites, night roosts, foraging areas, and nesting areas. The studies at the Hanford Site showed that use by bald eagles can occur virtually anywhere along the Columbia River.	D	C,E,T	--	--	No	No
DOE/RL-94-151	Rev. 0	1995 FEB	100-KR-2	*Approach and Plan for Cleanup Actions in the 100-KR-2 Operable Unit of Hanford Site*	The purposes for this plan was to describe the approach and activities needed to reach a cleanup action decision for the 100-KR-2 OU, and to invite public participation in the planning process.	D,P	Z	Y	M	Yes	Yes
DOE/RL-94-48	Rev. 0	1995 AUG	100-KR-4	*100-KR-4 Operable Unit Focused Feasibility Study*	This focused feasibility study (FFS) report presents a detailed analysis of alternatives for an IRM. The IRM addresses groundwater contamination in the 100-KR-4 OU. The FFS focused on chromium based on ecological receptor exposure.	D,H,P	G,Z,C, E,T	Y,S, X,P	A,M	Yes	Yes
DOE/RL-94-61	Rev. 0	1995 AUG	100-K	*100 Area Source Operable Unit Focused Feasibility Study*	This 100-KR-1 OU FFS evaluated remedial alternatives for interim action at high-priority waste sites in the 100 Area, including the 100-KR-1 and 100-KR-2 OUs, and provided information for selecting waste site interim actions. The FFS appendices presented the individual waste site information and development site profiles, identified representative individual waste site groups, comparison against applicability criteria, identified alternative enhancements, discussed alternative deviations, and presented detailed waste site analyses.	D,H,P	G,Z,E	Y,S, X	M	No	Yes
DOE/RL-94-66	Draft A	1994 NOV	100-KR-1	*100-KR-1 Operable Unit Focused Feasibility Study Report*	This FFS identified the remedial alternatives initially developed and screened in DOE/RL-92-11, *100 Area Feasibility Study Phases 1 and 2*.	D,H,P	E	Y,X	A,M	No	Yes

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-94-77	--	1994 AUG	Hanford Site	*Tritiated Wastewater Treatment and Disposal Evaluation for 1994*	This report presented the first response to Milestone M-26-05A, *Tritiated Wastewater Treatment Evaluation*. It included information, summaries, analyses, and discussions on aspects and issues for tritium. One well at the K Reactor area reported a tritium level of 1,690,000 pCi/L. The K groundwater tritium groundwater plume showed spreading to the east from the reactors and the river.	H	--	Y,X, P	A	Yes	No
DOE/RL-96-107	Rev. 0	1996 NOV	100-HR-3 100-KR-4	*Mitigation Action Plan for the 100-HR-3 and 100-KR-4 Pump and Treat Project*	The pump and treat projects involved drilling wells, improving access roads, laying connecting pipes, and constructing groundwater treatment facilities in the 100-KR-4 and 100-HR-3 OUs. This plan identified actions designed to minimize or lessen potential project impacts on cultural and natural resources.	D,H	E	--	A	Yes	Yes
DOE/RL-96-17	Rev.6	2009 SEP	100 Area	*Remedial Design Report Remedial Action Work Plan for 100 Area*	This document addressed the remedial designs and remedial actions for high-priority waste sites in the 100-B/C, 100-D, 100-H, 100-F, 100-K, 100-IU-2, and 100-IU-6 Areas. This document formed the basis for remedial actions at contaminated sites across the 100 Area.	D,H,P	G,Z, E,T	Y,S, P	A	Yes	Yes
DOE/RL-96-22	Rev. 5	2009 OCT	100 Area	*100 Area Remedial Action Sampling and Analysis Plan*	This SAP presented the rationale and strategies for the sampling, onsite measurements, and analyses that will be conducted during the remediation of the 100 Area waste sites. These waste sites are past-practice waste units located in the 100 Area OUs.	D,H,P	G,Z	Y,S, X,P	--	No	Yes
DOE/RL-96-44	Rev. 0	1996 NOV	100-HR-3 100-KR-4	*Treatment Plan for Protection of Cultural Resources for the 100-KR-4 Pump-and-Treat Project*	Interim remediation activities planned for the 100-K Area focused on protecting the Columbia River by pumping the chromium contaminated groundwater to a treatment system. The treated water will then be pumped back into the ground upstream of the trench. This document described modifications to the planned construction activities to protect cultural resources in the area.	D,H	E	Y,S, X	--	No	No
DOE/RL-96-84	Rev. 0	1996 SEP	100-HR-3 100-KR-4	*Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*	This document was a combination RDR/RAWP for the 100-HR-3 and 100-KR-4 OU's interim action. The interim action represented the first phase of an ongoing program to address groundwater contamination per the interim action ROD issued in April 1996. This document described the design basis, description of the interim action, and identified how the actions meet the requirements set forth in the interim action ROD.	D,P	G,Z,T	Y,S, X,P	A,M	Yes	Yes
DOE/RL-96-84	Rev. 0-A	2003 APR	100-HR-3 100-KR-4	*Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*	Revision 0-A updated the RDR/RAWP to include reporting requirements and an addendum with a summary of major system modifications since they came on line in 1997.	D,P	--	Y,X	--	No	No
DOE/RL-96-90	Rev. 0	1997 APR	100-HR-3 100-KR-4	*Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*	The monitoring plan presented the performance and compliance monitoring for the 100-HR-3 and 100-KR-4 OUs Cr(VI) groundwater interim action. The interim action was designed to meet the three remedial action objectives identified in the interim action ROD. The monitoring plan included the methods and procedures to meet interim action ROD requirements.	D,H	--	--	M	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-97-01	Rev. 0	1997 MAR	100-HR-3 100-KR-4	*Interim Action Waste Management Plan for the 100-HR-3 and 100-KR-4 Operable Units*	This interim action waste management plan established requirements for management and disposal of waste associated with the interim actions for the 100-HR-3 and 100-KR-4 OUs. The waste management plan identified waste streams, handling, and disposal methods to use.	D,P	Z	Y,X	M	No	No
DOE/RL-97-01	Rev. 6	2016 FEB	100-HR-3 100-KR-4	*Interim Action Waste Management Plan for the 100-HR-3 and 100-KR-4 Operable Units*	The interim action waste management plan was revised periodically between 1997 and 2016 to update and track the list of wells that were included in the interim action for the 100-HR-3 and 100-KR-4 OUs.	D,P	Z	Y,X	M	No	No
DOE/RL-97-1047	--	2002	Hanford Site	*History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990*	This book was prepared to preserve words, diagrams, and photographs of structures at the site during the Cold War because many may have been or will be demolished due to safety concerns and lack of future use.	D,H,P	G,E	Y,S, X	--	No	No
DOE/RL-97-83	Rev. 0	1998 OCT	100 Area	*Proposed Plan for Interim Remedial Actions at the 100 Area Remaining Sites*	This plan identified the preferred alternative for interim remedial actions at waste sites in the 100 Areas. The waste sites subject to this plan were included in the 100 Area Remaining Sites ROD.	D,P	Z	Y,X	--	Yes	Yes
DOE/RL-97-96	Rev. 0	1998 APR	100-HR-3 100-KR-4	*100-HR-3 and 100-KR-4 Operable Units Interim Action Performance Evaluation Report*	This report presented a summary and evaluation of the treatment process data, water level data, and hydrochemical data from 1997 to 1998 for the 100-HR-3 and 100-KR-4 OUs interim actions.	D,H,P	Z	Y,S, X,P	A/M	Yes	No
DOE/RL-98-03	--	1998 APR	Hanford Site	*Management and Integration of Hanford Site Groundwater and Vadose Zone Activities*	This document presented the integrated management approach for Phase I, development of the planning approach for management, and integration of the groundwater and vadose zone programs. The approach was needed to develop an effective site-wide strategy to assess the impacts of Hanford Site contaminants in the vadose zone and groundwater.	D,H,P	--	Y,S, P	A/M	Yes	No
DOE/RL-98-18	Rev. 1	2000 SEP	100 Area	*100 Area Burial Ground Focused Feasibility Study*	This FFS provided the results for an evaluation of alternatives for the remediation of 45 burial grounds located in the 100 Areas of the Hanford Site. Three remedial alternatives were developed and evaluated, including RTD, containment, and combined RTD/containment.	D,H,P	G,Z,C, E,T	Y,S, X	A,M	Yes	Yes
DOE/RL-99-12	Rev. 1	1999 APR	100-BC 100-D/H 100-K	*Sampling and Analysis Plan for Disposition of the Standing Legacy Wastes in the105-B, -D, -H, -KE, and -KW Reactor Buildings*	This SAP presented the rationale and strategy for the sampling and analysis activities that support disposition of legacy waste in the Hanford Site's 105-B, 105-D, 105-H, 105-KE, and 105-KW Reactor buildings. Legacy waste was identified as any item present in a facility not permanently attached to the facility and is easily removed without the aid of equipment larger than a standard forklift.	D,P	--	Y	M	No	No
DOE/RL-99-13	Rev. 0	1999 MAY	100-HR-3 100-KR-4	*Annual Summary Report, February to December 1998, for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and Operable Units*	This report discussed the interim remedial actions at the 100-HR-3 and 100-KR-4 OUs. It included performance and compliance monitoring results.	D,H,P	Z	Y,X	A,M	No	No
DOE/RL-99-58	Rev. 1	2003 FEB	100 Area	*Sampling and Analysis Plan for the 100/300 Area Remaining Sites*	This SAP presented the rationale and strategy for the sampling and analysis activities that support no action or RTD of waste sites. The SAP was prepared to support evaluation of 200 candidate waste sites included in the 100 Area remaining sites ROD. The purpose of the proposed sampling and analysis activities was characterization of waste sites that were candidates for clean site confirmation without remedial action.	D,H,P	G,Z	Y,S, X	M	No	No
DOE/RL-99-59	Rev. 1	2000 MAY	100 Area	*Proposed Plan for the 100 Area Burial Grounds Interim Remedial Action*	This proposed plan identified the preferred alternative for interim remedial action at 45 solid waste burial grounds located in the 100 Area source OUs and included summaries of other alternatives analyzed for burial grounds remediation.	D,P	E	Y	M	Yes	Yes

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOI: 10.2172/820366	--	2003 NOV	100-K 100-N	*Speciation, Mobility and Fate of Actinides in the Groundwater at the Hanford Site*	This project obtained field data on the chemical and physical forms of plutonium in groundwater at the Hanford Site. The focus was on the 100-K and 100-N Areas near the Columbia River, where prior reactor operations and waste storage was in close proximity to the river. The distribution and migration of actinides in groundwater were evaluated to enhance monitoring and clean up, and minimize risk.	H	G,Z	Y,S, X	A	No	No
DUN-3259	--	1967 OCT	100 Area	*Program Review—Ground Disposal of Reactor Effluent*	With the exception of the N Reactor, the plutonium production reactors operated by Douglas United Nuclear, Inc., used treated Columbia River water as coolant on a once-through basis. Radionuclides formed by neutron activation of Columbia River salts not removed in the water treatment process and water treatment additives are discharged to the river. Although, the quantity and possible effects of the radionuclides released were within accepted limits, emphasis was placed on reducing the releases to as low as possible. One alternative to reduce radionuclide content and heat load to the river was ground disposal of reactor effluent, either at ponds or trenches. This had already been tested at F and D Reactor Areas. This report proposed similar tests at the B, C, and K Areas.	D,H,P	Z	Y,P	M	Yes	Yes
DUN-7661	--	1971 MAY	100-K	*Reactor Plant Deactivation History 100-KE and K Plant*	This report described the main phases of the K Reactor plant deactivation programs, including post shutdown surveillance and maintenance action requirements. It also contained references to manuals, logs, letters, and other material with program details.	D,P	--	--	--	Yes	No
HNF-11208	Rev. 0	2002 JUL	100-K	*Sampling and Analysis Plan for Characterization of 105-K West Basin Wastewater*	This SAP presented the rationale and strategy for activities to support transfer of water from the 105-K West Basin via tanker truck to the Liquid Effluent Retention Facility/Effluent Treatment Facility. This SAP detailed the necessary steps to ensure that adequate information is obtained to meet applicable waste stream acceptance requirements.	D,P	Z	Y	M	No	No
HNF-11967	Rev. 0	2002 SEP	100-K	*Sampling and Analysis Plan for Characterization of 105-K East Basin Wastewater*	This SAP presented the rationale and strategy for activities to support transfer of water from the 105-K East Basin via tanker truck to the Liquid Effluent Retention Facility/Effluent Treatment Facility. This SAP detailed the necessary steps to ensure that adequate information is obtained to meet applicable waste stream acceptance requirements.	D,P	Z	Y	M	No	No
HNF-20896	Rev. 0	2004 AUG	100-K	*Remedial Design Report and Remedial Action Work Plan Supplement: K Basins Discharge Chute Grouting*	This document identified plans for the deactivation of the 105-K East and 105-K West discharge chutes to supplement the remedial actions identified in the RDR/RAWP for the K Basins Interim Remedial Action.	D,H,P	--	S,X	A	No	No
HNF-8918	Rev. 0	2001 DEC	100-K	*Sampling and Analysis Plan for Removal of Structures External to the 100 K Storage Basin*	This SAP presented the rationale for waste characterization and the strategy for sampling and analysis activities to support removal of structures and soil external to the K East and K West fuel transfer system buildings. The SAP identified characterization to support waste designation for disposal at an appropriate disposal facility.	D,H,P	G	Y	A	No	Yes
HNF-EDC-07-32909	Rev. 2	2007 MAY	105-K	*Sampling and Analysis Plan for the 105-K East Basin Monoliths*	This SAP provided a systematic process for defining criteria for a data collection design. It included descriptions of the processes to achieve end point criteria for sludge removal, encapsulate below water debris, and basin and pit removal as they relate to characterization of the basin pit monoliths, rubblized basin, and pits for disposal.	D,H,P	G,Z	Y	M	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
HW-60601	--	1959 JUN	Hanford Site	*Aquifer Characteristics and Ground-Water Movement at Hanford*	This report described the hydrological studies and tests at the Hanford Site to calculate aquifer hydraulic characteristics, determine the general directions and average rates of groundwater flow, identify factors that affect groundwater and waste movement, estimate a mean lateral path of potential groundwater contamination from disposal sites and the "time of travel" to the Columbia River, and indicate additional geological and hydrological information data needs.	D	D,G,T	--	--	No	No
HW-71061	--	1960 NOV	100-K	*Performance Characteristics Modified Low Lift Pumps 100-K Area*	The process water flow rates at the 100-K Reactors were increased from plant modifications under Project CGI-883. This document presented the results of an analytical study of the effluent system capabilities and set forth the additional design work to be performed in order to complete the detailed design of required alterations to the effluent system.	D,H	G	Y,S	A	Yes	No
HW-74075	--	1962 JUN	100-K	*Interim Report - C-14 in Reactor Effluents*	This study was conducted to determine the C-14 activity discharged to the environment from Hanford Site reactors. The results served as a basis for predicting the increase in C-14 activity released when a change is made in the reactor atmosphere composition. Since January 1961 the 105-KE Reactor was operating with a mixture of nitrogen and helium.	P	--	Y	--	No	No
HW-74095	Rev. 0	1963 APR	100-K	*Hazards Summary Report Volume 3 – Description of the 100-KE and the 100-KW Production Reactor Plants*	This report presented a physical description of the 100-KE and 100-KW production plants at the Hanford Site. The term "Production Reactor Plant" is defined as a Hanford Site production reactor plus its associated water supply and effluent water disposal facilities. This text provides a good description of the cooling and waste water systems as active in the early 1960s.	D,P	--	S,Y, X	--	No	No
HW-74095	Rev. 0	1963 JUN	100-K	*Hazards Summary Report Volume 1 Safety Analysis and Hazards Evaluation Hanford K Production Reactors*	This series of documents reviewed the status of reactors' safety and assessed the hazards associated with the operation of the two Hanford Site K Production Reactors. This report was limited to standard plutonium production reactor loading. Supplements to the Hazards Summary Reports covered hazards analyses applicable to other loading and operating techniques utilizing variations of the primary load.	D,P	--	S,Y, X	--	No	No
HW-74095	Rev. 0	1963 MAY	100-K	*Hazards Summary Report Volume 2 Process Control and Technical Data Hanford K Production Reactors*	This report was part of an overall Hazards Summary Report for the Hanford Site K Reactors. This volume examined the elements of reactor control, and provided the basic reactor physics and engineering data for the analysis of reactor control and safeguards.	D,P	--	S,Y, X	--	No	No
HW-74095, Supplement 2	Rev. 0	1965 JAN	100-K	*Hazards Summary Report Supplement 2 Supplemental Information in Support of Higher Power Levels at the K Reactors*	A supplement prepared to address operational changes considered in K Reactor plant operations. These are published accident analyses that addressed proposed changes to reactor operations, in this case higher graphite core temperatures. Cooling system capacity was a concern in all of the supplements and is a factor in accident analysis.	D,H,P	Z	Y,P	M	No	No
HW-75618	--	1962 NOV	100-K	*Release of Carbon-14 from the K-Reactor Stacks*	This investigation measured the difference in C-14 release when a reactor atmosphere used a coolant gas mixture of helium-nitrogen compared to a mixture of helium-carbon dioxide. Measurements showed the release of C-14 from the reactor stacks was about 2.8 times greater when nitrogen was substituted for carbon dioxide in the reactor atmosphere.	P	--	Y	--	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
HW-76784	--	1963 MAR	100-K	*Status Report Carbon-14 in the Condensate from the Silica Gel Dryers of the Production Reactors*	Volatile compounds containing C-14 produced in the cooling systems of Hanford Site reactors were lost from the cooling gas by escape via the reactor stacks through leaks in the cooling gas systems and by adsorption with water vapor on the silica gel of the dryers for the cooling gas, with subsequent regeneration of the silica gel and condensation of the water for disposal. The report provided data for the C-14 loss rates through the condensate obtained from regeneration of the silica gel dryers of the reactor gas cooling system.	D,P	--	S,Y, X	--	No	No
HW-77378	--	1963 APR	100-K	*Pressure and Flow Data PT IP-573-I, 100-K Flow Tests*	This report presented pressure and flow data results of emergency flow backup adequacy tests conducted at the K Reactors on February 16, 1963.	D,H	--	--	A	No	No
HW-77803	--	1963 JUN	100-K	*Design Bases, Bauxite-Sulfuric Acid Feed Facilities 100-K Area*	Criteria provided in this report delineated the objective, bases, and functional requirements that governed the preparation of detail design of the bauxite-sulfuric acid feed facilities installed in the 183-KE and KW Buildings. The document defined the process operational and technical requirements and outlined the functional requirements of the proposed facilities for the purpose of detail design. The criteria defined the requirements for a K Area water plant.	D,P	Z	--	A	No	No
HW-78770	--	1963 SEP	100-K	*Design Criteria: Bauxite-Sulfuric Acid Feed Facilities 100-K Area*	These criteria provided objectives, bases, and functional requirements governing preparation of design of the bauxite-sulfuric acid feed facilities installed in the 183-KE and KW Buildings. These facilities produced the chemical coagulant used in the treatment of Columbia River water in the K Area water plants and replaced the existing liquid alum feed systems.	D,H,P	Z	Y,P	M	No	No
HW-84569	--	1964 DEC	100 Area	*Report on Carbon-14 Generation and Release at Some of the Hanford Reactors*	This report answered questions for the generation and release of carbon-14 in the operation of graphite moderated reactors. The principle question was whether an increase in the nitrogen content of the reactor atmosphere increased the release of carbon-14 sufficiently to create a health hazard? Other questions were: • What are the main sources and the main release route? • How much does carbon-14 build up in the graphite in the reactor stack? • Is the total release of carbon-14 to the atmosphere sufficient to enhance the carbon-14 levels in the vegetation surrounding the reactors?	D,H,P	Z	Y,P	M	No	No
KBC-24414	Rev. 1	2005 MAY	100-KR-2	*Sampling and Analysis Plan for the 105-K East Basin Monoliths*	This SAP provided a systematic process for defining criteria for a data collection design. It included descriptions of the processes to achieve end point criteria for sludge removal, encapsulate below water debris, and basin and pit removal as they relate to characterization of the basin pit monoliths, rubblized basin, and pits for disposal.	D	--	Y, S	A	Yes	No
KBC-24706	Rev. D	2006 MAY	100-KR-2	*Sampling and Analysis Plan for 105-K East Basin Sand Filter Monolith*	The 105-KE Basin sand filter and the surrounding vault were removed as necessary components in implementing Milestone M-034-32 (Complete Removal of the K East Basin Structure). This document specified the data, data quality control, and data management to dispose of the sand filter monolith as low-level waste at ERDF.	D,H,P	--	--	M	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
KBC-27149	Rev. B	2006 APR	100-KR-2	*Sampling and Analysis Plan for 105-K East and West Basins Wastewater*	This SAP presented the rationale and strategy for sampling and analysis activities to support wastewater transfer from the 105-KW and 105-KE Basins via tanker truck to the Liquid Effluent Retention Facility/Effluent Treatment Facility. This SAP was used for routine K Basins water sampling and analyses associated with maintenance operations and to facilitate future hose-in-hose transfer and K Basins decontamination and decommissioning closure activities.	D,P	--	Y	M	No	No
KBC-28343	Rev. 1	2006 JAN	100-KR-2	*Disposal of K Basin Ion Exchange Column Evaluation*	This document demonstrated the need for waste stabilization, and that stabilized waste was acceptable for disposal at ERDF. The K Basins Closure Project had six spent ion exchange columns in the 105-K E Basin that had high dose rates.	D	--	Y	A	No	No
OSR-2008-0003	Rev. 0	2009 MAR	100-K	*100-K Area Orphan Sites Evaluation Report*	This report summarized the approach and results obtained from the orphan sites evaluation of the 100-K Area, conducted from January, 2007 through August, 2008. The orphan sites evaluation process is a systematic approach to review land parcels and identify potential waste sites that were not listed in existing CERCLA decision documents. Evaluations included document, drawing, map, and photograph reviews, interviews, field investigations, and geophysical surveys.	D,H	G	--	--	Yes	No
PNL-10195	--	1994 NOV	Hanford Site	*Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System: FY 1994 Status Report*	This report provided an update on the development of a three-dimensional conceptual model of groundwater flow in the unconfined aquifer system at the Hanford Site. The conceptual model provided a basis for three-dimensional numerical modeling and enabled better understanding and more accurate predictions of contaminant transport under changing site conditions.	D	G,Z	--	A,M	No	No
PNL-10398	--	1995 JAN	100-KR-2	*K Basin Spent Fuel Sludge Treatment Alternatives Study, Volume I - Regulatory Options*	This report assessed technical and regulatory options for managing sludge, including schedule and cost impacts, and presented strategies to establish a preferred path. The information provided was intended to assist in developing a sludge management approach.	D,P	--	Y,X	--	No	Yes
PNL-10398	--	1995 JAN	100-KR-2	*K Basin Spent Fuel Sludge Treatment Alternatives Study, Volume II Technical Options*	This report examined options for cleanup of the FSBs in the 100-K Area. This report evaluated maintaining the classification of the sludge as spent nuclear fuel until the fuel and other sludge components are separated in terms of cost, schedule, and technical risk.	D,P	--	Y,X	--	No	Yes
PNL-3127	--	1980 APR	100 Area	*Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence*	This document described radiological survey results that evaluated the magnitude and distribution of radioactive contamination on the exposed shorelines of the Columbia River, along and downstream of the Hanford Site. Areas considered in the survey included the riverbank, broad flood plains, low lying peninsulas, sloughs and islands from the uppermost point of production reactor discharge at the 100-B Area to the confluence of the Snake and Columbia Rivers.	D,H,P	G,Z,T	Y,S, X	A	No	No
PNL-5407 PNL-5817 PNL-6120 PNL-6464	--	1985 to 1988	Hanford Site	*Environmental Monitoring at Hanford for 1984* *Environmental Monitoring at Hanford for 1985* *Environmental Monitoring at Hanford for 1986* *Environmental Monitoring at Hanford for 1987*	These reports presented results and effects from surveillance activities, media samples collected, and radionuclide concentrations.	D,H,P	G,Z,E, C,T	Y,X	A	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNL-7500	--	1990 DEC	Hanford Site	*1988 Hanford Riverbank Springs Characterization Report*	This report presented results of a study performed by the Surface Environmental Monitoring Project to investigate the radiological and nonradiological characteristics of the riverbank springs entering the Columbia River along the Hanford Site shoreline.	D,P	Z	Y,S, X,P	A	Yes	No
PNL-8073	--	1992 JUN	Hanford Site	*Hanford Site Ground-Water Monitoring for 1990*	This report discussed results of groundwater monitoring at the Hanford Site during 1990. Topics discussed included: • Carbon tetrachloride in the 200 West Area • Cyanide in and north of the 200 East and the 200 West Areas • Cr(VI) contamination in the 100, 200, and 600 Areas • Trichloroethene near the solid waste landfill, 100-F Area, and 300 Area • Nitrate across the Hanford Site • Tritium across the Hanford Site • Other radionuclide contamination across the Hanford Site	D,P	--	Y,S, X,P	A	No	No
PNL-8284	--	1992 OCT	Hanford Site	*Hanford Site Ground-Water Monitoring for 1991*	This report discussed results of groundwater monitoring at the Hanford Site during 1991.	D,P	G,Z	Y,S, X,P	A,M	Yes	Yes
PNL-8819	--	1993 SEP	100 Area	*Fiscal Year 1992 Report on Archaeological Surveys of the 100 Areas, Hanford Site, Washington*	The report presented results from the fiscal year 1992 field survey of the 100-HR-3 OU and excavation at three sites near the 100-F and 100-K Reactors to determine their eligibility for listing on the National Register of Historic Places.	D,H	G,E,T	--	A	No	Yes
PNL-8916	--	1993 OCT	Hanford Site	*A Preliminary Survey of Selected Structures on the Hanford Site for Townsend`s Big-Eared Bat (Plecotus townsendii)*	This report presented results from the survey of structures on the Hanford Site for Townsend`s big-eared bat (*Plecotus townsendii*). The report identified buildings in the 100-D and 100-K Areas, canyon buildings in the 200 Areas, and other structures reported to contain bats.	D	G,E	--	--	No	No
PNL-9437	--	1994 APR	100 Area	*Monitoring Groundwater and River Interaction Along the Hanford Reach of the Columbia River*	This report presented results from an automatic monitoring network used to measure Columbia River and adjacent groundwater levels in several areas of the Hanford Site since 1991. Water level, temperature, and electrical conductivity were measured to provide an initial database to calibrate models and infer groundwater and river water interactions for site characterization and remediation activities. This report described the equipment, procedures, and results from 1993 measurements.	D,H,P	Z,T	S,X	A	No	No
PNL-SA-16118	--	1990 NOV	100-HR-3 100-KR-4 100-NR-2	*Strontium-90 in Canada Goose Eggshells and Reed Canary Grass from the Columbia River, Washington*	Strontium-90 released to the ground near the N Reactor at the Hanford Site enters the Columbia River through shoreline seeps. The strontium-90 is then potentially available for uptake by plants and animals. The life history and foraging behavior of nesting Canada geese is such that female geese could ingest strontium-90 while foraging on shoreline plants. This report presented results from radiochemical analyses that indicated a relationship between releases of strontium-90 to the Columbia River and enhanced levels in some environmental samples.	D	E	Y,X	A	No	No
PNNL-11989	Rev. 1	1999 SEP	Hanford Site	*Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project*	This monitoring plan was developed to implement monitoring at the Hanford Site to fulfill *Atomic Energy Act of 1954* (AEA) requirements. It documents well and constituent lists and implementing orders, includes other established monitoring plans by reference, and appends a master well/constituent/frequency matrix.	D,H, P	G,Z, E,T	Y,S, P	A	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-12023	--	1998 OCT	100-K	*Groundwater Monitoring for the 100-K Area Fuel-Storage Basins: July 1996 through April 1998*	This report presented results of groundwater monitoring and summarized interpretations of conditions influencing groundwater quality and flow in the 100-K Area. The interpretations used previous work and statistical evaluations of contaminant concentrations between July 1996 and April 1998. No new basin leaks were indicated by the data.	D,H,P	G,Z,C	Y,S, X	A,M	No	No
PNNL-12086	--	1999 MAR	100-K	*Hanford Site Groundwater Monitoring for Fiscal Year 1998*	This report presented the results of groundwater, vadose zone monitoring, and remediation.	D,H,P	G,Z,E	Y,S, X,P	A/M	Yes	No
PNNL-12087 PNNL-13117 PNNL-13469 PNNL-13859 PNNL-14242 PNNL-14616 PNNL-15160	--	1998 to 2004	Hanford Site	*Hanford Site Climatological Data Summary 1998 with Historical Data* *Hanford Site Climatological Data Summary 1999 with Historical Data* *Hanford Site Climatological Data Summary 2000 with Historical Data* *Hanford Site Climatological Data Summary 2001 with Historical Data* *Hanford Site Climatological Data Summary 2002 with Historical Data* *Hanford Site Climatological Data Summary 2003 with Historical Data* *Hanford Site Climatological Data Summary 2004 with Historical Data*	These reports presented climatological data summaries from 30 monitoring stations located within and near the Hanford Site.	D	E	--	--	No	No
PNNL-13116	--	2000 MAR	Hanford Site	*Hanford Site Groundwater Monitoring for Fiscal Year 1999*	This report presented results of groundwater, vadose zone monitoring, and remediation for fiscal year 1999.	D,H,P	G,Z, E,T	Y,S, X,P	A,M	Yes	Yes
PNNL-13217	--	2000 JUN	100-K	*Measurement of Tritium in Gas Phase Soil Moisture and Helium-3 in Soil Gas at the Hanford Townsite and 100 K Area*	This report presented results from a soil gas survey for helium-3 at the Hanford Townsite and the 100-K Area. No detectable tritium (<240 pCi/L) was found in the soil moisture samples from either location. The results suggested that a major tritium plume did not lie within the 100-K study area and recommended that the study be continued by placing additional soil gas sampling points along the perimeter road to the west and to the south of the initial study area.	D,H	G,Z	Y,S, X,P	A	No	No
PNNL-13698	--	2001 OCT	Hanford Site	*FY 2002 Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project*	This monitoring plan was developed to implement monitoring at the Hanford Site to fulfill AEA requirements. It documented well and constituent lists and implementing orders, included other monitoring plans by reference, and appended a master well/constituent/frequency matrix.	D,H	Z,E,T	S,X, P	A	No	No
PNNL-13788	--	2002 MAR	Hanford Site	*Hanford Site Groundwater Monitoring Fiscal Year 2001*	This report summarized annual groundwater, vadose zone monitoring, and remediation results.	D,P	G,Z	Y,S, X	A,M	Yes	No
PNNL-13910	--	2002 SEP	Hanford Site	*Hanford Site Environmental Report for Calendar Year 2001*	This report summarized: 1. The Hanford Site and its mission 2. Hanford Site environmental programs 3. Estimated radionuclide exposures to the public from Hanford Site activities 4. Status of compliance with the Hanford Site's environmental regulations 5. Information on environmental monitoring, surveillance, groundwater protection, and monitoring	D,H,P	Z,C, E, T	Y,S, X, P	A,M	Yes	Yes

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-14031	--	2002 SEP	100-KR-2 100-KR-4	*Evaluation of Potential Sources for Tritium Detected in Groundwater at Well 199-K-111A, 100-K Area*	This report presented results from soil gas samples and additional hydraulic parameters to evaluate the 100-K Burial Ground as a tritium source. The results did not provide conclusive results that the burial ground was the source of increasing tritium in well 199-K-111A.	D	--	Y,S, X	--	No	Yes
PNNL-14031	--	2002 SEP	100-K	*Evaluation of Potential Sources for Tritium Detected in Groundwater at Well 199-K-111A, 100-K Area*	This report summarized results from several investigations during fall 2001 on a possible source for tritium observed in groundwater at well 199-K-111A. Results included groundwater flow direction and gradient analysis, soil gas from previously installed sample tubes, and modeling the buildup of a groundwater mound beneath the interim remedial action injection site. The results did not provide conclusive results that the burial ground was the source of increasing tritium in well 199-K-111A.	D,H,P	G	Y,X, P	A	Yes	Yes
PNNL-14033	Rev. 0	2002 SEP	100-KR-4	*Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins*	This monitoring plan presented sampling and analysis, data interpretation, and reporting requirements for groundwater near the KE and KW FSBs.	D,H,P	G,Z,E, T	S,X, P,A	A	Yes	No
PNNL-14111	--	2002 NOV	Hanford Site	*Fiscal Year 2003 Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project*	This monitoring plan was developed to implement monitoring at the Hanford Site to fulfill AEA requirements. It documented well and constituent lists and implementing orders, included other monitoring plans by reference, and appended a master well/constituent/frequency matrix.	D,P	G,Z,T	Y,X, P	A,M	No	No
PNNL-14187	--	2003 MAR	Hanford Site	*Hanford Site Groundwater Monitoring for Fiscal Year 2002*	This report summarized annual groundwater, vadose zone monitoring, and remediation results.	D,H,P	T	Y,S, X,P	A,M	Yes	Yes
PNNL-14295	--	2003 SEP	Hanford Site	*Hanford Site Environmental Report for Calendar Year 2002*	This report summarized: 1. The Hanford Site and its mission 2. Hanford Site environmental programs 3. Estimated radionuclide exposures to the public from Hanford Site activities 4. Status of compliance with the Hanford Site's environmental regulations 5. Information on environmental monitoring, surveillance, groundwater protection, and monitoring	D,H,P	G,Z, C,E	Y,S, X,P	A,M	Yes	Yes
PNNL-14444	--	2003 OCT	Hanford Site	*Aquifer Sampling Tube Results for Fiscal Year 2003*	This report presented and discussed aquifer tube sampling results.	D,H,P	T	Y,S, X,P	A,M	Yes	Yes
PNNL-14548	--	2004 MAR	Hanford Site	*Hanford Site Groundwater Monitoring for Fiscal Year 2003*	This report summarized annual groundwater, vadose zone monitoring, and remediation results.	D,P	G,Z,E	Y,X, P	A,M	No	No
PNNL-15176	--	2005 JUN	Hanford Site	*Fiscal Year 2005 Integrated Monitoring Plan for the Hanford Groundwater Performance Assessment Project*	This report presented the groundwater project monitoring objectives combined into a single sampling schedule to improve sample collection efficiency.	D,P	Z,T	Y,S, P	A,M	No	No
PNNL-15670	--	2006 FEB	Hanford Site	*Hanford Site Groundwater Monitoring for Fiscal Year 2005*	This report summarized annual groundwater, vadose zone monitoring, and remediation results.	D,H,P	G,Z,E	Y,S, X,P	A/M	Yes	No
PNNL-16760	--	2007 SEP	100 Areas	*Review of Techniques to Characterize the Distribution of Chromate Contamination in the Vadose Zone of the 100 Areas at the Hanford Site*	This report identified and evaluated techniques for characterization of chromate contamination in the vadose zone. The information was used to assess potential chromate contamination sources.	P	--	Y,S, P	A	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-17674	--	2008 JULY	100 Areas	*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*	This study identified Cr(VI) leaching characteristics from contaminated sediments collected from 100 Area spill sites; possible Cr(VI) mineral and chemical associations through the use of macroscopic leaching studies; microscale characterization of contaminated sediments; and provided information to construct a conceptual model of Cr(VI) vadose zone geochemistry.	D,H,Z	G,Z	Y,P	A,M	No	Yes
PNNL-17865	--	2011 JAN	100 Areas	*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site: Part 2*	This report identified processes for chemical reactions and hydrogeologic processes that control or affect Cr(VI) interactions with sediments during movement through the vadose zone. Processes included sorbtion to mineral surfaces, precipitation in mineral phases with varying stability, and reduction to Cr(III). An estimation of the extent and rates of these reactions and processes was required to understand Cr(VI) vadose zone geochemistry.	D,P	Z	Y,X	A,M	No	No
RHO-BWI-ST-5	--	1979 OCT	Hanford Site	*Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge*	The Basalt Waste Isolation Project evaluated the feasibility of storing radioactive waste within Columbia River basalt. Hydrologic studies were one of the principal research activities for the Basalt Waste Isolation Project. Study objectives included evaluation of the hydrologic systems within the Columbia River basalt significant to the possible siting of a repository. This report summarized the data and interpretations regarding Pasco Basin hydrology.	D,T,Z	D,T,Z	--	--	No	No
SD-SNF-ES-002	Rev. 0	1994 SEP	100-K	*Engineering Study 105KE to 105KW Basin Fuel and Sludge Transfer*	This engineering study was performed to identify and recommend the most feasible and practical method of transferring canisters of irradiated fuel and basin sludge from the 1061-KE FSB (HE Basin) to the 105-KW FSB (KW Basin). Six alternatives were identified during the performance of this study as possible methods for transferring the fuel and sludge from the KE Basin to the KW Basin.	D,P	E	Y	A	Yes	Yes
SD-SNF-ES-005	Rev. 0	1994 OCT	100-K	*Options for Disposition of KE-Basin Water*	This work is to present K-Basin water treatment options for planning purposes that supported changes to the physical plant. (e.g., the construction joint isolation barrier) and to project planning for removal of the fuel and sludge from the basins.	D,P	Z	Y	A	No	Yes
SD-SNF-PD-007	Rev. 0	1994 OCT	100-K	*Schedule for Final Disposition of Contaminated K-East Basin Water*	This document provided a recommended schedule describing the activities for the final disposition of contaminated KE Basin water. The goal was to move the fuel, sludge and water from the K Basins and relocate it away from the Columbia River pending disposal.	D,P	--	--	A	No	Yes
SGW-40896	Rev. 1	2010 AUG	100-KR-1 100-KR-2	*Air Monitoring Plan for Waste Site Remediation in the 100-K Area*	This document supported the 100 Area RDR/RAWP (DOE/RL-96-17) for remediation of the K Area waste sites. It provided information on radiological air emissions, criteria/toxic air emissions, radiological airborne source information, emission controls, and monitoring.	D,P	G	Y,X	--	No	No
SGW-41213	Rev. 0	2009 AUG	100-KR-4	*100-KR-4 Remedial Process Optimization Modeling Data Package*	This report provided details on model development and assignment of parameter values, including the types and sources of information used to support model development, and application of the model in the evaluation of the remedy expansion alternatives for the 100-KR-4 OU.	D,H,P	G,Z,T	Y,S, X,P	A,M	No	No
SGW-42305	Rev. 0	2009 NOV	100-KR-4 200-ZP-1	*Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*	This document described a method for preparing groundwater-level maps to improve inference estimating the extent of hydraulic capture developed by groundwater pump and treat remedies.	D,P	H	--	A,M	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
SGW-44686	Rev. 0	2010 AUG	100-KR-4	*Description of Work for Aquifer Testing at Extraction Well 199-K-178*	This description of work was for a pumping test at extraction well 199-K-178. This test was performed following connection to the KX pump and treat system. The test measured aquifer properties in and around well 199-K-178 and provided data for modeling Cr(VI) capture.	D	Z	Y,P	M	No	No
SGW-47256	Rev. 0	2010 MAY	100-KR-2	*100-K-63 Waste Site GIS Fill Analysis Report*	Remediation was planned for waste site 100-K-63 located on the KW Reactor floodplain. The area was posted for underground radioactive material and soil contamination. Remediation was to include the removal of up to 4.6 m (15 ft) of contaminated material. Since this area is adjacent to the Columbia River, and had high cultural resource sensitivity, it was imperative to ensure that project activities did not affect potential cultural resources under fill material. A geographic information system analysis of the waste site was conducted to identify the extent of earthwork.	D,H	G,T	Y	A	No	No
TPA-CN-273	--	2009 MAY	100-HR-3 100-KR-4	*Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2006-75 Rev. 1, Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System*	Change notice to the RDR/RAWP list of wells associated with the KR4 and KX well networks. It identified changes to groundwater monitoring requirements for wells and the flow rates for wells connected to the pump and treat systems.	--	--	Y	M	No	No
TPA-CN-357	--	2010 MAY	100-KR-4	*Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study, DOE/RL-2009-41, Rev. 0*	Change notice addressed relocating a proposed well from a culturally sensitive area, expanding vadose zone soil sampling for seven wells near the 100-K Reactor Area, adjusting well design for a waste site remediation and building demolition area, and revising an analytical reporting list to coincide with other RI/FS SAPs.	D,P	Z	Y	A	No	No
TPA-CN-359	--	2010 OCT	100-KR-4	*Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE-RL-2006-75, Rev. 1, Reissue Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System (As amended by TPA-CN-273, May 20, 2009).* *DOE-RL-2006-52. Rev. 2, The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action, October 2009*	Change notice that revised DOE/RL-2006-75, Rev. 1 (as amended by TPA-CN-273), and DOE/RL-2006-52. Rev. 2, to add new wells to the KR-4 pump and treat systems and realign existing wells to target treatment of higher Cr(VI) contamination in 2010.	D	--	Y	A	No	No
UNI-3714	Rev. 1	1987 APR	100 Area	*Radionuclide Inventory and Source Terms for the Surplus Production Reactors at Hanford*	This document estimated inventories of radionuclides and other hazardous materials in the eight reactor buildings. This information supported preparation of an EIS for the final decommissioning of these facilities.	D,H,P	--	Y,S	A	No	No
WCH-201	Rev. 0	2007 OCT	100 Areas	*Columbia River Component Data Gap Analysis*	This data gap analysis report documented the results of a study to compile and review the currently available surface water and sediment data for the Columbia River near and downstream of the Hanford Site. The data gap analysis study was conducted to review the adequacy of the existing surface water and sediment data set from the Columbia River, with specific reference to the use of the data in future site characterization and screening level risk assessments. The goal was to determine if there are sufficient data to characterize the current effects of Hanford Site operations on the Columbia River. The specific technical objective of this effort was the identification of spatial, temporal, or analytical data gaps.	D,H,P	G,Z, E, T	Y,S, R	A,	Yes	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
WHC-EP-0258-2	--	1992 MAY	100 Area	*Westinghouse Hanford Company Environmental Surveillance Annual Report--100 Areas, Calendar Year 1990*	This report presented results of the near-field environmental surveillance program for the Hanford Site 100 Areas. The environmental surveillance program provides sampling and monitoring of parameters to evaluate the environmental impact of 100-N Area Reactor Facilities and the shutdown reactor facilities and burial grounds in the retired 100 Areas.	D,P	E	Y,S, X	A	Yes	No
WHC-EP-0394-10	--	1995 JUN	Hanford Site	*Groundwater Maps of Hanford Site, December 1994*	This is a continuation of a series of reports that documented the configuration of the uppermost unconfined aquifer beneath the Hanford Site. This series presented results of the semiannual water level measurement program and water table maps generated from these measurements. The reports document the changes in the groundwater level at the Hanford Site during the transition from nuclear material production to environmental restoration and remediation. In addition, these reports provided water level data to support the various site characterization and groundwater monitoring programs on the Hanford Site.	D	--	--	--	No	No
WHC-EP-0394-5	--	1992 DEC	Hanford Site	*Groundwater Maps of Hanford Site, June 1992*	This is a continuation of a series of reports that documented the configuration of the uppermost unconfined aquifer beneath the Hanford Site. This series presented results of the semiannual water level measurement program and water table maps generated from these measurements. The reports document the changes in the groundwater level at the Hanford Site during the transition from nuclear material production to environmental restoration and remediation. In addition, these reports provided water level data to support the various site characterization and groundwater monitoring programs on the Hanford Site.	D	--	--	--	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
WHC-EP-0394-6	--	1993 SEP	Hanford Site	*Groundwater Maps of Hanford Site, December 1992*	This is a continuation of a series of reports that documented the configuration of the uppermost unconfined aquifer beneath the Hanford Site. This series presented results of the semiannual water level measurement program and water table maps generated from these measurements. The reports document the changes in the groundwater level at the Hanford Site during the transition from nuclear material production to environmental restoration and remediation. In addition, these reports provided water level data to support the various site characterization and groundwater monitoring programs on the Hanford Site.	D	--	--	--	No	No
WHC-EP-0394-7	--	1994 FEB	Hanford Site	*Groundwater Maps of the Hanford Site, June 1993*	This is a continuation of a series of reports that documented the configuration of the uppermost unconfined aquifer beneath the Hanford Site. This series presented results of the semiannual water level measurement program and water table maps generated from these measurements. The reports document the changes in the groundwater level at the Hanford Site during the transition from nuclear material production to environmental restoration and remediation. In addition, these reports provided water level data to support the various site characterization and groundwater monitoring programs on the Hanford Site.	D	--	--	--	No	No
WHC-EP-0497	--	1991 NOV	100-K	*Facility Effluent Monitoring Plan for K Area Fuel Storage Basins*	This plan consisted of a Facility Effluent Monitoring Plan (FEMP) and an environmental surveillance plan. The facilities in the 100-K Area release radionuclides to the environment and require a FEMP. This FEMP for the 100-K Area was prepared to ensure that releases are monitored, the quantities measured, and the impacts to the public are evaluated. The K Area FEMP determination evaluated the gaseous emissions and liquid effluent of 105-KE and 105-KW FSBs, 1706-KE Environmental and Engineering Demonstration Laboratory (1706-KEL), and the 1706-KE Water Studies Recirculation Building (1706-KER) and determined the potential annual radiation exposure to the maximally exposed individual offsite. This evaluation determined airborne emission and liquid effluent monitoring requirements.	D,P	--	Y,S, X	A	No	Yes
WHC-EP-0909	--	1996 JUL	100-KE	*Feasibility Study 100 K East Area Water Purification Pools Fish-Rearing Program*	As part of the feasibility study, a design analysis was conducted to determine the usefulness of the existing sand filters and associated media for reuse. The sand filters were located on the northern end of the 100-K East Area water filtration plant. The water that circulated through the water purification pools (K pools) and associated sand filters was clean river water, so there was little chance of radioactive structure contamination. Separate K pools were previously used for raising a variety of cold water fish species, as well as for providing potable water to the 100-K Area for fire and service water.	D,P	G,Z,C	Y,S	A	No	No
WHC-MR-0170	NA	1990 JUN	100-K	*Environmental Impact of KE Basin Operation*	Environmental & Occupational Safety summarized the environmental impact of operation of the KE FSB evaluations. This report provided a synopsis of these evaluations.	D, H, P	G, Z	Y	A	No	No
WHC-SD-EN-AP-082	Rev. 2	1992 JUL	100-KR-4	*Description of Work for the 100-KR-4 Groundwater Operable Unit*	This description of work detailed the field activities associated with cable-tool drilling of groundwater wells in the 100-KR-4 OU and served as a field guide for performing the work.	D	G	--	--	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
WHC-SD-EN-AP-083	Rev. 1	1992 SEP	100-KR-1	*Description of Work for Vadose Drilling in the 100-KR-1 Operable Unit*	This description of work detailed the field activities associated with cable-tool drilling of four vadose boreholes and backhoe excavation of four test pits in the 100-KR-1 OU and served as a field guide for performing the work.	D	G	--	--	No	No
WHC-SD-EN-AP-153	Rev. 1	1994 MAY	100-K	*Installation of Groundwater Monitoring Wells in Support of the 100-K Area Fuel Storage Basins*	This plan described a program to enhance groundwater monitoring capabilities around the 100-K Area FSBs. The plan provided background information on groundwater monitoring and described installation of three new wells at the KW Basin. The installation of three additional new wells near the KE Basin was included in this revision.	D,P	G,Z,T	--	A	No	No
WHC-SD-EN-AP-174	Rev. 0	1995 SEP	100-K	*Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins*	This plan identified monitoring requirements for compliance with DOE requirements for nuclear fuel and waste storage facilities. This plan described the portion of the environmental monitoring program whose goals are to monitor the influence of current operations at the KE and KW FSBs on groundwater quality and to assess its environmental and public health significance.	D,P	G,Z,T	Y,S, X,P	A,M	No	Yes
WHC-SD-EN-DP-090	Rev. 0	1994 DEC	100-K	*Borehole Data Package for 100-K Area Groundwater Wells, CY 1994*	This data package compiles data and information on well drilling, construction, development, and borehole hydrogeologic characterization. The report includes forms, notes, and diagrams completed in the field.	D	G,Z	--	--	No	No
WHC-SD-EN-RA-009	Rev. 0	1994 AUG	100-KR-1	*Qualitative Risk Assessment for the 100-KR-1 Source Operable Unit*	This QRA for the 100-KR-1 OU focused on exposure scenarios to provide information in IRM decisions. It included an evaluation of the data sources and process information, identification of maximum constituent concentrations, a human health risk evaluation, and an ecological risk evaluation.	D,H,P	E	Y,S, X	A,	Yes	No
WHC-SD-EN-RA-010	Rev. 0	1994 JUN	100-KR-4	*Qualitative Risk Assessment for the 100-KR-4 Groundwater Operable Unit*	This QRA evaluated risk using a limited amount of data and a predefined set of human and environmental exposure scenarios.	D,H,P	Z,E	Y,X	A	Yes	No
WHC-SD-EN-SAD-002	Rev. 0	1991 SEP	100 Area	*100 Area Low Hazard Characterization Activities Safety Assessment*	This safety assessment documented the analysis of hazards and concluded the activity did not present an unacceptable hazard to the three receptor groups of concern: the facility worker, the onsite person located 100 m (330 ft) from the activity, or the offsite individual.	D,H,P	G,Z, C,T	Y,S, X	A,M	Yes	No
WHC-SD-EN-SAD-027	Rev. 0	1994 APR	100-BC 100-F 100-K	*Safety Assessment for Decontamination and Dismantlement of 107-C, 107-KE, 107-KW, and 107-F Retention Basins*	This document provided a safety assessment of potential hazards associated with the decontamination and dismantlement of the 107-C, 107-KE, 107-KW, and 107-F retention basins. The basins stored reactor cooling water discharged during operation. Large volumes of water, contaminated with radioactive nuclides and chemicals, were stored in the basins before discharge to the Columbia River or cribs. The structures deteriorated after shutdown and contaminants were detected.	D,P	G,Z,C	Y,S, X	A	Yes	No
WHC-SD-EN-TI-006	Rev. 0	1992 MAR	Hanford Site	*Hydrologic and Geologic Data Available for the Region North of Gable Mountain, Hanford Site, Washington*	This report contained an inventory of available information on existing wells, hydrology, and geology. It was intended as a reference document to describe the available data, when data were collected, and how the data can be accessed. It was designed as a supplement to other reports that evaluate existing information relative to past-practices objectives.	D	G,Z,T	--	A	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
WHC-SD-EN-TI-011	Rev. 0	1992 MAR	100 Area	*Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas*	This report outlined the types of geologic data for the Hanford Site north of the Gable Mountain anticline and where this data is available. Preliminary geologic interpretations were presented for 100-BC and 100-K, 100-N and 100-D, 100-H, and 100-F. This report included a brief discussion of regional geology to provide geologic context.	D	G,Z,T	--	A	No	No
WHC-SD-EN-TI-056	Rev. 0	1992 NOV	100-K	*100-KR-4 Columbia River Shoreline Radiological Survey*	This report summarized results of radiological surveys of the Columbia River shoreline area at 100-K. The 100-KR-4 radiological survey field task included characterization of the OU-specific background conditions and radiological survey of the shoreline.	D	G,Z	Y	A	No	No
WHC-SD-EN-TI-095	Rev. 0	1993 JAN	100-K	*Ground Penetrating Radar Investigation for Proposed Borehole, 116- KW-3A, 100-K Area*	This survey was conducted to locate subsurface obstructions affecting drilling of borehole 116-KW-3A. The proposed location was in a radiological controlled area designated corridor within a surface contaminated area. The results of the survey identified possible drill sites with the least likelihood of encountering obstructions.	D	--	--	A	No	No
WHC-SD-EN-TI-155	Rev. 0	1993 JUN	100-K	*Geology of 100-K Area, Hanford Site, South-Central Washington*	The report discussed the geologic setting of the 100-K Area and vicinity. The discussion was based on data from drilling activities, older projects, area boreholes and analogous geologic units analysis. The report included a brief review of the regional setting and a detailed discussion of the 100-K Area geology.	D	G,Z,T	--	A	No	No
WHC-SD-EN-TI-204	Rev. 0	1994 SEP	100 Area	*Ground-Penetrating Radar Investigation Conducted in the 100 Areas, Hanford sites: Fiscal Year 1992*	Forty-five ground-penetrating radar surveys were conducted in the 100 Areas in fiscal year 1992 to identity waste sites to help locate boreholes. The investigation results were provided as maps that summarized site interpretation.	D	--	--	--	No	No
WHC-SD-EN-TI-216	Rev. 0	1994 JAN	100 Area 200 Area	*Vegetation Communities Associated with the 100-Area and 200-Area Facilities on the Hanford Site*	This study identified plant communities and estimated vegetative cover in and near the 100 and 200 Areas, primarily in relation to waste sites.	D	E	--	A	No	No
WHC-SD-EN-TI-228	Rev. 0	1994 JUL	100-K	*Geophysical Survey for Proposed Borehole 199- K-108A, 100-K Area*	This survey located subsurface obstructions near proposed borehole 199-K-108A. The survey results identified possible drill sites within an area with the least likelihood of encountering obstructions.	D	--	--	A	No	No
WHC-SD-EN-TI-229	Rev. 0	1994 NOV	100-K	*Geophysical Survey for Proposed Borehole 199-K-107A, 100-K Area*	This survey located subsurface obstructions near borehole 199-K-107A. Possible drill sites within the survey area with the least likelihood of encountering identified obstructions were identified.	D,H	G, E	--	--	No	No
WHC-SD-EN-TI-230	Rev. 0	1994 JUL	100-K	*Geophysical Survey for Proposed Borehole 199- K-106, 100-K Area*	This survey located subsurface obstructions near proposed borehole 199-K-106A. The survey results identified possible drill sites within an area with the least likelihood of encountering obstructions.	D	--	--	A	No	No
WHC-SD-EN-TI-239	Rev. 0	1994, FEB	100-K	*100-K Area Technical Baseline Report*	This document provided a technical baseline of waste sites located at the 100-K Area The report presents an evaluation of numerous historical reports, drawings and photographs, supplemented by site inspections and employee interviews.	--	--	--	--	--	--
WHC-SD-EN-TI-239	Rev. 0	1994 APR	100-K	*100-K Area Technical Baseline Report*	This report provided the technical baseline of waste sites located at the 100-K Area. The report summarized evaluation of historical reports, drawings, and photographs, and was supplemented by site inspections and employee interviews information.	D,H,P	G,E	Y,S, X	A	No	No

Table B-1. Annotated Bibliography

Document Number	Revision/Draft	Date	Area or Operable Unit	Title	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
WHC-SD-EN-TI-253	Rev. 0	1995 JAN	100-K	*Geophysical Survey for Proposed Boreholes, 199-K-109A, 199-K-110A, and 199-K-111A, 100K Area*	A geophysical survey was conducted to locate subsurface obstructions that may affect the drilling of three boreholes in the 100-K Area. Drill sites with the least likelihood of encountering obstructions were identified with ground-penetrating radar. These results are presented in this document.	D,P	G,Z, E,T	--	A	No	No
WHC-SD-EN-TI-278	Rev. 0	1994 JUL	100 Area	*Columbia River Effluent Pipeline Survey*	This report presented geophysical survey results mapping the location and burial depth for 14 reactor effluent pipelines that extended into the Columbia River. The survey was conducted from April 11 to April 17, 1994.	D	G,Z	--	A	No	No
WHC-SD-EN-TI-294	Rev. 0	1995 MAR	100-K	*Hydrogeology of 100-K Area, Hanford Site, South-Central Washington*	This report presented geologic and hydrologic characteristics of the 100-K Area and vicinity. It was associated with enhancing groundwater monitoring near the 100-K Area FSBs. Results are presented from drilling activities, older projects and boreholes from the area, and evaluation of analogous geologic units from outcrops and boreholes. The report presented a review of the regional setting, and discussions of 100-K Area geology and hydrology.	D,H	G,Z,T	--	A	No	No
WHC-SD-SNF-SM-004	--	1995 SEP	100-K	*183 KE Potable Water System Analysis Plan*	This SAP was prepared to satisfy the data quality objectives for operation of the 183-KE potable water system for the 100-K Area.	D,P	--	--	A	No	No
WHC-SD-W405-PD-002	Rev. 0	1994 OCT	100-K	*Tech Assist/Fire Safety Assessment of 100K Area Facilities*	This document assessed the risk from fire within each facility in relation to existing or proposed fire protection features, and identified recommended fire protection upgrades.	D,H	Z	Y	A	No	No
WMP-27726	Rev. 0	2005 OCT	100-KR-4	*Borehole Summary Report for Wells, 199-K-133, 199-K-134, 199-K-135 and 199-K-136, FY 2005*	This report presented records and summarized field activities from drilling and constructing injection wells 199-K-133 through 199-K-136. These wells supported the planned treatability test for fixation of chromium in the groundwater at the 100-K Area. This report documented the drilling, well completion, and sample collection activities. The information included field notes and forms, geologic borehole logs, well construction details, and lithologic descriptions.	D	G,Z	Y,S, X	--	No	No

Note: Acronyms/terms are defined at first use within the table.

A	=	analysis	P	=	process
C	=	climate	S	=	source
D	=	description	T	=	topography
E	=	ecology	X	=	release
G	=	geology	Y	=	contaminant of potential concern
H	=	history	Z	=	hydrology
M	=	modeling			

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Appendix C

Borehole and Well Information

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Terms

bgs	below ground surface
COPC	constituent of potential concern
Cr(VI)	hexavalent chromium
DWS	drinking water standard
FS	feasibility study
KUT	potassium, uranium, and thorium
MDA	minimum detectable activity
MDL	method detection limit
OU	Operable Unit
P&T	pump and treat
PRZ	periodically rewetted zone
PVC	polyvinyl chloride
RI	remedial investigation
RUM	Ringold Formation upper mud

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C1 Introduction

This appendix presents the lithologic descriptions and geophysical logs from remedial investigation (RI) boreholes and wells, and additional well installations from post-RI remedial actions. The borehole and well information are used to support the remedial investigation (RI) and feasibility study (FS) for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units (OUs). Table C-1 provides the RI well list.

Table C-1. Identification of 100-K RI Wells

Well Identification	Borehole Identification	RI Well ID [a]
199-K-183	C7683	Well 1
199-K-184	C7684	RUM Well 1
199-K-185	C7685	Well 2
199-K-186	C7686	Well 9
199-K-187	C7687	Well 3
199-K-188	C7688	RUM Well 3
199-K-189	C7689	Well 5
199-K-190	C7690	Well 4
199-K-191	C7691	Well 6
199-K-192	C7692	RUM Well 2
199-K-193	C7693	Well 7
199-K-194	C7694	Well 8
199-K-195	C7695	RUM Well 4
199-K-200	C7831	116-K-2 Trench Borehole [b]
199-K-201	C7832	116-K-2 Trench Borehole [b]
199-K-221	C8796	116-KE-3 Waste Site Characterization [c]
199-K-222	C8797	UPR-100-K-1 Waste Site Characterization [c]

a. Wells for the 100-K RI are identified and described in the 100-K Work Plan (DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*).

b. Vadose zone characterization borehole completed as a temporary monitoring well. See Section 2.1.1.

c. Well installed in 2015 for additional characterization.

RI = remedial investigation

RUM = Ringold Formation upper mud

Table C-2 identifies post-RI wells installed between 2011 and 2017 for groundwater interim remedial action.

Table C-2. Identification of 100-K Post-RI Wells

Well Identification	Borehole Identification	Location
199-K-202	C8289	Northwest of the KE Reactor and 116-KE-3 Crib
199-K-203	C8290	North of the KE Reactor and 116-KE-1 Crib
199-K-204	C8291	North of the KW Reactor and 116-KW-1 Crib, within the 116-KW-4 Heat Recovery Station site footprint
199-K-205	C8292	At the former 183-KW Headhouse area
199-K-207	C8294	Within the northern portion of the 118-K-1 Burial Ground footprint
199-K-210	C8297	In the river embankment north of the 116-KE-4 Retention Basin site; within the 100-K-64 site
199-K-220	C8795	At the former 183-KE Flocculation and Sedimentation Basins area
199-K-223	C9595	At the former 183-KW Flocculation and Sedimentation Basins area
199-K-224	C9596	At the former 183-KW Flocculation and Sedimentation Basins area, northwest of well 199-K-223
199-K-225	C9597	At the former 183-KE Flocculation and Sedimentation Basins area, northwest of well 199-K-220
199-K-226	C9598	At the northeastern corner of the 100-K operational area, within the 116-KE-4 Retention Basin site footprint
199-K-227	C9711	Within the southeastern portion of the 118-K-1 Burial Ground footprint, at the 100-K-132 site
199-K-228	C9712	East of the KE Reactor and southwest of the 118-K-1 Burial Ground site
199-K-229	C9713	North of the northwestern corner of the former 183-KW Flocculation and Sedimentation Basins area
199-K-230	C9714	Northeast of the 116-KE-3 Retention Basin site

C2 Data from RI Characterization Boreholes and Wells

Chapter 3 in the main text of this document discusses geologic data for RI boreholes and wells and post-RI wells in 100-K. Chapter 4 presents soil contaminant data and vertical profiles of the RI wells and boreholes. The 100-K RI borehole and well data, and borehole and well locations are discussed in this appendix. The post-RI groundwater data are in the annual pump and treat (P&T) reports (e.g., DOE/RL-2016-68, *Calendar Year 2017 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump and Treat Operations, and 100-NR-2 Groundwater Remediation).* Geologic and geophysical logs for the RI and post-RI wells with data used in the RI are in the following documents:

- SGW-48760, *Borehole Summary Report for Two Characterization Boreholes in the K2 Trench in the 100-KR-4 Operable Unit to Support WCH in FY 2010* (hereinafter called K-2 Trench Borehole Summary Report)

- SGW-49459, *Borehole Summary Report for the Drilling and Installation of RI/FS Wells in the 100-KR-4 Operable Unit* (hereinafter called Borehole Summary Report for KR-4 RI/FS Wells)
- SGW-58157, *Borehole Summary Report for the Installation of Three Wells in the 100-KR-4 Operable Unit, FY2013*
- SGW-59027, *Borehole Summary Report for the Installation of Two Wells in the 100-KR-4 Operable Unit, with and option of Three Wells, FY2014*
- SGW-59494, *Borehole Summary Report for the Installation of Two Characterization, Monitoring, and Extraction Wells in the 100-KR-4 Operable Unit, FY2015*
- SGW-60149, *Report for Soil Borings and Well Installations in the UPR-100-K-1 and 116-KE-3 Waste Sites*
- SGW-60241, *Borehole Summary Report for the Installation of Four 100-KR-4 Operable Unit Extraction Wells, FY16*

The following subsections discuss geologic information for each RI borehole/well. Each location was chosen to address specific data gaps and data needs. Geophysical logs are included later in this appendix, and provide a visual information summary, including geology, sampled intervals, well completions, geophysics, and soil contaminants.

C3 Hydrogeologic Cross Sections

Hydrogeologic cross sections provide representations for geologic units, their associated contacts, and stratigraphic changes in 100-K. Considerable information now exists to accurately define the 100-KR-4 OU unconfined aquifer system. Most boreholes were drilled to establish the Ringold Formation upper mud (RUM) surface depth, which forms the unconfined aquifer base. Hydrogeologic information about the deeper Ringold sediments (e.g., Ringold unit B, RUM) historically was limited compared to the Hanford formation and Ringold Formation unit E sediments. In the 1990s, several wells at 100-KR-4 were drilled to provide information on the RUM and Ringold unit B. However, the RI characterization combined with data from post-RI wells has improved understanding the relationships and properties in and between these units. Figure C-1 is a Location Map showing the orientations for ten hydrogeologic cross sections, which includes the RI wells and active extraction and monitoring well locations. Cross sections (Figures C-2 to C-11) show hydrogeologic information and selected waste site locations. Cross sections A-A' to F-F' are generally perpendicular to the Columbia River, while cross sections G-G' to J-J' are generally parallel to the river.

Cross section A-A' (Figure C-2) focuses on the hexavalent chromium (Cr(VI)) plume around the KW Reactor. This section includes RI wells 199-K-185, 199-K-184, and 199-K-195. Wells 199-K-184 and 199-K-195 (decommissioned) were drilled deeper than 15.2 m (50 ft) into the RUM but did not encounter a water-bearing unit. A slight depression in the RUM surface is near wells 199-K-106A, 199-K-184, and 199-K-108A, extending to well 199-K-175. This corresponds roughly with the K West plume area (Section 4.3), from the KW Reactor to the 183.1KW Headhouse. Several existing K West upgradient wells (e.g., 199-K-165, 199-K-173, and 199-K-35) have Cr(VI) at concentrations ranging from 770 to 3,540 µg/L from CY 2013 through CY 2016, which is greater than the concentrations expected from cooling water use. Cr(VI) concentrations in RI well 199-K-195, now decommissioned, ranged to 4,890 µg/L during drilling.

Figure C-3 depicts cross section B-B', which passes through the K East area. It is aligned to examine Cr(VI) concentrations around this reactor, starting near the Columbia River and terminating southeast of the

183.1KE Headhouse and the 183.2-KE sedimentation basin at well 199-K-187. RI wells 199-K 189, 199-K-186, 199-K-188, and 199-K-187, drilled near the KE Reactor, are included in this cross section. Well 199-K-188 planned a screen in the RUM; however, it was drilled deeper than 15.2 m (50 ft) into the RUM (71.65 m [235.00 ft] below ground surface [bgs]) without encountering a water-bearing unit. Thus, the well was screened in the overlying unconfined aquifer. A small channel in the RUM was located with well 199-K-109A, from which the RUM surface rises as seen in well 199-K-186. Cr(VI) concentrations are generally lower in wells along this cross section than wells near the KW Reactor. Cr(VI) at well 199-K-141 reached 459 µg/L during the initial extraction in February 2009. The Cr(VI) concentrations at well 199-K-36, near the 183.1KE Headhouse, rose to 1,332 µg/L between 2001 and 2002, then decreased to near 20 µg/L by 2006.

Cross section C-C' (Figure C-4) starts near the Columbia River and runs east beneath the 116-K-1 crib and the southwestern end of the 116-K-2 trench before continuing southeast past the 126-K-1 demolition landfill. It includes RI wells 199-K-192 (completed in the uppermost RUM confined aquifer), 199-K-191, and 199-K-200 (a temporary well completed in the Ringold Formation unit E). The RUM surface along this cross section dips near the river and then gradually increases in elevation inland. Cr(VI) monitoring at wells along this cross section has not encountered high concentrations, with recent sampling results <30 µg/L. Strontium-90 analysis reported 251 pCi/L in well 199-K-200, and tritium concentrations to 1,400,000 pCi/L at 199-K-192.

Figures C-5, C-6, and C-7 are cross sections D-D', E-E', and F-F', respectively. These sections are generally perpendicular to the Columbia River and follow lower-concentration Cr(VI) plumes from the river to inland wells. Section D-D' (Figure C-5) passes through higher Cr(VI) concentrations in well 199-K-18 at the southwest end of the 116-K-2 trench. Closer to the river, the cross section passes through RI wells 199-K-197 and 199-K-199 in a low hydraulic conductivity zone; the Ringold Formation unit E is visible at the surface and the aquifer thins. Inland from well 199-K-18, the cross section intersects the KR-4 and KX P&T systems injection well fields between wells 199-K-169 and 199-K-124A. Cross section D-D' includes RI wells 199-K-192, screened in the RUM and located between well 199-K-18 and the 116-K-2 trench, and well 199-K-194, located on the southeast end of the cross section. Depicted in this cross section are the lowest points of the RUM surface at well 199-K-192, and one of the highest points in the RUM surface at well 199-K-128. These two wells are located on either side of the 116-K-2 trench, with the lowest elevation RUM surface closer to the river. Farther inland the cross section includes well 199-K-171, where the initial 75 to 80 µg/L Cr(VI) detections have been reduced through P&T processing.

Cross section C-6 (E-E') tracks a Cr(VI) plume extending upgradient from the river past the 116-K-2 trench and well 199-K-201, inland to well 199-K-171 and RI well 199-K-193. Wells 199-K-22 and 199-K-201 have elevated Cr(VI) concentrations ranging from 86.3 µg/L in well 199-K-22 to 111 µg/L in well 199-K-201 in April 2011. Both wells are screened in lower hydraulic conductivity materials within Ringold Formation unit E. Wells upgradient from the 116-K-2 trench, 199-K-163 and 199-K-154, encountered Cr(VI) concentrations >100 µg/L during drilling. The cross section reveals a steady rise in surface elevation from the nearshore Columbia River east to the highest bench at 100-K. The RUM surface slopes upward from the topographic high to the Columbia River, with a slight rise in the RUM surface near well 199-K-115A relative to the rest of the RUM surface.

The northernmost cross section is F-F' (Figure C-7), which extends from the Columbia River inland through an area with moderately elevated Cr(VI) concentrations. Well 199-K-182 is the upgradient terminus and has reported a relatively steady Cr(VI) concentration range between 74 and 82 µg/L. Closer to the river, concentrations drop below 40 µg/L at well 199-K-148. The RUM surface slopes slightly away from the river.

Cross sections G-G' and H-H' (Figures C-8 and C-9) are consecutive, are oriented parallel and proximal to the Columbia River, and cover the near river area for the 100-KR-4 OU. Cross section G-G' starts at the 116-K-1 crib and extends past the 116-K-2 trench towards 100-N. Cross section H-H' starts at RI well 199-K-183, in southwestern 100-K, and includes RI wells 199-K-183, 199-K-185, and 199-K-190. These cross sections overlap midway along the 116-K-2 trench, with well 199-K-16 on both. Cross section H-H' includes one of the lowest (at 199-K-16) and highest (at 199-K-114A) RUM surface elevations within 100-K. The aquifer thins locally near wells 199-K-114A, 199-K-161, and 199-K-113A where the water table is into the Hanford formation.

Running essentially parallel to the Columbia River, cross sections I-I' and J-J' (Figures C-10 and C-11) at 100-KR-4 are progressively farther from the river. The unconfined aquifer is in the Ringold Formation unit E. These cross sections show no wells encountered a transmissive RUM lens. Cross Section I-I' starts on the west side of the KW Reactor, extends past the KE Reactor, continues northeasterly through the 118-K-1 Burial Ground, and ends at well 199-K-156. Section I-I' incorporates RI wells 199-K-184 in the K West area and 199-K-189 in the K East area. The RUM surface is slightly higher under each reactor, but is poorly defined between them. The RUM surface gently slopes downward easterly from the 118-K-1 Burial Ground. Cross Section J-J' extends from the 183.1 KW Headhouse and well 199-K-195 through the 183.1 KE Headhouse and easterly through well 199-K-191 to end at well 199-K-122A. The RUM surface on section J-J' western end is similar to that on I-I', but the RUM surface increases approximately 15 m (50 ft) between wells 199-K-191 (C7691) and 199-K-122A.

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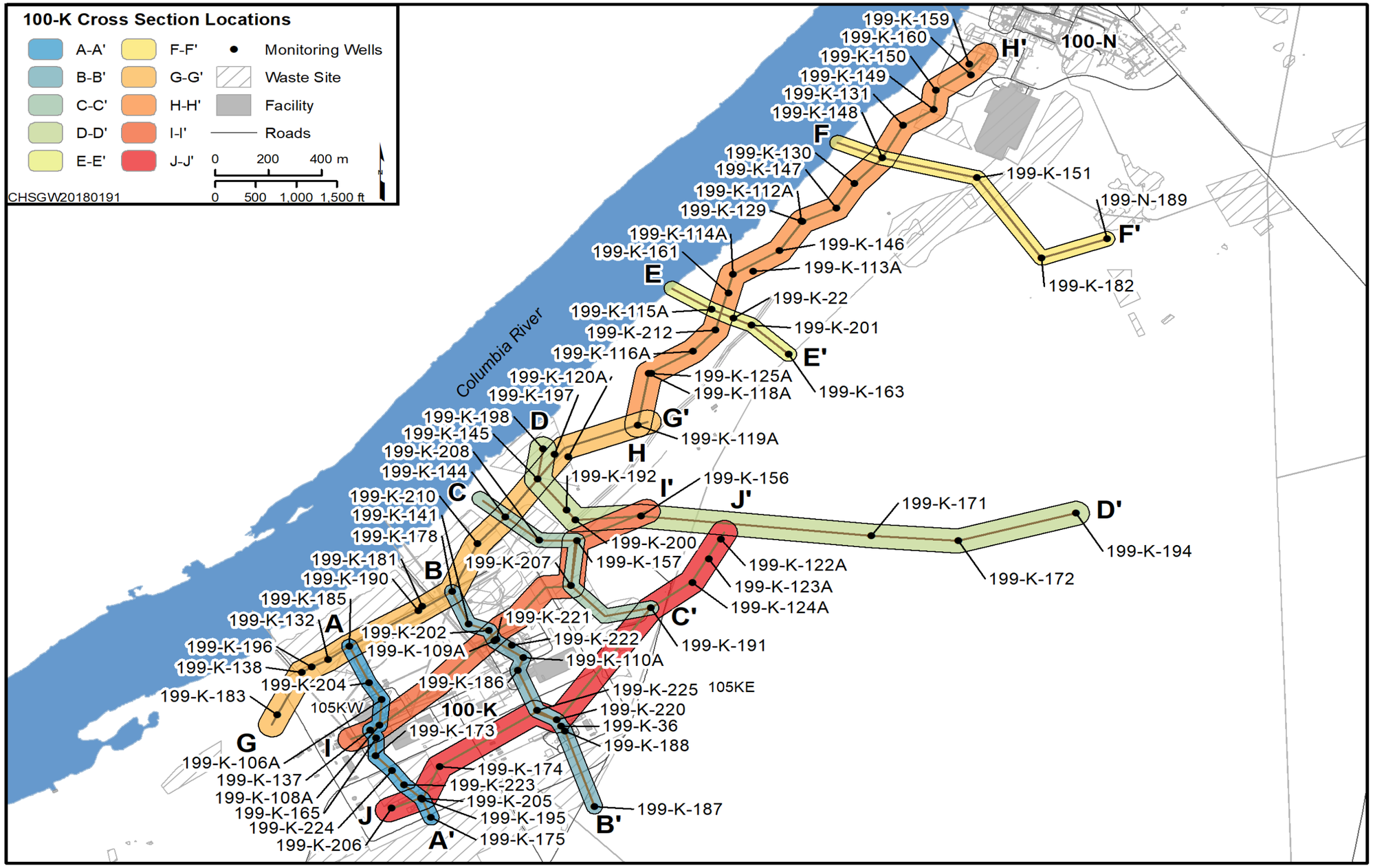
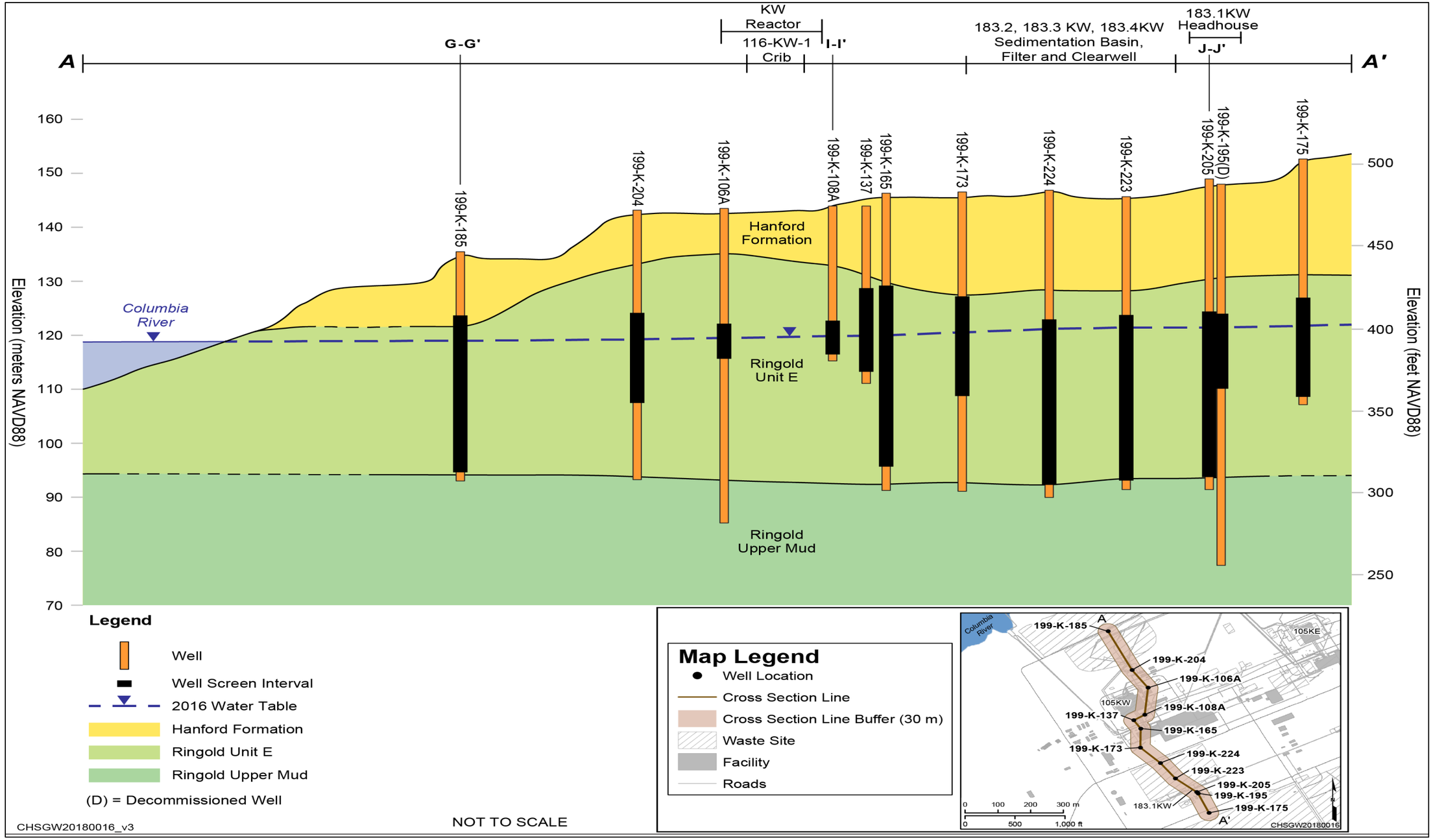
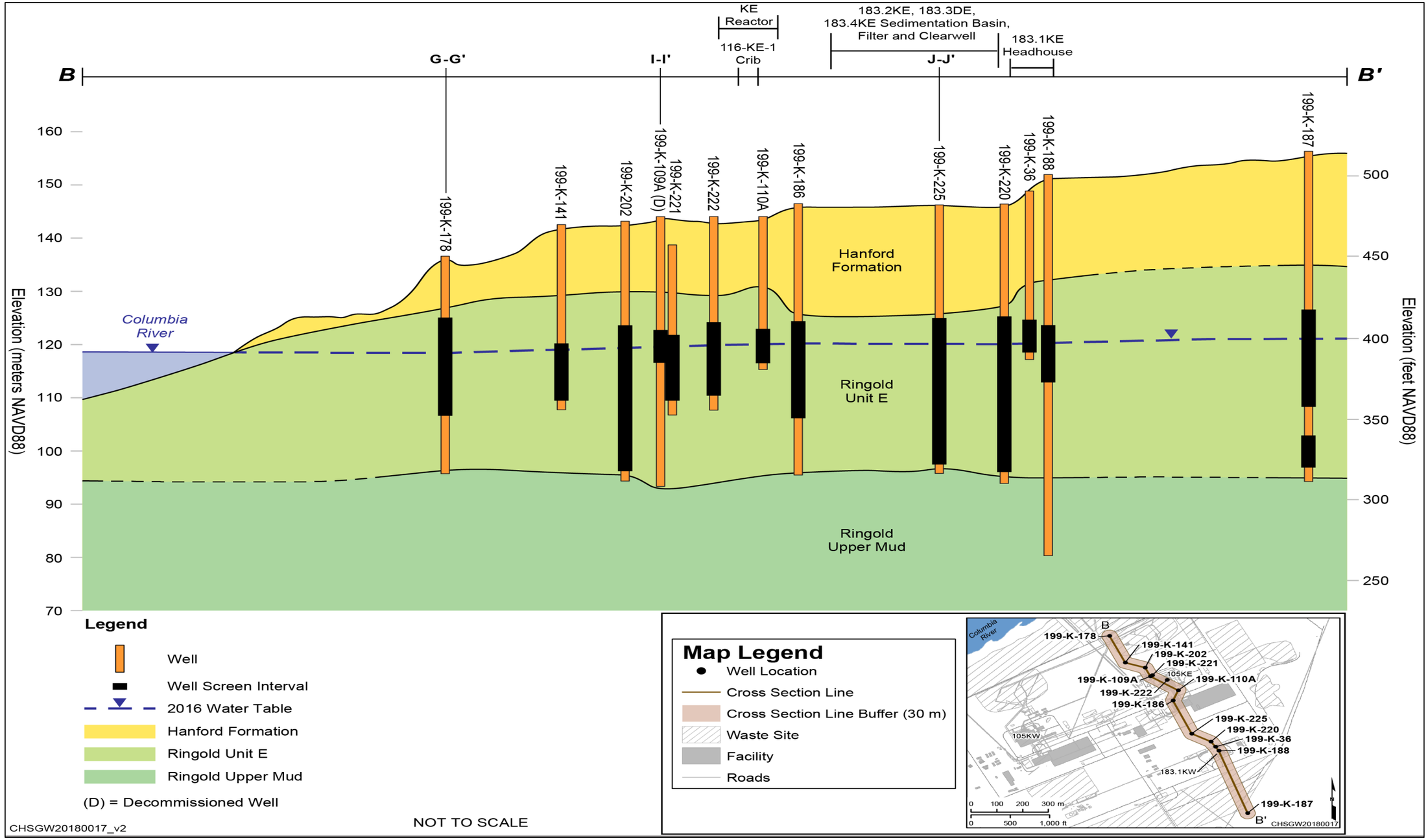


Figure C-1. Location Map for 100-KR-4 Hydrogeologic Cross Sections



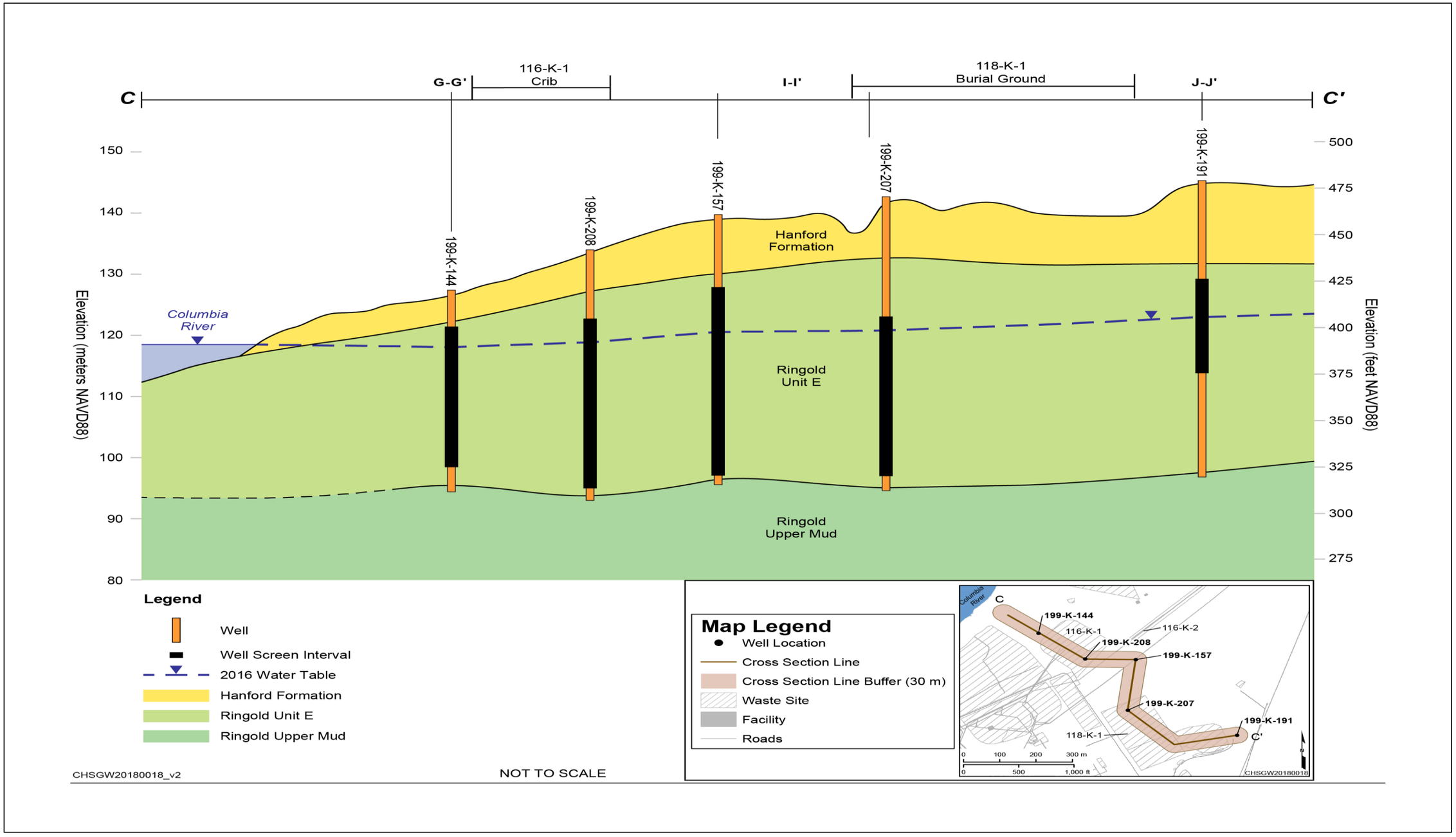
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-2. 100-K Hydrogeologic Cross Section A-A'



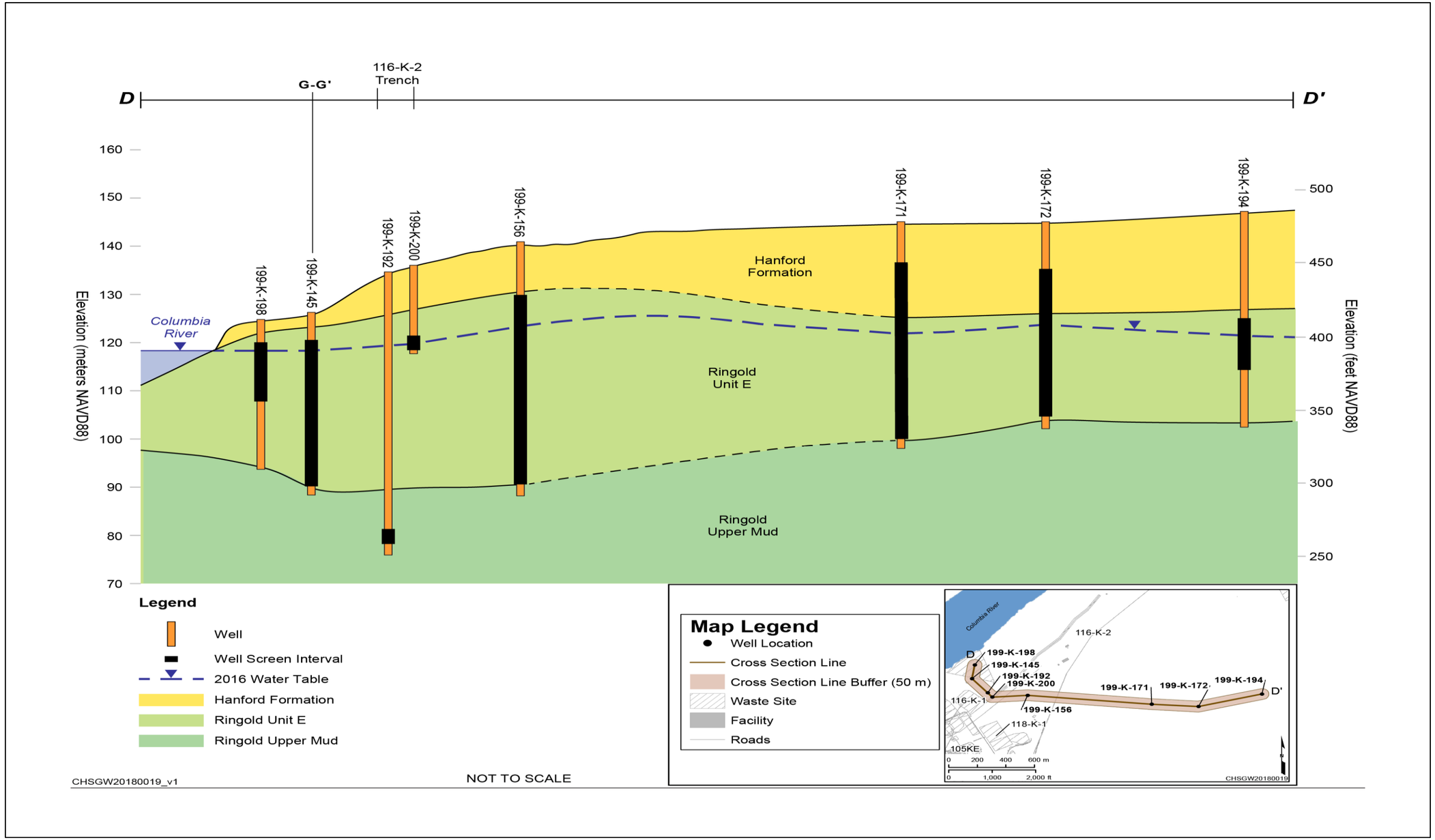
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-3. 100-K Hydrogeologic Cross Section B-B'



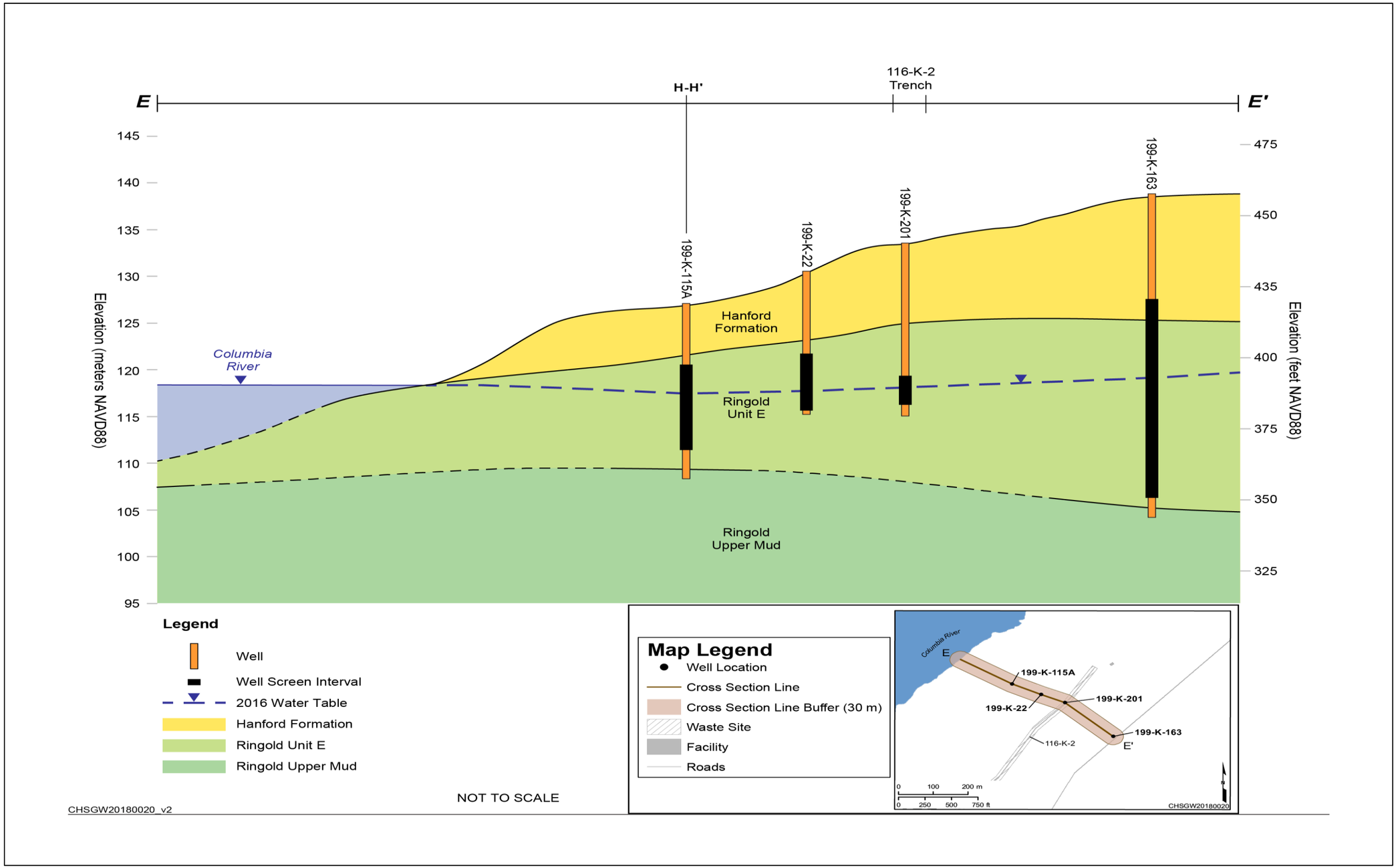
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-4. 100-K Hydrogeologic Cross Section C-C'



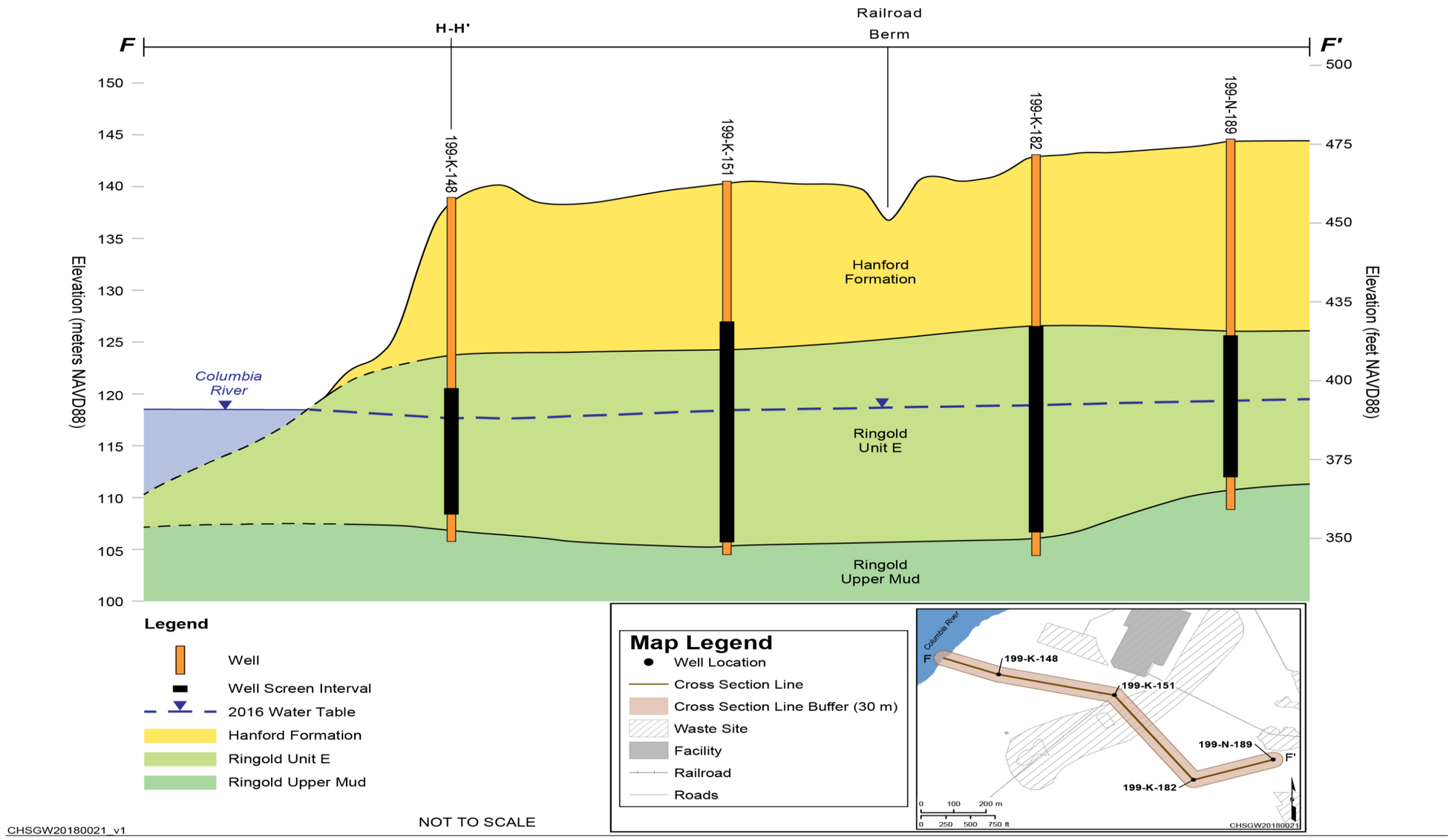
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-5. 100-K Hydrogeologic Cross Section D-D'



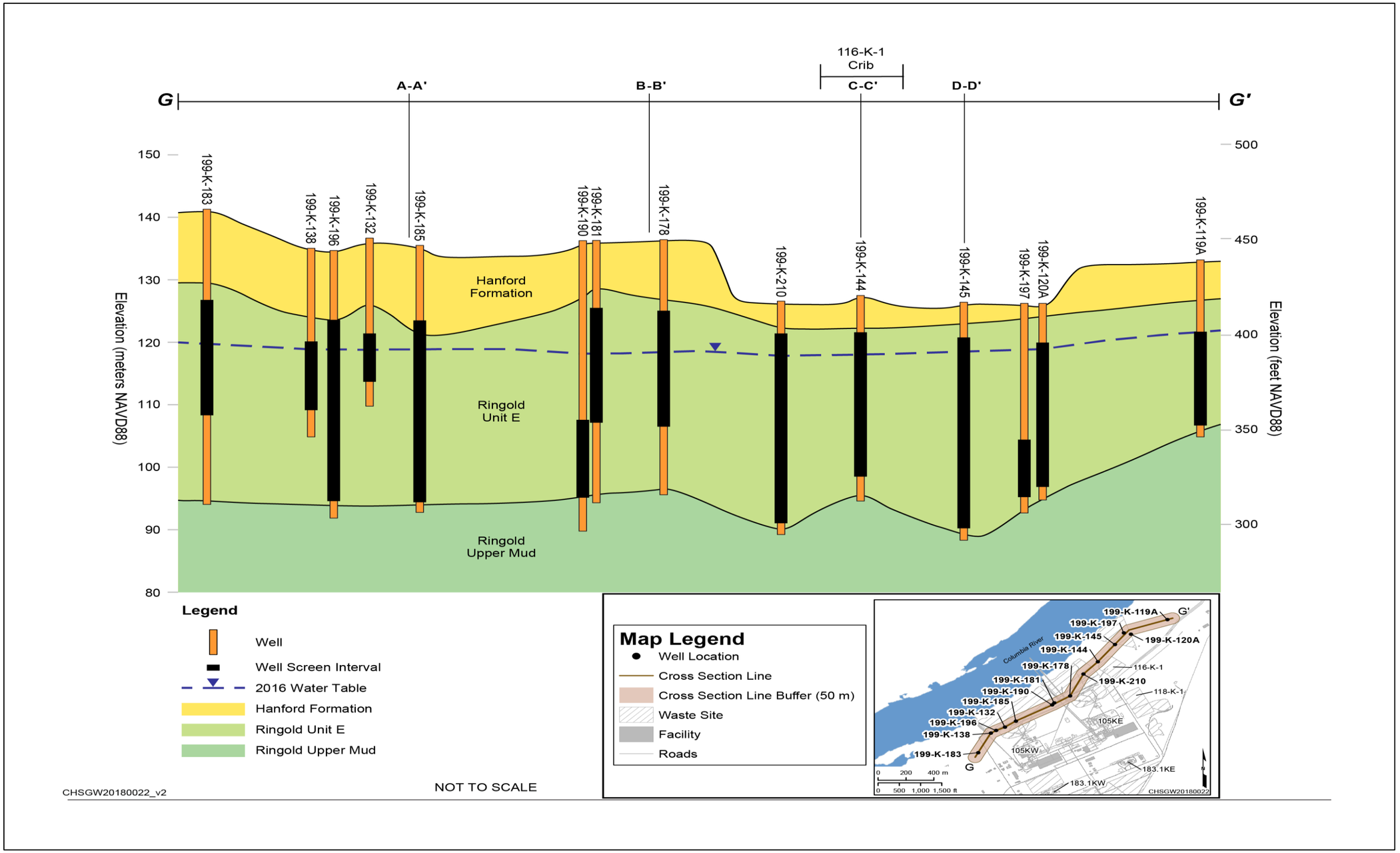
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-6. 100-K Hydrogeologic Cross Section E-E'



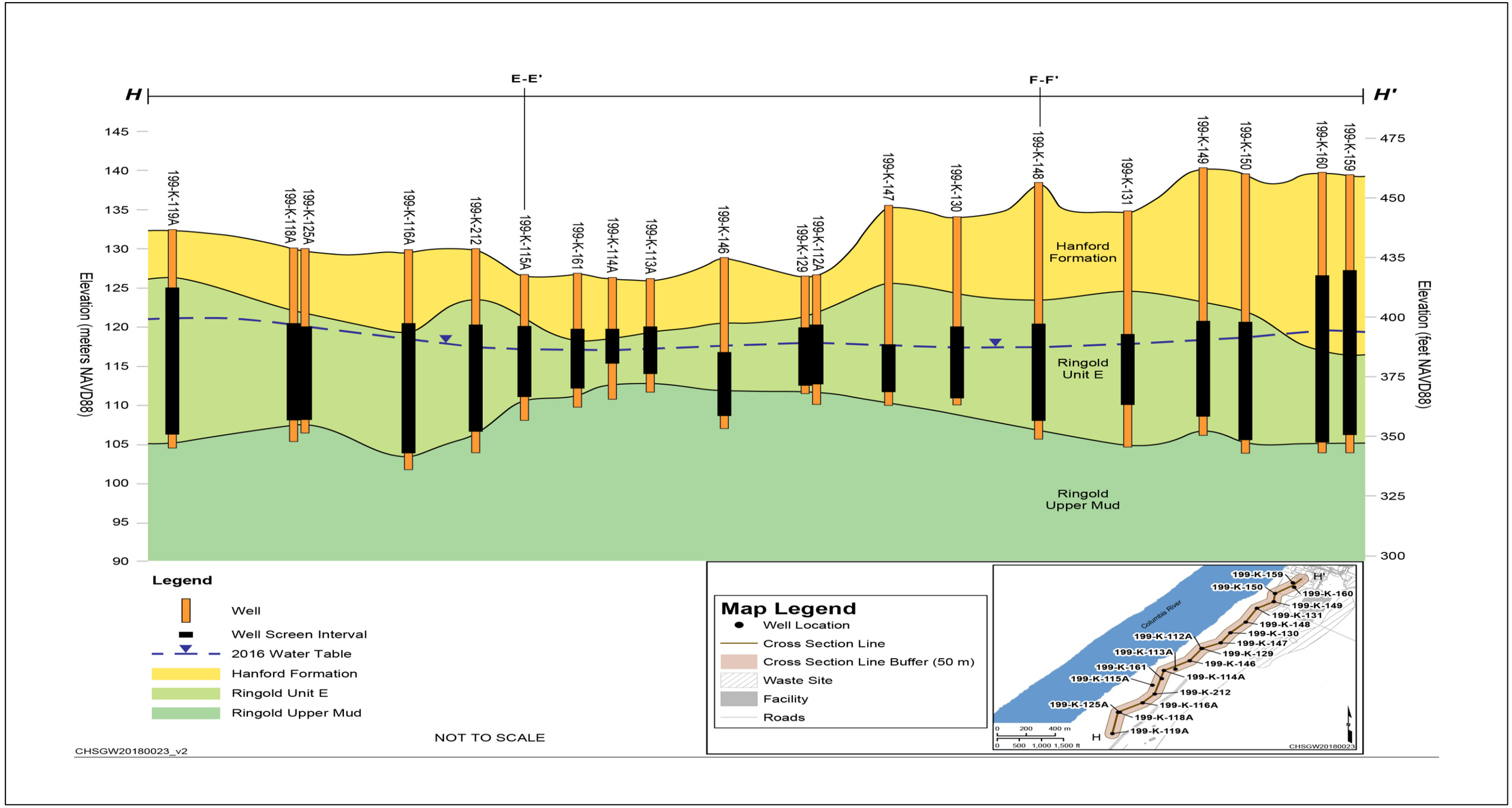
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-7. 100-K Hydrogeologic Cross Section F-F'



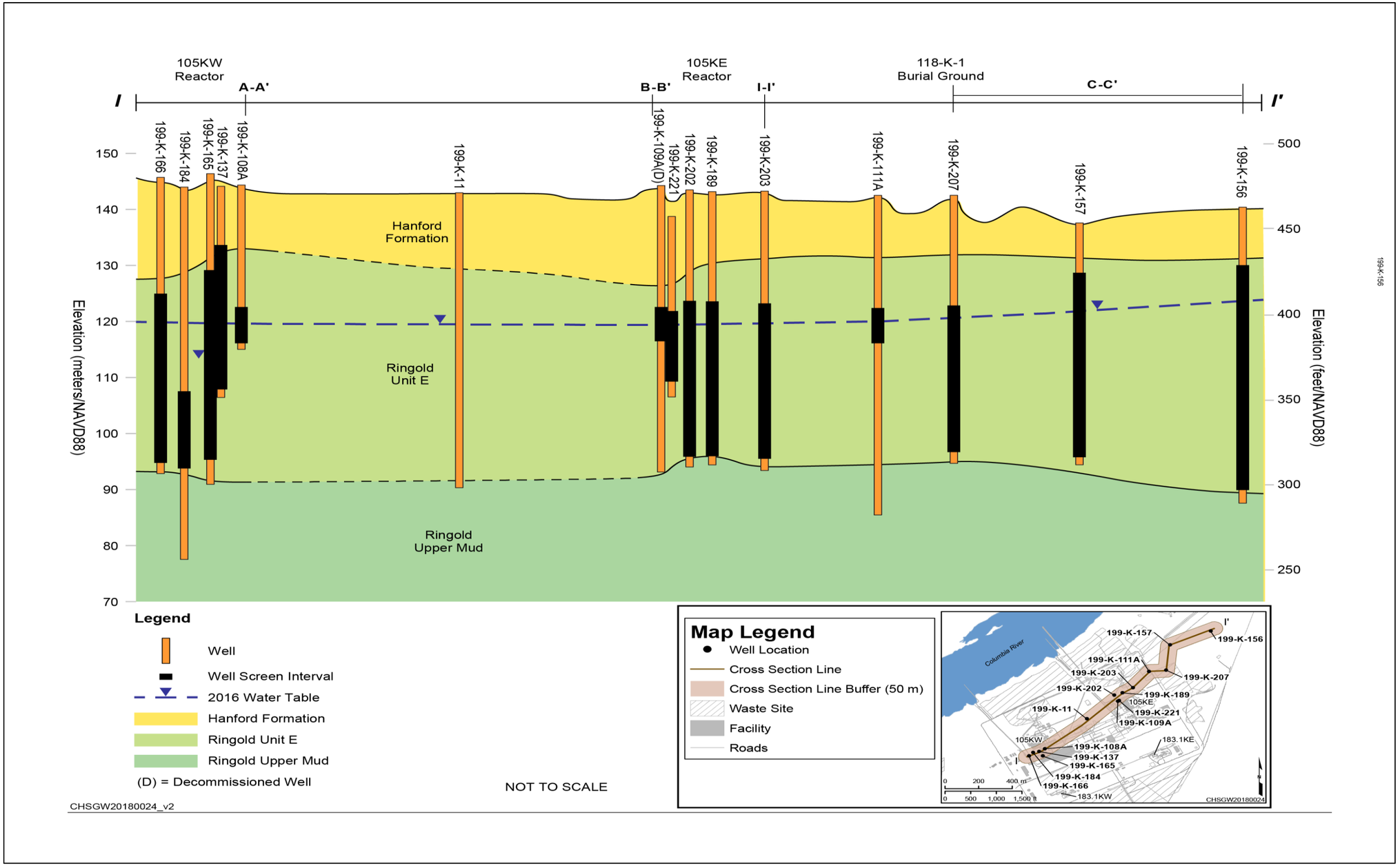
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-8. 100-K Hydrogeologic Cross Section G-G'



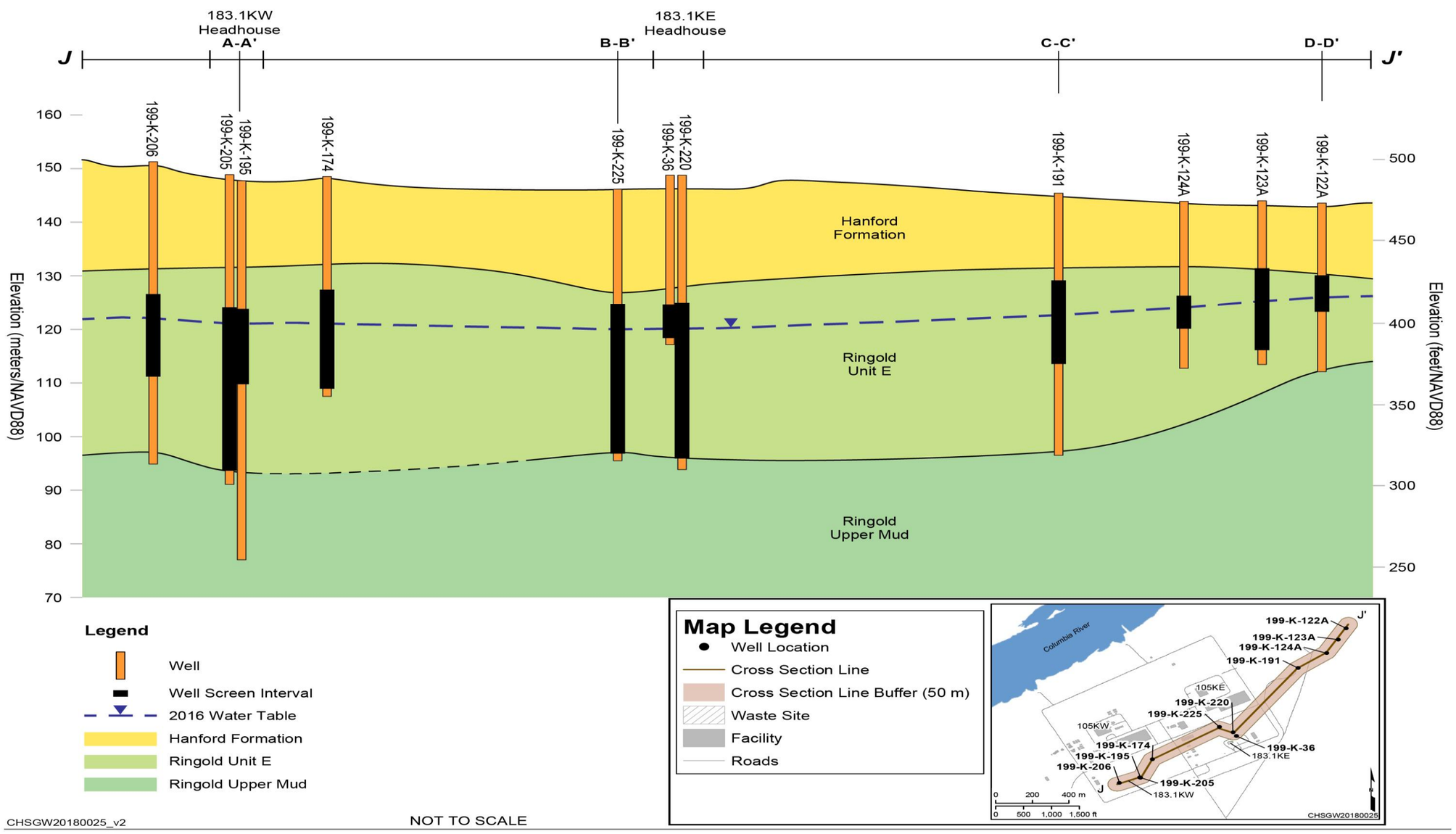
Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-9. 100-K Hydrogeologic Cross Section H-H'



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-10. 100-K Hydrogeologic Cross Section I-I'



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure C-11. 100-K Hydrogeologic Cross Section J-J'

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C4 Geophysical and Analytical Data Logs

This section provides a brief information summary on the RI boreholes and wells, including the purpose, location, general lithology, Hanford formation/Ringold Formation unit E and RUM contact depths, water table or potentiometric surface, and a brief geophysical logs discussion. Geophysical logs for each borehole follow this appendix section rather than immediately following individual borehole discussions due to the large number of these figures.

Figures C-12 to C-26 depict the composite geological, geophysical, well completion, and contaminant data for the 13 RI wells. Well-related information are in the four left columns, followed by three geophysical log columns. Analytical results for selected constituents and radionuclides in both soil and groundwater are presented in the next four columns. A discussion of each log and accompanying data tables follow the figures.

Vadose zone and aquifer soil and groundwater samples were collected from discrete depth intervals for the analyses identified in the 100-K Work Plan (DOE/RL-2008-46ADD2) and 100-K SAP (DOE/RL-2009-41). Sample summaries are in Chapter 2, and results are discussed in Chapter 4. The soil and groundwater analytical results on the composite log figures (C-12 to C-26) do not include all analytical data obtained and available for the depth discrete sample intervals. Instead, select contaminants of potential concern (COPC) concentrations in vadose zone soil (i.e., total chromium, Cr(VI) and strontium-90) and saturated zone groundwater (i.e., total chromium, Cr(VI), nitrate, carbon-14, strontium-90, and tritium) are included to illustrate contaminant distribution within each profile.

C4.1 Well 199-K-183 Log

Figure C-12 shows the composite analytical results for well 199-K-183. The well is located outside and west of the K West Cr(VI) plume and the security fence line near the KW Reactor. The well location was selected to bound the K West plume near the Columbia River. It was completed in the unconfined aquifer above the RUM contact and 6.1 m (20 ft) into the vadose zone. The design provides a multipurpose function for future use during remediation as an extraction, monitoring, or injection well. During drilling, the June 2010 groundwater levels rose by 1.2 m (4 ft) in the well coincident with a 1.5 m (5 ft) river stage increase.

The Hanford formation is a gravel dominated formation that includes a range of grain sizes from boulder-sized gravel to sand, silty sand, and silt. The contact with the Ringold Formation unit E at this location is at 8.2 m (27 ft) bgs, based on geophysical logging and geological descriptions. The Ringold Formation unit E exhibits various sandy gravel, sand, and occasional silty sandy gravel layers. The water table is located in Ringold Formation unit E. A neutron moisture log was not requested for this well, but the soil sample percent moisture measurements indicate relatively low moisture, at up to 4.2%. The moisture data indicate a slightly lower moisture below the Hanford formation/Ringold Formation unit E contact. This profile exhibits moisture contents below the presumed background moisture levels for these sediments. Therefore, very little vertical flow is expected under the measured conditions, given typical specific retention capacities of 1% to 2% for these sediments.

The total gamma and natural potassium-40, uranium-238, and thorium-228 (KUT) geophysical log plots show an increased count rate at depth, indicating the RUM contact at 45 m (147 ft) bgs. A more subtle increase in total gamma is visible at 6.5 m (21 ft) bgs; the increase defines the Hanford formation/Ringold Formation unit E contact.

Additional analytical results and discussion are in Section 4.2. Cr(VI) values are generally less than total chromium values, which is expected, because total chromium includes all chromium ionic states. There is

high total chromium from 16.8 to 17.2 m (55 to 56.5 ft) bgs with reported 53.6 mg/kg values and below that depth, concentrations decrease. Cr(VI) concentration is not correspondingly high, as there is a high reduction zone within that interval. The reduction may have resulted from additional iron or increased microbial activity. There is no strontium-90 in the vadose zone or aquifer sediment, nor groundwater at this location. No contaminant analyses were above background within the periodically rewetted zone (PRZ); however, groundwater sample results from the upper 10 m (33 ft) of the 25 m (82 ft) thick unconfined aquifer are slightly elevated and suggest a shallow contaminated groundwater intrusion. The initial sampling attempt at 1.5 m (5 ft) below static water level encountered inadequate groundwater. Drilled soil showed alternately wet and dry zones within a cemented layer. Cr(VI) and total chromium concentrations in groundwater are <10 µg/L at this location, with Cr(VI) values less than total chromium, as expected. There is a total chromium to trivalent chromium ratio reduction in this portion of the aquifer. Nitrate is approximately half the drinking water standard, or less. Carbon-14 is less than or equal to the 2,000 pCi/L drinking water standard (DWS) and tritium is <1,600 pCi/L, with the highest levels shallower in the aquifer. Slug testing indicates hydraulic conductivity in the aquifer is approximately 15 m/day (49 ft/day), which is within the expected range.

Groundwater sampling following well acceptance was performed at well 199-K-183 in June 2011, when one sample and a duplicate were collected. Analytical results were as follows:

- Filtered Cr(VI): 2.9 (B-qualified) and 5.0 µg/L
- Filtered total chromium: 7.5 and 8.0 µg/L (both B-qualified)
- Carbon-14: 550 and 340 pCi/L
- Tritium: 1,500 and 1,510 pCi/L
- Strontium-90: below detection, with a minimum detectable activity (MDA) of 1.8 pCi/L in one sample, and a reported detection of 1.6 pCi/L in the duplicate
- Nitrate: 23,800 and 26,800 µg/L (both D-qualified)
- Trichloroethene: 4.6 µg/L, with no duplicate

C4.2 Well 199-K-184 Log

Figure C-13 provides the composite analytical results for well 199-K-184. The well is located upgradient from the KW Reactor and was drilled 15.2 m (50 ft) into the RUM. The RUM unit had no water-bearing zone within this interval, and the well subsequently completed in the lowermost unconfined aquifer with the screen bottom located at the RUM contact. The water table lies within Ringold Formation unit E. The Hanford formation/Ringold Formation unit E contact is at 16.8 m (55 ft) bgs, although evidence for the contact depth is not definitive. The well location is downgradient from a suspect groundwater Cr(VI) source around the former 183.1 KW Headhouse. This well is near three active extraction wells (199-K-137, 199-K-165, and 199-K-166). Well 199-K-184 was screened in the lower unconfined aquifer to investigate contaminant trends below the 15.4 to 30.1 m (50 to 100 ft) bgs screened interval of extraction well 199-K-137.

The Hanford formation at this location consists of silty gravel overlying a thin silty layer overlying sand, gravelly sand, and silty sandy gravel. Ringold Formation unit E is predominantly sandy gravel and gravelly sand with occasional sand or silty sandy gravel. Soil sample moisture ranged from 5% to 10%, with 20% at a thin silt unit 6.2 m (20 ft) bgs. The neutron moisture logging conducted indicates reasonable consistency with laboratory moisture, including the high at 6.2 m (20 ft). The moisture profiles indicate a

lower moisture content below the Hanford formation/Ringold Formation unit E contact. This profile exhibits moisture content within the probable background moisture levels under unvegetated conditions. Given typical specific retention capacities of 1% to 2%, vertical flow is expected.

The total gamma and natural KUT geophysical surveys reveal an increased count rate at depth corresponding to the RUM contact at approximately 50 m (168 ft) bgs. The total gamma signature is indistinct for the Hanford formation/Ringold Formation unit E contact at 28 m (90 ft) bgs; however, the silty lens at 6 m (20 ft) below the surface has an elevated gamma signature.

The composite log (Figure C-13) presents the vertical distribution and concentrations from the analyses. Section 4.2 in the main text of this document provides results for additional analytes and discussion. Total chromium ranges up to 27 mg/kg from 15 to 23 m (50 to 75 ft).

Strontium-90 was not detected in the groundwater, vadose zone, or aquifer sediment at this location. There were no elevated contaminant concentrations near the PRZ. Groundwater sample results from the unconfined aquifer upper 10 m (33 ft), in the 25 m (82 ft) thick unit, are slightly elevated. Cr(VI) and total chromium concentrations in groundwater were <10 µg/L at this location, with values for Cr(VI) less than total chromium, as expected. There appears to be some reduction to trivalent chromium in this portion of the aquifer. Nitrate is approximately half the drinking water standard or less. Carbon-14 does not exceed the 2,000 pCi/L DWS, although the unconfined aquifer has concentrations as high as 1,640 pCi/L. Tritium concentrations range from 1,100 to 8,800 pCi/L, with the highest concentration at the base of the unconfined aquifer. Slug testing indicates hydraulic conductivity in the aquifer is approximately 6 m/day (20 ft/day), within the conductivity range expected for the saturated Ringold Formation unit E.

Routine water sampling was performed at this well in May 2011, with a filtered and an unfiltered sample collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) detected at 15.7 and 16.5 µg/L
- Total chromium detected at 21 and 17 µg/L (B-qualified)
- Carbon-14 detected at 211 pCi/L
- Strontium-90 not detected at an MDA of 1.5 pCi/L
- Tritium detected at 1,400 pCi/L
- Nitrate reported at 13,800 µg/L
- Trichloroethene at 3.1 µg/L (J-qualified, which indicates an estimated value)

C4.3 Well 199-K-185 Log

Figure C-14 shows the composite analytical results for well 199-K-185. This well replaced 199-K-33, decommissioned in 2003 to accommodate remediation actions at the 107-KW site. Well 199-K-33 historically exhibited elevated carbon-14 concentrations greater than the 2,000 pCi/L DWS, and tritium values occasionally exceeded the 20,000 pCi/L DWS. Total chromium results at 199-K-33 ranged from 10 to 25 µg/L; Cr(VI) was not an analyte. Well 199-K-185 was intended to provide information on the extent of contaminants in the unconfined aquifer. The well is screened across the 26 m (85.5 ft) unconfined aquifer with the base of the screen located at the RUM contact. The Hanford formation/ Ringold Formation unit E contact is at 7.6 m (25 ft) bgs based on the geologic log. The water table is within the Ringold Formation unit E.

Neutron moisture logging results show a slight relative decrease in volumetric moisture below the Hanford formation/Ringold Formation unit E contact. Soil moisture sample content calculations ranged from 7% in the Hanford formation to 2% in Ringold Formation unit E. The well sediments have moisture

contents within the probable background moisture levels under unvegetated conditions. Given typical specific 1 to 2% retention capacities, the expectation is vertical downward flow occurs in these sediments.

The total gamma and natural KUT geophysical log plots show an increased count rate at depth, indicating the RUM contact at approximately 41 m (133 ft) bgs. The total gamma signature is indistinct for the Hanford formation/Ringold Formation unit E contact at 7.5 m (25 ft) bgs. There is one zone of higher counts at approximately 5 m (16 ft) below the surface, although there is no apparent change in lithology; however, there is a high probability the sediment exhibits a higher than average silt content.

Contaminant vertical distribution and concentrations are on the composite log (Figure C-14). Results and discussion for additional analytes are in Section 4.2. Soil sampling indicates relatively low Cr(VI) levels in the vadose zone with total chromium up to 21.2 mg/kg at 7.6 to 8.4 m (24.9 to 27.4 ft) bgs and generally decreasing below that depth. Results indicate that Cr(VI) is approximately 1% to 2% of the total vadose zone chromium, suggesting that most chromium is reduced and immobile. Cr(VI) concentrations are below detection over the aquifer thickness until the measurement closest to the RUM contact. There are total chromium detections at 5.27 µg/L at the aquifer base; however, the detections are close to the method detection limit (MDL) and introduces uncertainty regarding the value.

Strontium-90 was not detected in the vadose zone soil, aquifer sediments, and groundwater at this location. Carbon-14 concentrations to 2,390 pCi/L were reported near the unconfined aquifer top. No elevated contaminant concentrations were reported near the PRZ. Groundwater sample results from the unconfined aquifer upper 10 m (33 ft) are slightly elevated. Tritium concentrations range to 2,900 pCi/L, with the highest concentrations near the RUM contact. Cr(VI) concentrations in groundwater are <10 µg/L, with values for Cr(VI) less than total chromium, as expected. Nitrate concentrations are above the standard in the upper 6 m (20 ft) of the aquifer. Slug testing indicates the aquifer hydraulic conductivity is approximately 2 m/day (6.6 ft/day), within the conductivity range for saturated Ringold Formation unit E.

Routine groundwater monitoring was performed at 199-K-185 (C7685) in May 2011. Both filtered and unfiltered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported at 7.0 and 5.0 µg/L
- Total chromium concentrations reported below the detection limit of 5.1 µg/L in both the primary and duplicate sample
- Carbon-14 detected at 175 pCi/L
- Strontium-90 detected at 3.1 pCi/L
- Tritium detected at 680 pCi/L
- Nitrate reported at 20,800 µg/L
- Trichloroethene reported at 4.9 µg/L (J-qualified, which indicates an estimated value)

C4.4 Well 199-K-186 Log

Figure C-15 is the composite log with analytical results for well 199-K-186. The well is screened in the upper two-thirds of the unconfined aquifer due to elevated Cr(VI) concentrations in the middle of the aquifer. The screen bottom is 9 m (30 ft) above the RUM contact. The Hanford formation/Ringold Formation unit E contact at 14.9 m (49 ft) bgs was reported in the geologist's log as a gradual contact.

The water table is within Ringold Formation unit E. A possible concrete fragment was reported in the Hanford formation at 1.8 m (6 ft) bgs, suggesting fill to this depth.

Neutron moisture logging indicated that moisture ranged from 5% to 10% in the Hanford formation samples, and 2% to 3% in Ringold Formation unit E. This profile exhibits moisture content within the probable background levels under unvegetated conditions. Given typical specific retention capacities of 1% to 2% for these sediments, vertical flow is expected.

The total gamma and natural KUT geophysical log plots show an increased count rate at approximately 49 m (162 ft) bgs and defines the RUM contact. The total gamma signature is reasonably distinct for the Hanford formation/Ringold Formation unit E contact at 15 m (49 ft) bgs. There are higher gamma counts within the upper 3 m (10 ft) of the Ringold Formation unit E that probably represent a higher silt content in the lithology.

Contaminant vertical distribution and concentrations are on the composite log (Figure C-15). The results and discussion for additional analytes are in Section 4.2. Total chromium was 21.1 mg/kg at 16.8 to 17.6 m (55.2 to 57.7 ft) bgs, with the highest concentration of 27 mg/kg at 48.8 to 49.5 m (160 to 162.5 ft) bgs. Soil sampling reported relatively low Cr(VI) levels, up to 0.5 mg/kg, in the vadose zone. This indicates Cr(VI) is <1% of the total chromium in the vadose zone, and suggests most chromium is reduced and immobile.

In the aquifer, Cr(VI) concentrations are below detection except from 35.1–39.6 m (115.1–130 ft) bgs, with correspondingly higher total chromium.

Strontium-90 was not detected in the groundwater, vadose zone soil, or aquifer sediments. Carbon-14 concentrations range from below detection to 716 pCi/L near the RUM contact. Tritium concentrations are higher near the RUM, except for a 2,300 pCi/L concentration at 38.5 m (126.3 ft) bgs. Nitrate concentrations ranged from <1mg/L to over 10 mg/L in the lower unconfined aquifer. The well screen is in highly permeable material. A slug test was attempted, but the groundwater flow rate reduced or eliminated the water level changes as they occurred, indicating a high hydraulic conductivity.

Routine groundwater sampling began in May 2011 at well 199-K-186. Both filtered and unfiltered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported at 3.2 and 3.9 µg/L (B-qualified)
- Total chromium concentrations reported at 7.0 and 9.0 µg/L (both B-qualified)
- Carbon-14 detected at 104 pCi/L
- Strontium-90 not detected at an MDA of 1.6 pCi/L
- Tritium not detected at an MDA of 260 pCi/L
- Nitrate concentrations reported at 1,650 µg/L
- Trichloroethene not detected at a detection limit of 1.0 µg/L

C4.5 Well 199-K-187 Log

Figure C-16 is the composite log with analytical results for well 199-K-187. The well site was chosen to place an upgradient boundary on the Cr(VI) plume, and is located about 325 m (1,066 ft) upgradient from the 183.1 KE Headhouse site. The well has two screen sections separated by an inflatable packer designed and installed with equipment allowing sampling at a fixed depth below the packer. The upper screen extends 4.6 m (15 ft) above the aquifer (potentially for use as either an extraction, monitoring, or injection well), whereas the lower screen section accesses lower portion of the aquifer near the RUM contact.

The Hanford formation/Ringold Formation unit E contact is at 20.9 m (68.5 ft) bgs based on the borehole log. The water table is within Ringold Formation unit E.

Soil sample moisture content ranged from 2% to 4% from the basal Hanford formation into the RUM. The neutron log generally concurred with the laboratory results but indicated slightly lower moisture in the Hanford formation relative to below the Hanford formation/Ringold Formation unit E contact. The 1% to 2% specific retention capacities for these sediments indicate vertical flow is expected.

The total gamma and natural KUT geophysical logs show an increased count rate at the RUM contact, approximately 60 m (197 ft) bgs. The total gamma and KUT signatures exhibit a slight count rate increase at the Hanford formation/Ringold Formation unit E contact at 21 m (67 ft) bgs. There is a natural attenuation in total gamma at the water table.

Contaminant vertical distribution and concentrations are illustrated on the composite log (Figure C-16). Section 4.2 in the main text of this document provides results for additional analytes and discussion. Sediment sampling indicates total chromium concentrations up to 26.6 mg/kg in a zone 1.5 to 3 m (5 to 10 ft) above the water table. At 31.3 to 32.1 m (102.8 to 105.3 ft) bgs, the single detected Cr(VI) soil concentration was 0.13 mg/kg.

Cr(VI) concentrations in groundwater are generally below detection throughout the aquifer except near the base (56 to 60 m [185 to 195 ft]) bgs, where concentrations range from 11.3 to 30.1 µg/L. Total chromium and Cr(VI) concentrations are nearly equal, indicating chromium is in the mobile hexavalent form and minor natural reduction occurs in the aquifer. Strontium-90 was not detected in this well. Carbon-14 concentrations were detected near the RUM contact at approximately 60 pCi/L. Tritium concentrations ranged from below detection to 760 pCi/L, corresponding to the location of higher concentrations for the other analytes. Nitrate concentrations ranged from 2.78 to 24.7 mg/L. Slug testing indicates the aquifer hydraulic conductivity is approximately 27 m/day (89 ft/day), within the conductivity range expected for the saturated Ringold Formation unit E.

After well acceptance, routine sampling occurred in April 2011 at well 199-K-187. Both filtered and unfiltered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results from sampling the aquifer are as follows:

- Cr(VI) concentrations reported at 3.3 and 3.0 µg/L (both B-qualified)
- Total chromium concentrations reported at 11.0 and 5.0 µg/L (both B-qualified)
- Carbon-14 not detected at an MDA of 7.93 pCi/L
- Strontium-90 detected at 4.5 pCi/L
- Tritium detected at 280 pCi/L
- Nitrate concentrations reported at 20,500 µg/L
- Trichloroethene not detected at a detection limit of 1.0 µg/L

C4.6 Well 199-K-188 Log

Figure C-17 shows the composite analytical results for well 199-K-188. The well location was selected to determine contaminant nature and extent, physical and hydrological properties, and potential Cr(VI) transport mechanisms within the RUM. The well was drilled 15.2 m (50 ft) into the RUM, but no water bearing units were encountered. The highest Cr(VI) concentration was detected at the bottom of the aquifer (10 µg/L). The well screen was placed to intercept possible contaminant movement at the top of the aquifer. Well construction used 4 in. polyvinyl chloride (PVC) due to anticipated waste site remediation.

The Hanford formation/Ringold Formation unit E contact is 18.3 m (60 ft) bgs as identified on the geologic log. The water table is in Ringold Formation unit E at about 30 m (98 ft) bgs. The well received neutron moisture logging, along with laboratory soil sample analyses. Soil sample moisture was slightly higher (3% to 6%) in the Hanford formation relative to the 1% to 5% in Ringold Formation unit E. The Hanford formation/Ringold Formation unit E contact exhibits noticeable increase in moisture content as the sediments transition from a gravelly sand to a silty sandy gravel. The profile exhibited moisture content consistent with an unvegetated surface.

The total gamma and natural KUT geophysical logs show an increased count rate at the RUM contact, about 66 m (183 ft) bgs. An increase in the KUT log count occurs at approximately 33 m (108 ft) bgs associated with a lithologic change within Ringold Formation unit E.

Contaminant vertical distribution and concentrations are on the composite log (Figure C-17). Results for additional analytes and discussion are in Section 4.2. Cr(VI) was encountered in the first soil sample at 1.6 mg/kg; this may be from spills around the 120-KE-6 Tank. Total chromium concentrations ranged from 4 to 26 mg/kg, with a concentration of 108 mg/kg at 13 m (43 ft) bgs. The corresponding Cr(VI) concentration at this depth was <0.4 mg/kg.

Groundwater sample results show total chromium at low concentrations, and Cr(VI) at or near the detection limit through most of the unconfined aquifer. A total chromium concentration of 10 µg/L at 54.5 m (178.9 ft) bgs had a corresponding 10.7 µg/L Cr(VI) concentration. Heaving sand prevented groundwater sampling at 47.3 m (155 ft) and 52.7 m (173 ft) bgs. Potable water (1,900 L [500 gal]) was added to the well between 45.7 and 51.8 m (150 and 170 ft) bgs to control the heaving sand.

Strontium-90 was not detected at this location. Nitrate concentrations were approximately 20 mg/L in the aquifer upper, with lower concentrations in the lower aquifer. Carbon-14 concentrations ranged from below minimum detectable activity to 181 pCi/L. Tritium concentrations were generally <500 pCi/L with higher concentrations of 820 pCi/L at 36.6 m (120.2 ft); 1,100 pCi/L at 48.8 m (160 ft); and 3,700 pCi/L at 56.1 m (184 ft) bgs. Slug testing indicated the hydraulic conductivity is approximately 16 m/day (53 ft/day), within the range expected for saturated Ringold Formation unit E.

Following well acceptance, routine sampling at well 199-K-188 began in June 2011. Filtered and unfiltered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) detected at 41.1 and 41.6 µg/L
- Total chromium detected at 37.0 and 38.0 µg/L
- Carbon-14 detected at 62.3 pCi/L
- Strontium-90 detected at 6.6 pCi/L
- Tritium not detected at an MDA of 280 pCi/L
- Nitrate concentrations reported at 17,700 µg/L

C4.7 Well 199-K-189 Log

Figure C-18 shows the composite analytical results for well 199-K-189. The initial planned location was downgradient from the 116-KE-3 crib to replace well 199-K-109A, where the strontium-90 concentration was 1,120 pCi/L when decommissioned. Waste site remediation at the KE Fuel Storage Basin and 116-KE-3 crib caused well relocation to a cross-gradient location 67 m (220 ft) northeast. The well is screened across the 24.4 m (80 ft) aquifer thickness. The Hanford formation/Ringold Formation unit E

contact is 11.2 m (37 ft) bgs, below a thin caliche layer. The water table is in Ringold Formation unit E at about 20.5 m (74 ft) bgs.

This well received neutron moisture logging and soil sample analyses, with good agreement between the methods. Soil sample moisture showed a slightly higher level in the Hanford formation sediment compared to Ringold Formation unit E, although there was greater variability than other locations. This profile exhibits moisture content consistent with an unvegetated surface. Therefore, vertical flow happens under the measured conditions given typical specific retention capacities of 1% to 2% for these sediments. The moisture content is at or near specific retention at about 4.6 m (15 ft) bgs and 19 and 22 m (62 and 72 ft) bgs.

Increased total gamma and KUT log counting rates occurs at 12 m (40 ft) bgs, and marks the Hanford formation/Ringold Formation unit E contact. The total gamma and natural KUT geophysical log plots reveal an increased count rate at 47 m (154 ft) bgs, and designates the RUM contact.

Vadose zone soil, aquifer sediment, and groundwater samples were collected at discrete depth intervals for contaminant analyses. Contaminant vertical distribution and concentrations are on the composite log (Figure C-18). Results for additional analytes and discussion are in Section 4.2 in the main text of this document. There is a slight Cr(VI) increase to 0.8 mg/kg at 3 m (10 ft) bgs. Total chromium concentrations are <25 mg/kg except at 12.2 to 13 m (40 to 42.5 ft) bgs, the concentration was 211 mg/kg. The corresponding Cr(VI) value was 0.15 mg/kg.

Elevated contaminant concentrations were not observed in the PRZ. Groundwater sample results showed elevated total chromium values in the unconfined aquifer, with concentrations at 18.8 µg/L at 35.7 m (117 ft) bgs. Cr(VI) and total chromium concentrations in groundwater range from below detection to 20 µg/L, with values for Cr(VI) <total chromium, as expected. Two zones measured above 10 µg/L—23 to 25 m (80 to 85 ft) and 33 to 40 m (110 to 130 ft)—both are in sandy gravels. A fine-grained layer separates these zones.

Strontium-90 is nondetect in the vadose zone and aquifer sediment. There is a reported strontium-90 detection (4.1 pCi/L) in the groundwater at 23.5 m (77 ft) bgs. Nitrate levels range from 2,660 to 33,800 µg/L, with concentrations generally decreasing with depth. Carbon-14 concentrations generally decrease with depth. The highest detected value was 1,200 pCi/L at 25 m (82 ft) bgs. With only one exception, tritium exceeds the 20,000 pCi/L standard between 26.7 to 32.6 m (87.7 to 107 ft) bgs, with the highest value at 140,000 pCi/L. Tritium concentrations generally decrease with depth to nondetect at 41.8 m (137 ft) bgs, then increase to 4,000 pCi/L at the RUM contact. Slug testing calculations reported hydraulic conductivity is approximately 1 m/day (3.3 ft/day), within the conductivity range expected for the saturated Ringold Formation unit E.

Following well acceptance, a routine groundwater sample and a duplicate were collected in June 2011 at well 199-K-189. Analytical results were as follows:

- Filtered sample Cr(VI) concentrations reported at 23.0 and 33.6 µg/L
- Filtered total chromium concentrations reported at 28.0 and 28.5 µg/L
- Carbon-14 detected at 263 and 117 pCi/L
- Strontium-90 detected at 3.9 pCi/L
- Tritium detected at 10,800 and 7,500 pCi/L
- Nitrate detected at 9,300 and 9,650 µg/L (both D-qualified)

C4.8 Well 199-K-190 Log

Figure C-19 shows the composite analytical results for well 199-K-190. The well is located downgradient from the KE Reactor and near the northern edge of the area. It was sited to define the Cr(VI) and strontium-90 plume extent. The well screen design monitors low concentration plumes at the aquifer bottom. The Hanford formation/Ringold Formation unit E contact is 10 m (33 ft) bgs based on geophysical logging and geologic descriptions.

The water table is in the Ringold Formation unit E at about 17 m (55 ft) bgs. Soil sample moisture in the vadose zone ranged from 6% to 8%, with an increase to 20% at 12 m (40 ft). Neutron logging shows slightly higher soil moisture in the Hanford formation upper 5.2 m (17 ft) before declining slightly within a siltier gravelly unit. The lower moisture content continues into the upper Ringold Formation unit E. The two data trends diverge at 12 m (40 ft) bgs, as the neutron log does not increase, similar to the laboratory value.

The total gamma and natural KUT geophysical log plots show an increased count rate near and at the RUM contact, approximately 40.5 m (133 ft) bgs.

Groundwater, vadose zone soil, and aquifer sediment samples were collected at discrete depth intervals for analysis. The vertical distribution and concentrations are on the composite log (Figure C-19). Results for additional analytes and discussion are in Section 4.2. The soil sample from 16 to 16.8 m (52.5 to 55 ft) bgs, reported total chromium at 90 mg/kg. The corresponding Cr(VI) concentration was 0.12 mg/kg, near the MDL. The disparity suggests that most chromium at this location is trivalent.

Cr(VI) concentrations in groundwater are <10 µg/L across the unconfined aquifer, except at or near the RUM contact. The Cr(VI) concentrations ranged from nondetect to 12.9 µg/L, and total chromium concentrations ranged from 1.69 to 16.1 µg/L, with no discernible pattern. The total chromium concentration at 35 m (115 ft) bgs was 16.1 µg/L, and the corresponding Cr(VI) concentration was 4.3 µg/L.

Strontium-90 was not detected in vadose zone soil, aquifer sediments, and groundwater. The nitrate concentration was 54,000 µg/L at 18 m (59 ft) bgs. Nitrate concentrations decreased to 10,300 µg/L at the bottom of the unconfined aquifer. Carbon-14 concentrations ranged from 193 to 469 pCi/L, with no obvious vertical distribution trend. Tritium concentrations increased with depth, with values below the MDA in the upper aquifer and a 1,400 pCi/L high value at the RUM contact. Slug testing calculations indicate the hydraulic conductivity is approximately 12 m/day (39 ft/day), within the conductivity range expected for the saturated Ringold Formation unit E.

Sampling followed well acceptance for 199-K-190 during June 2011. Both filtered and unfiltered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported at 17.5 and 17.4 µg/L
- Total chromium concentrations reported at 17.0 µg/L for both samples (both B-qualified)
- Carbon-14 detected at 131 pCi/L
- Strontium-90 detected at 4.1 pCi/L
- Tritium detected at 470 pCi/L
- Nitrate concentrations reported at 31,900 µg/L

C4.9 Well 199-K-191 Log

Figure C-20 shows the composite analytical results for well 199-K-191. The well is located 523 m (1,715 ft) east-northeast from the KE Reactor. The well was intended to define the Cr(VI) plume upgradient from the 116-K-2 trench. The well screen is in the uppermost unconfined aquifer but extends an additional 6.1 m (20 ft) into the vadose zone. The Hanford formation/Ringold Formation unit E contact is 12.8 m (42 ft) bgs, and is gradual, suggesting the Ringold Formation unit E and Hanford formation sediments were reworked during deposition. The water table is in the Ringold Formation unit E approximately 22 m (72 ft) bgs.

Vadose zone soil sample moisture content ranged from 1% to 6%. Neutron moisture logging detected volumetric moisture content relatively greater in the top 3 m (10 ft) than through the remaining vadose zone. Volumetric moisture content increased slightly in the Ringold Formation unit E to the water table. Soil sample moisture content decreased to 1% to 2% in the upper Ringold Formation unit E, although the neutron log did not show this change. The sediment is silty, sandy gravel. This profile exhibits moisture content consistent with an unvegetated surface.

The total gamma and natural KUT geophysical log plots show an increased count rate at depth, indicating the RUM contact at 46.5 m (153 ft) bgs. An increase in both the total gamma and KUT log count occurs at 13 m (42 ft) bgs, marking the Hanford formation/Ringold Formation unit E contact.

Groundwater, vadose zone soil, and aquifer sediment samples were collected at discrete depth intervals for analysis. The vertical distribution and concentrations are on the composite log (Figure C-20). Section 4.2 in the main text of this document provides results for additional analytes and discussion. Total chromium values ranged from 7.58 to 38.7 mg/kg in soil, with Cr(VI) values ranging from below detection limits to 0.19 mg/kg. A soil sample from 17.7 to 18.5 m (58.2 to 60.7 ft) bgs reported total chromium value at 38.7 mg/kg, with a corresponding Cr(VI) concentration of 0.07 mg/kg. This suggests that most chromium at this location is trivalent chromium.

Total chromium concentrations in groundwater were mostly non-detect. The highest reported total chromium concentrations were 27.5 and 38.4 µg/L at 23.8 and 25.3 m (78 and 83 ft) bgs, respectively. The Cr(VI) concentrations in groundwater are non-detect except for one sample reported at 35.3 µg/L at 25.3 m (83 ft) bgs, which corresponds to the high detection for total chromium.

Strontium-90 is nondetected in both soil and groundwater samples. Nitrate concentrations were >45 mg/L in the upper part of the aquifer and then decreased to a range of 11.4 to 17.6 mg/L between 32.9 and 47.2 m (108 and 155 ft) bgs. There was no carbon-14 detected in this well. Tritium concentrations ranged from 5,000 to 6,200 pCi/L across the lower two-thirds of the aquifer. Slug testing calculations show the hydraulic conductivity is 0.5 m/day (1.7 ft/day), within the range expected for saturated Ringold Formation unit E.

Sampling followed well acceptance for 199-K-191 in June 2011. A filtered sample and an unfiltered sample were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported below the detection limit of 2 µg/L and at 2.1 µg/L (B-qualified)
- Total chromium concentrations reported at 7.0 and 6.0 µg/L (both B-qualified)
- Carbon-14 not detected at an MDA of 8.13 pCi/L
- Strontium-90 detected at 3.4 pCi/L
- Tritium detected at 4,500 pCi/L
- Nitrate concentrations reported at 12.0 mg/L

C4.10 Well 199-K-192 Log

Figure C-21 shows the composite analytical results for well 199-K-192. The location investigates the contamination extent, potential transport mechanisms, and physical and hydrological properties of the RUM. The well is located near the southwest, head end of the 116-K-2 trench. The well was drilled 15.2 m (50 ft) into the RUM and encountered a 2.75 m (9 ft) thick water-bearing, sand lens at 10.7 m (35 ft) into the RUM. The well screen spans this confined aquifer. The Hanford formation/Ringold Formation unit E contact is at 6.7 m (22 ft) bgs, but the exact boundary is difficult to confirm because of depositionally reworked sediments. The unconfined aquifer is in the Ringold Formation unit E, and the water table was at 15 m (49 ft) bgs. Following well development, the water level from the screened RUM unit was 9 m (30 ft) bgs. The confined aquifer higher hydraulic head shows an upward gradient at this location.

The vadose zone received neutron moisture logging. The soil sample percent moisture ranged from 2% to 5% across the upper 6.1 m (20 ft) of Hanford formation. The vadose zone sediment is sandy gravel with a layer of gravelly silt from 1.5 to 4.5 m (5 to 15 ft); the atypical gravelly mud sediments resulted from numerous washouts over the 199-K-2 trench operating history. This profile has moisture content consistent with an unvegetated surface.

The total gamma and natural KUT geophysical log plots show an increased count rate at depth, indicating the RUM contact at 45 m (148 ft) bgs. There are no definitive total gamma or KUT log count changes to indicate the Hanford formation/Ringold Formation unit E contact 6.7 m (22 ft) bgs, as identified on the geologic log.

The composite log (Figure C-21) shows contaminant vertical distribution and concentrations. Results for additional analytes and discussion are in Section 4.2. Cr(VI) values are below detection limits throughout the soil column while the total chromium concentrations range from 4.57 to 56.0 mg/kg, with no obvious pattern. The highest value is proximal to the PRZ.

Total chromium concentrations are <20 µg/L in groundwater, with two exceptions. Total chromium ranged from 22.3 to 72.5 µg/L at depths between 18.3 and 22.9 m (60 to 75 ft) bgs. Cr(VI) concentrations in groundwater are well correlated with the total chromium values, with the highest Cr(VI) concentrations within the same depth interval(s). Cr(VI) concentrations in the remainder of the aquifer are below 15 µg/L. The concentrations of Cr(VI) and total chromium are nearly equal in the groundwater, suggesting that most chromium in groundwater is hexavalent.

During drilling, strontium-90 was 0.282 pCi/g at 16.7 to 17.5 m (54.8 to 57.3 ft) bgs in the vadose zone. Groundwater strontium-90 was 19 pCi/L at the aquifer top and 2.4 pCi/L at 21.4 m (70.1 ft) bgs. Nitrate detections were >45 mg/L in the upper 6 m (20 ft), with concentrations decreasing to below 10 mg/L near the RUM contact. Tritium values in the top 6 m (20 ft) of the aquifer ranged from 87,000 to 1,400,000 pCi/L and decreased with depth. Slug testing indicates hydraulic conductivity is approximately 0.2 m/day (0.7 ft/day), within the conductivity range expected for RUM saturated zones.

Groundwater samples collected after well completion in April 2011 represent samples within the uppermost RUM aquifer at this location. A filtered sample and an unfiltered sample were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations below the 2 µg/L detection limit in both samples
- Total chromium concentrations below the 2 µg/L detection limit in both samples
- Carbon-14 not detected at an MDA of 7.93 pCi/L
- Strontium-90 detected at 3.8 pCi/L

- Tritium not detected at an MDA of 260 pCi/L
- Nitrate concentrations reported at 6,240 µg/L (D-qualified)

C4.11 Well 199-K-193 Log

Figure C-22 shows the composite analytical results for well 199-K-193. The well site is 1.1 km (3,600 ft) upgradient from the 116-K-2 trench and 1.4 km (4,600 ft) east of the KE Reactor. The well location was selected to investigate the Cr(VI) plumes extent. This well was screened in two sections, the unconfined aquifer upper and lower thirds. The lower screen base is at the RUM contact. The upper screen extends 4.9 m (16 ft) into the vadose zone for possible use as an injection well in future remediation activities. The Hanford formation/Ringold Formation unit E contact is 14.0 m (46 ft) bgs, as identified on the geologist's log. The water table is within the Ringold Formation at 23.5 m (77.2 ft) bgs. The RUM contact is 49 m (161 ft) bgs.

The soil sample moisture was between 2 and 3%. Neutron moisture logging indicates the vadose zone Ringold Formation unit E has slightly more moisture than the Hanford formation. The neutron log shows a relative change in residual soil moisture within the PRZ. The neutron moisture data indicate a slightly lower moisture level in the Hanford formation relative to below the Hanford formation/Ringold Formation unit E contact. Given typical specific retention capacities of 1% to 2%, vertical flow is expected.

The total gamma and natural KUT geophysical log plots have an increased count rate at the RUM contact, 49 m (160 ft) bgs. The total gamma signature and KUT exhibit an increased count rate at the Hanford formation/Ringold Formation unit E contact, 14 m (46 ft) bgs. The drop in the gamma log counts rate at the water table is from natural attenuation when water is the medium. There is a marked increase in both the total gamma and thorium signatures at 40 m (131 ft) bgs.

Samples from vadose zone soil, aquifer sediment, and groundwater were collected from discrete depth intervals for COPC analysis. Vertical distribution and concentrations are illustrated in the composite log (Figure C-22). Results for additional analytes and discussion are in Section 4.2. Cr(VI) was not detected in the vadose zone; however, total chromium was detected throughout the vadose zone, with concentrations to 57.8 mg/kg at 20 m (66 ft) bgs. The results indicate most chromium is reduced and immobile. The Cr(VI) may have migrated into this location during discharge to the 116-K-2 trench. A small Cr(VI) flux would have been reduced over time.

Both Cr(VI) and total chromium concentrations are generally below detection to 32.9 m (108 ft) bgs in groundwater, below which concentrations range to 14.9 µg/L from 9 to 15 m (30 to 50 ft) below the water table. Total chromium and Cr(VI) concentrations are nearly equal, indicating Cr(VI) is predominant; little natural reduction is occurring in the aquifer at this location.

Strontium-90 was not detected in vadose zone soil, aquifer sediments, or groundwater, and carbon-14 was not detected in groundwater. Nitrate concentration was less than 45 mg/L in the upper and central aquifer, and decreased to near non-detect at the base. Tritium was below the MDA. Slug testing indicates hydraulic conductivity is approximately 1 m/day (3.3 ft/day), the upper end expected for the saturated Ringold Formation unit E.

Following well acceptance at 199-K-193, a sample and duplicate were collected in May 2011. Cr(VI) was analyzed as a filtered sample only once. Analytical results were as follows:

- Unfiltered Cr(VI) concentrations reported at 24 and 31 µg/L, and a filtered result of 25 µg/L
- Filtered total chromium concentrations reported at 22 µg/L (B-qualified) and 25.6 µg/L

- Carbon-14 not detected at MDAs of 7.97 and 49.6 pCi/L
- Strontium-90 not detected at an MDA of 1.5 pCi/L
- Tritium not detected at MDAs of 260 and 328 pCi/L
- Nitrate concentrations reported at 10,600 and 11,100 µg/L (both D-qualified)

C4.12 Well 199-K-194 Log

Figure C-23 is the log with composite analytical results for well 199-K-194. The well is 1.4 km (4,600 ft) southeast from the northeast end of the 119-K-2 trench and 2.1 km (6,900 ft) east of the KE Reactor. The well was located to determine the Cr(VI) plume upgradient extent. The well screen is in the unconfined aquifer upper 7.6 m (25 ft). The Hanford formation/Ringold Formation unit E contact is 19.8 m (65 ft) bgs. The water table is in the Ringold Formation unit E at 25 m (82 ft) bgs.

Soil moisture ranged from 1% to 3% in laboratory testing. Neutron moisture logging revealed a relatively even trend in moisture content within the vadose zone. Slightly higher neutron log moisture content was measured near the ground surface and in a silty sandy gravel. The sediment ranges from silty gravel to sandy gravel in the vadose zone. The vadose zone exhibits moisture contents consistent with an unvegetated surface. Vertical flow will happen under the measured conditions, given typical 1% to 2% specific retention capacities.

The total gamma and natural KUT geophysical log plots show an increased count rate at depth, indicating the RUM contact at 43 m (141 ft) bgs. A slight increase in both the total gamma and KUT log count occurs at 13 m (42 ft) bgs, and marks the Hanford formation/Ringold Formation unit E contact.

Samples from vadose zone soil, aquifer sediment, and groundwater were collected from discrete depth intervals for COPC analysis. Vertical distribution and concentrations are illustrated in the composite log (Figure C-23). Section 4.2 in the main text of this document provides results for additional analytes and discussion. Cr(VI) values are generally less than total chromium values. Total chromium concentrations are less than 15 mg/kg, except for a reported concentration of 23.6 mg/kg at 40.5 m (133 ft) bgs. The corresponding sample Cr(VI) concentration was less than the detection limit. Groundwater total chromium concentrations were less than 10 µg/L, with Cr(VI) at correspondingly low or undetectable levels.

Strontium-90 was not detected in vadose zone soil, aquifer sediment, or groundwater at this location, and carbon-14 was not detected in groundwater. Groundwater nitrate concentrations were less than 25 mg/L, in the upper aquifer 3 m (10 ft), and decreased with depth. Tritium was less than the MDA except near 40.8 m (134 ft) bgs, which reported 1,100 and 190 pCi/L concentrations. Slug testing indicates hydraulic conductivity at approximately 1 m/day (3.3 ft/day), near the upper conductivity range for the saturated Ringold Formation unit E.

199-K-194 sampling followed well acceptance in May 2011. Both filtered and unfiltered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported at 5.2 and 5.6 µg/L
- Total chromium concentrations reported at 9 µg/L (B-qualified) in both samples
- Carbon-14 not detected at an MDA of 7.92 pCi/L
- Strontium-90 detected at 1.8 pCi/L
- Tritium not detected at an MDA of 260 pCi/L
- Nitrate concentrations reported at 9,780 µg/L (D-qualified)

C4.13 Well 199-K-195 Log

Figure C-24 shows the composite analytical results for well 199-K-195. This well is 372 m (1,220 ft) southeast from the KW Reactor. The well was located at the 100-K-97 french drain, about 4.6 m (15 ft) bgs in a waste site excavation, to help determine contaminant extent and potential transport mechanisms, and RUM physical and hydrological properties. The adjacent 183.1-KW Headhouse and the 183.2-KW Sedimentation Basin were demolished between July 2009 and July 2010. The well was drilled 15.1 m (50 ft) into the RUM and did not encounter any water-bearing zones. This temporary well was 10.1 cm (4 in.) PVC, screened in the upper unconfined aquifer. The well was decommissioned in April 2011 for waste site remediation. The Hanford formation/Ringold Formation unit E contact was 15.1 m (50 ft) below the trench bottom and approximately 19.8 m (65 ft) below the original ground surface. The water table was 30.3 m (100 ft) below the surrounding ground surface.

Soil moisture samples ranged from 4% to 8% in the Hanford formation and 1% to 5% in the Ringold Formation unit E vadose zone. The geologic material is gravelly sand in the vadose zone, and exhibited moisture content consistent with an unvegetated surface. Vertical flow will happen under the measured conditions, given typical specific retention capacities of 1% to 2%.

The total gamma and natural KUT geophysical log plots reveal increased count rates at depth, indicating the RUM contact at 64 m (177 ft) bgs. A slight increase in both the total gamma and KUT log count was at 15 m (49 ft) bgs, marking the Hanford formation/Ringold Formation unit E contact.

Samples from vadose zone soil, aquifer sediment, and groundwater were collected from discrete depth intervals for COPC analysis. Vertical distribution and concentrations are illustrated in the composite log (Figure C-24). Additional analytes and discussion are in Section 4.2. Cr(VI) concentrations were less than total chromium in soil. Total chromium concentrations are mostly below 25 mg/kg, except for samples from 23 to 23.6 m (75.3 to 77.3 ft) and 22.4 to 25.2 m bgs, where total chromium was 3,560 mg/kg and 54.8 mg/kg, respectively. The corresponding Cr(VI) analyses were non-detect.

The groundwater Cr(VI) concentrations were 4,980 and 1,970 µg/L in the 30.4 and 31.9 m (99.7 and 104.5 ft) samples The Cr(VI) concentration was 753 µg/L at 50.3 m (165 ft) bgs, but was non-detect in the next lower sample interval. Total chromium levels reflect a similar pattern, with the highest values at 4,300 and 1,780 µg/L in the upper aquifer, and a 701 µg/L concentration corresponding to the sample from 50.3 m (165 ft) bgs.

Strontium-90 was non-detect in this borehole. Nitrate was less than 45,000 µg/L throughout the water column, with the highest (37,200 µg/L) concentration in the 30.4 m (99.7 ft) bgs sample. There were carbon-14 detections in the upper aquifer to 899 pCi/L, but these decreased with depth. Carbon-14 was reported at 534 and 68.6 pCi/L in the 3.3 m (10.8 ft) interval above the RUM contact. Tritium activity was very low, with a 1,900 pCi/L maximum activity at 33.6 m (110.3 ft) bgs. Slug testing indicated hydraulic conductivity is approximately 15 m/day (50 ft/day), within the conductivity range expected for the saturated Ringold Formation unit E.

Sampling followed well 199-K-195 acceptance in mid-April 2011, with the well subsequently decommissioned. Duplicate samples were collected, and the analytical results were as follows:

- Filtered Cr(VI) concentrations at 3,150 and 3,340 µg/L (both D-qualified)
- Filtered total chromium concentrations at 3,360 and 3,320 µg/L
- Carbon-14 detected at 310 and 316 pCi/L
- Strontium-90 detected at 2.7 pCi/L in one sample, and not detected at an MDA of 1.6 in the duplicate

- Tritium detected at 1,300 and 1,200 pCi/L
- Nitrate concentrations reported at 32,500 and 32,900 µg/L (both D-qualified)

C4.14 Wells 199-K-196, 199-K-197, 199-K-198, and 199-K-199

Wells 199-K-196, 199-K-197, 199-K-198, and 199-K-199 were installed as part of the P&T system interim action. Well 199-K-196 is located downgradient from the current K West plume area, approximately midway between extraction wells 199-K-138 and 199-K-132. These wells were installed in spring and summer 2011. Wells 199-K-197, 199-K-198, and 199-K-199 are located downgradient from the 116-K-2 trench southwest end. These wells addressed a Cr(VI) plume outside of the then 2011 existing extraction well field. Downgradient aquifer tubes AT-K-3-D, AT-K-3-M, and AT-K-3-S reported Cr(VI) concentrations between 32 and 85 µg/L for the prior 7 years, and did not show decreasing concentrations similar to other aquifer tubes.

Monitoring well 199-K-197 and extraction wells 199-K-198, and 199-K-199 are located downgradient from wells 199-K-162 and 199-K-120A. Well 199-K-197 is closest to wells 199-K-162 and 199-K-120A 51 m (167 ft) cross gradient from 199-K-120A and 142 m (466 ft) from the Columbia River. Well 199-K-198 is located 100 m (328 ft) equidistant between well 199-K-120A and the river. Well 199-K-199 is also located equidistant (93 m [305 ft]) between the river and well 199-K-120A. The three wells are located on the lowest terrace above the current river channel and are 4.6 to 6.2 m (15 to 20 ft) above the groundwater table. The local geology, contaminant distribution, and well designs details are in the following paragraphs.

The total depth for well 199-K-197 is 32.3 m (106 ft). The unconfined aquifer was 4.6 m (15 ft) bgs and the RUM was 30.8 m (101 ft) bgs. There is no Hanford formation described in the geologic log, with all samples Ringold Formation unit E sands and gravels. Water levels in the well rose to 3.7 m (12 ft) bgs during high river stage.

Soil samples were collected at 1.5 m (5 ft) intervals in the vadose zone and the RUM in wells 199-K-197, 199-K-198, and 199-K-199. At 199-K-197, total chromium concentrations ranged between 6.53 and 48.8 mg/kg, while Cr(VI) concentrations ranged from non-detect to 0.914 mg/kg.

Groundwater samples were collected at 3.1 m (10 ft) intervals during drilling. Well 199-K-197 first detected Cr(VI) in groundwater at 22.7 m (74.4 ft) bgs. Between that depth and 31 m (101 ft) bgs, Cr(VI) concentrations ranged between 12 and 31 µg/L, reaching the maximum value at 25 m (82 ft) bgs. The well screen is 15.2 cm (6 in.) diameter, 20-slot stainless steel casing from 21.3 and 30.5 m (70 and 100 ft) bgs. Strontium-90 analyses were largely nondetects below 0.46 pCi/L except for one sample with 0.75 pCi/L at 4.57 m (15 ft) bgs.

The drilled depth for well 199-K-198 is 30.9 m (101.5 ft) bgs. The unconfined aquifer was 4.8 m (16 ft) bgs, and the RUM contact was at 28.5 m (93.6 ft) bgs. The Hanford formation and Ringold Formation unit E contact is not well defined, and may represent reworked Ringold Formation. Soil from ground surface to 6.1 m (20 ft) bgs match descriptions of Ringold Formation unit E but appear related to Hanford formation basaltic sediment from 6.1 to 20.7 m (20 to 68 ft) bgs. Sediments below this depth are Ringold Formation unit E felsic sands and gravels. Based on the Cr(VI) distribution in the aquifer, the well was screened with 15.2 cm (6 in.) 20-slot stainless steel casing between 4.57 and 16.8 m (15 and 55 ft) bgs.

Soil samples at 199-K-198 indicated total chromium concentrations between 9.4 and 19.1 mg/kg. Cr(VI) concentrations were nondetect with one exception at 0.046 mg/kg. Groundwater samples reported a single Cr(VI) detection, 9.8 µg/L at 14.14 m (46.3 ft) bgs. Total chromium concentrations ranged between

9.49 and 12.1 mg/kg. RUM soil samples reveal strontium-90 was not detected, but Cr(VI) (0.046 mg/kg) and total chromium (19.1 mg/kg) were detected.

Reported Cr(VI) concentrations in groundwater at well 199-K-198 were largely non-detect, with 9.6 µg/L at a depth of 14.1 m (46.3 ft) bgs. Detected total chromium was just above the MDL, ranging between 2.37 and 4.04 µg/L at depths between 14.1 and 26.1 m (46 and 86 ft) bgs. Strontium-90 was detected only in the deepest samples, 26.1 and 28.5 m (86 and 93 ft) bgs, at 5.1 and 3.8 pCi/L, respectively. Tritium concentrations ranged between 7,900 and 19,000 pCi/L across the unconfined aquifer, with the greater concentrations near the aquifer top. Nitrate concentrations reached 54,900 and 29,700 µg/L at 7.93 and 10.97 m (26 and 36 ft) below the top of the aquifer but were consistently between 12,000 and 13,300 µg/L over the rest of the aquifer. There was no carbon-14 detected in well 199-K-198.

Well 199-K-199 was drilled to 31.4 m (103.1 ft) bgs total depth. The unconfined aquifer was 5.5 m (18 ft) bgs, and the RUM at 29.5 m (96.6 ft) bgs. In well 199-K-199, after an initial 3.7 (12 ft) thickness of Ringold Formation unit E-like sediments, Hanford formation type basalt rich sands and gravels were encountered between 3.7 and 15.2 m (12 and 50 ft) bgs. Below that depth, the Ringold Formation unit E sediments continued to the RUM contact. Based on the Cr(VI) distribution in the aquifer, the well design was 15.2 cm (6 in.) 20-slot stainless steel screen between 19.5 and 28.7 m (64 and 94 ft) bgs. The screened interval spans where Cr(VI) concentrations exceeded 10 µg/L.

Soil samples at 199-K-199 revealed total chromium concentrations between 6.44 and 27.7 mg/kg. Cr(VI) results were largely nondetect except a single 0.203 mg/kg value at 4.57 m (15 ft) bgs. There were no strontium-90 detections in the vadose zone.

Cr(VI) was detected in most groundwater samples at well 199-K-199, with nondetect values at 12.1 and 27.3 m (40 and 89 ft) bgs. Cr(VI) concentrations ranged from 3.5 to 38.5 µg/L, with the highest concentration at the RUM contact. Total chromium concentrations followed the same pattern. Neither strontium-90 nor carbon-14 were detected in this well. Tritium and nitrate have opposite trends with depth: nitrate concentrations decreased from 17,700 to 8,200 µg/L, while tritium increased from 7,100 to 17,000 pCi/L.

Analytical data from the three wells indicate Cr(VI) concentrations passing extraction wells 199-K-120A and 199-K-162 are lower than observed at downgradient aquifer tubes. The KR-4 P&T system extraction wells were offline between October 2010 and mid-January 2011. Pumping then resumed, but Cr(VI) in the extraction wells, which had decreased below 10 µg/L by June 2010, remained low in 2011. The Cr(VI) distribution in the deeper aquifer is unusual but may reflect the local extraction effect.

C4.15 Well 199-K-200 Log

Figure C-25 has the composite analytical results for well 199-K-200. The well is at the 116-K-2 trench southwest end and was a planned characterization boring. The well is screened across the uppermost unconfined aquifer as a temporary well, with an 18 m (59 ft) total depth. The Hanford formation/Ringold Formation unit E contact is at 8.2 m (27 ft) bgs in reworked gravels from the Hanford formation and Ringold Formation unit E. The water table is 15.5 m (51 ft) bgs, in the Ringold Formation unit E. The well construction is 10.2 cm (4 in.) diameter PVC mounted flush with the ground surface.

Soil samples were not analyzed for moisture content. Neutron moisture logging was conducted in well casing for which the system was calibrated, and the results showed 3% to 11% volumetric moisture. The Hanford formation is gravelly sand, and supports a low moisture content. The vadose zone exhibits moisture content consistent with an unvegetated surface. Vertical flow is expected under the measured conditions given typical (1% to 2%) specific retention capacities.

The total gamma and natural KUT geophysical log plots show a minor increase at 13.5 m (45 ft) bgs that identifies the Hanford formation/Ringold Formation unit E contact.

Sediment and upper aquifer samples were collected at discrete depth intervals during drilling and analyzed for total chromium, Cr(VI), strontium-90, nitrate, carbon-14, and tritium. Contaminant distribution and concentrations are on the composite plot (Figure C-25). Results for additional analytes and discussion are in Section 4.2. The Cr(VI) results were below the MDL with a single exception at 12.9 to 13.7 m (42.4 to 44.9 ft), where a duplicate sample result reported a low concentration. Total chromium concentrations are below 30 mg/kg, except for 39.7 mg/kg at 10.1 m (33 ft) bgs. Groundwater samples are from the upper aquifer. Both total chromium and Cr(VI) concentrations were at or near the detection limits, with the highest total chromium value at 3.28 µg/L.

Strontium-90 is in the vadose zone and aquifer sediments at <5 pCi/g. Groundwater strontium-90 analyses reported 130 and 160 pCi/L. A carbon-14 result in groundwater is 44.4 pCi/L, but carbon-14 was detected in soil. Nitrate is present in the vadose zone soil at concentrations <10 mg/kg. Nitrate was less than 45 mg/L. Tritium activity in soil was below the MDA except for one very low detection. Groundwater tritium detections are 3,100 and 6,000 pCi/L. Slug testing was not conducted.

Following well acceptance, 199-K-200 was sampled in January 2011. Two filtered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported at 30.0 and 31.1 µg/L
- Total chromium concentrations reported at 32.1 (D-qualified) and 33.1 µg/L
- Carbon-14 not detected at an MDA of 41.8 pCi/L
- Strontium-90 detected at 190 pCi/L
- Tritium detected at 3,200 pCi/L
- Nitrate concentration reported at 29,500 µg/L (D-qualified)

C4.16 Well 199-K-201 Log

Figure C-26 shows the composite analytical results for well 199-K-201 (C7832). The well is located at the northeast end of the 116-K-2 trench. The location was intended as a characterization boring, but was completed as a temporary well to collect water samples. The screen is in the upper unconfined aquifer and the boring was drilled to 18 m (59 ft) bgs total depth. The Hanford formation/Ringold Formation unit E contact is 7.9 m (26 ft) bgs, and the water table is in Ringold Formation unit E at 15 m (50 ft) bgs.

A single soil sample for moisture content reported 1%. Neutron moisture logging ranged from 1% to 3%. The sediment is silty sandy gravel that grades into silty gravel about 2 m (2.5 ft) bgs. The vadose zone has moisture content consistent with a vegetated surface at Hanford. Therefore, and vertical flow will be low to nonexistent under the measured conditions, given typical 1% to 2% specific retention capacities.

The total gamma and natural KUT geophysical log plots show a slight increase at 8 m (26 ft) bgs, which marks the Hanford formation/Ringold Formation unit E contact.

Soil and groundwater samples were collected at discrete depth intervals during drilling and analyzed for total chromium, Cr(VI), strontium-90, nitrate, carbon-14, and tritium. Vertical distribution and concentrations are on the composite plot (Figure C-26). Results for additional analytes and discussion are in Section 4.2. Cr(VI) values are below detection throughout the soil column. Total chromium values decrease with depth, from 82 mg/kg at the surface to about 15 mg/kg at depth. There is no increased chromium contamination near the PRZ. Total chromium in groundwater was <10 µg/L, with Cr(VI) concentrations at or near the detection limit.

Strontium-90 was detected in both soil and groundwater at this location, with soil concentrations <6 pCi/g and groundwater at 4.6 pCi/L. Carbon-14 was nondetect in soil, and not analyzed in groundwater. Nitrate concentrations in soil were <18 mg/kg), and 29.5 mg/L in groundwater. Tritium was not detected in the soil above the MDA, but was in groundwater at 210 pCi/L. Slug testing was not conducted in this well.

Following well acceptance, 199-K-201 was sampled in January 2011. Two filtered samples were collected and analyzed for Cr(VI) and total chromium. Analytical results were as follows:

- Cr(VI) concentrations reported at 107 and 111 µg/L
- Total chromium concentrations reported at 105 (D-qualified) and 113 µg/L
- Carbon-14 not detected at an MDA of 57.1 pCi/L
- Strontium-90 not detected at an MDA of 1.7 pCi/L
- Tritium detected at 280 pCi/L
- Nitrate concentration reported at 27,700 µg/L (D-qualified)

C5 Borehole/Well Physical Property Data

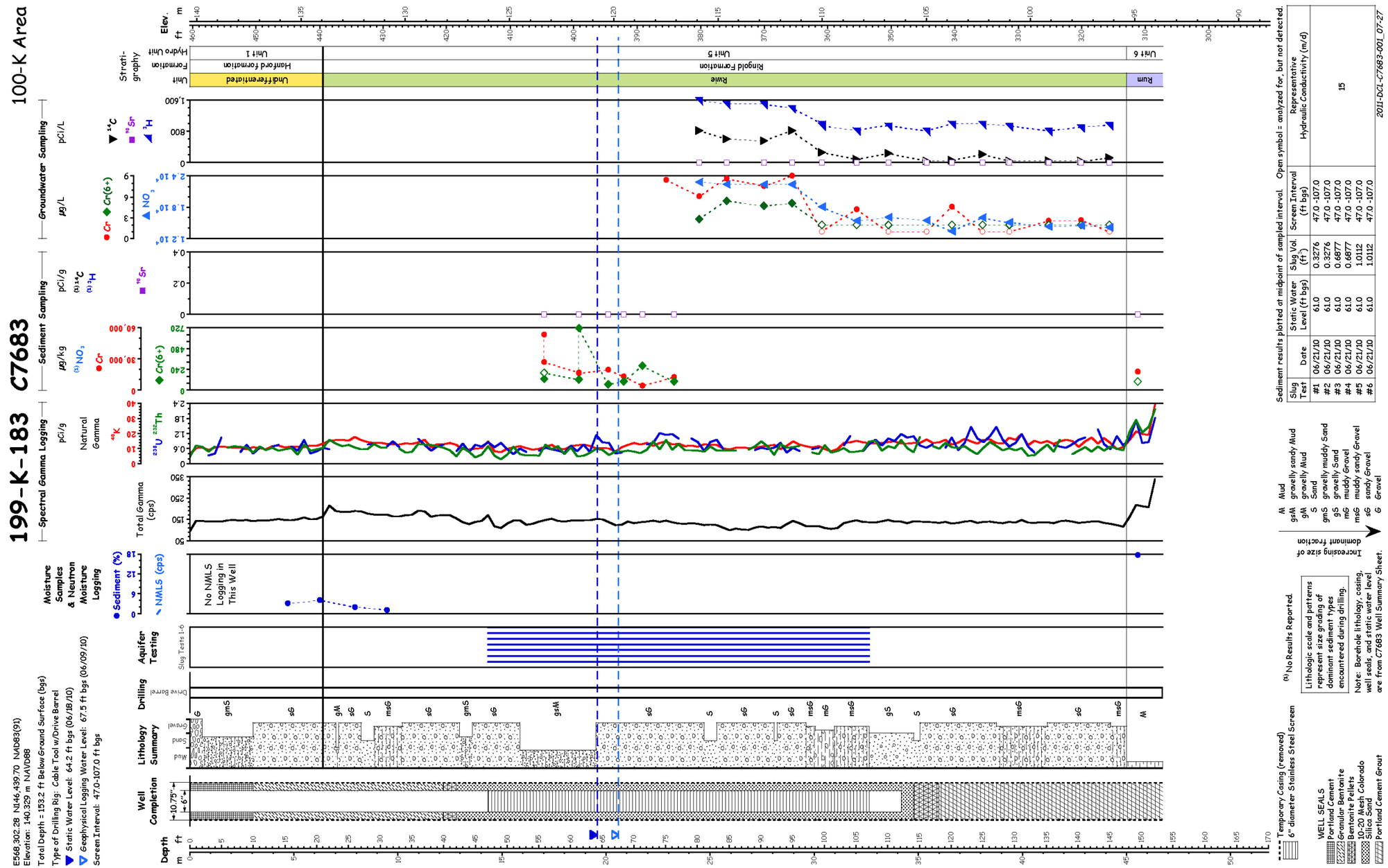
Table 2-4 in the main text of this document presents a summary of the RI soil samples. Soil sampling for the RI is discussed in Section 2.1.10, and analytical results are discussed in Section 4.2. Table C-3 presents the physical property results for soil samples collected during drilling.

C6 Hydraulic Conductivity Data

Table C-4 provides the vertical hydraulic conductivity data. Table C-3 summarizes historical site-specific information on horizontal saturated hydraulic conductivity for the Hanford formation, Ringold Formation unit E, first water-bearing unit in the RUM, and the lower water-bearing unit in the RUM, presumed to be Ringold Formation unit B. Values in this table rely on slug and pumping test field data. Part of the modeling effort in SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*, evaluated hydraulic conductivity data to estimate representative values for the Ringold Formation unit E and the Hanford formation.

As discussed in Section 3.7.2.2 in the main text of this document, three factors make evaluation of current vertical hydraulic gradients at 100-K difficult. These factors include the current monitoring well network consisting mainly of wells screened in Ringold Formation unit E. Although screened intervals vary between wells, the screen intervals of neighboring wells often overlap. The second factor, natural stresses (such as recharge) that would result in significant vertical gradients, are limited, except close to the Columbia River, where three-dimensional flow occurs in responses to stage-driven cycles. The third factor, operation of the P&T system, generates vertically and horizontally convergent/divergent flow, overwhelming ambient vertical gradient patterns.

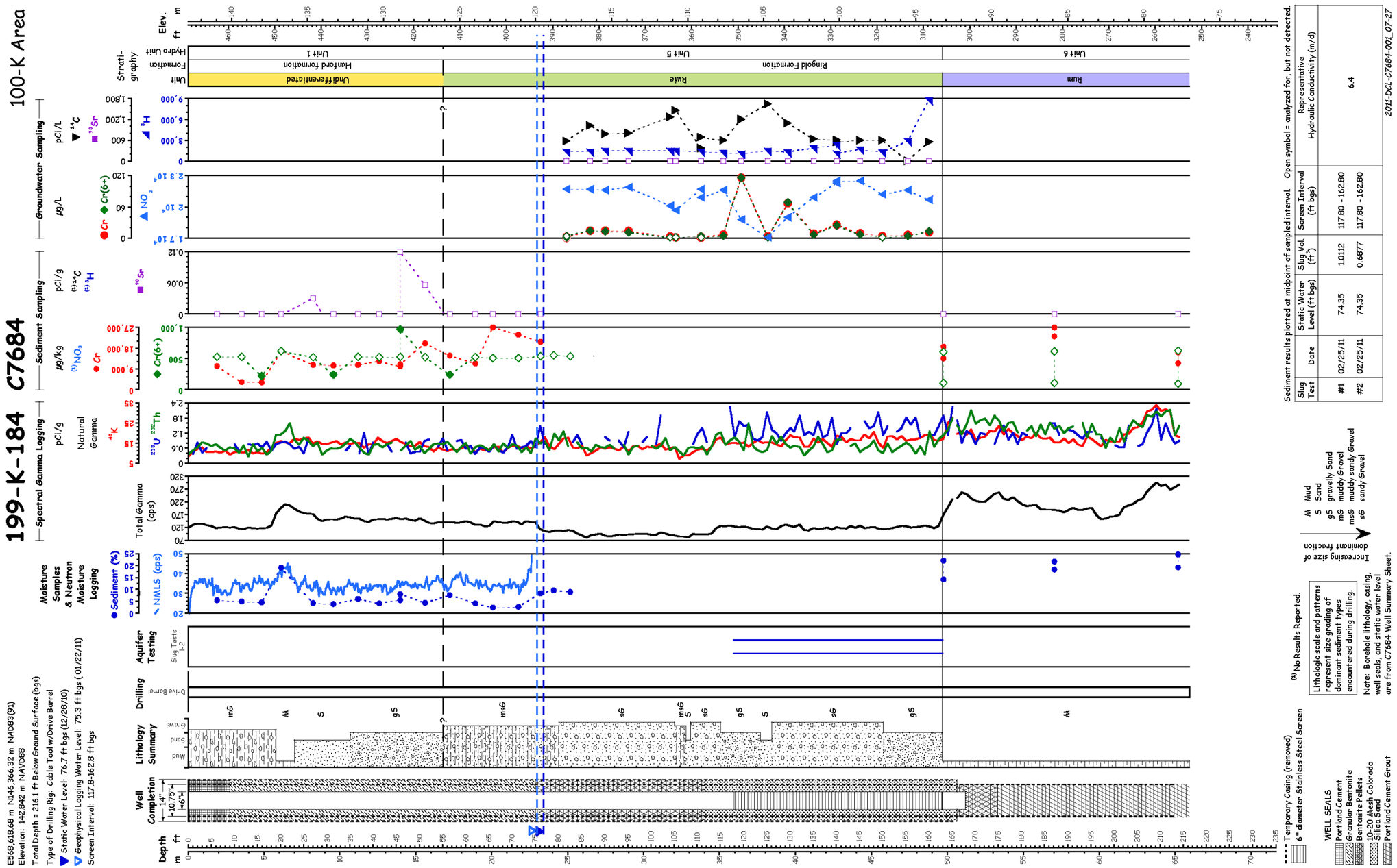
For construction and parameterization of the vadose zone fate and transport model (Section 5.3.2.2) the fitted saturated hydraulic conductivity was assumed to represent vertical hydraulic conductivity. For the fitted saturated hydraulic conductivities, hydraulic conductivities were measured on the bulk samples that included the gravel fraction using the constant-head permeameter method for saturated hydraulic conductivity and the unit gradient method for unsaturated hydraulic conductivity (Section 5.3.2.2, Table 5-3 in the main text of this document).



Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

Slug Test	Date	Static Water Level (ft bgs)	Slug Vol. (ft^3)	Screen Interval (ft bgs)	Representative Hydraulic Conductivity (m/d)
#1	06/21/10	61.0	0.3276	47.0 -107.0	15
#2	06/21/10	61.0	0.3276	47.0 -107.0	
#3	06/21/10	61.0	0.6877	47.0 -107.0	
#4	06/21/10	61.0	0.6877	47.0 -107.0	
#5	06/21/10	61.0	1.0112	47.0 -107.0	
#6	06/21/10	61.0	1.0112	47.0 -107.0	

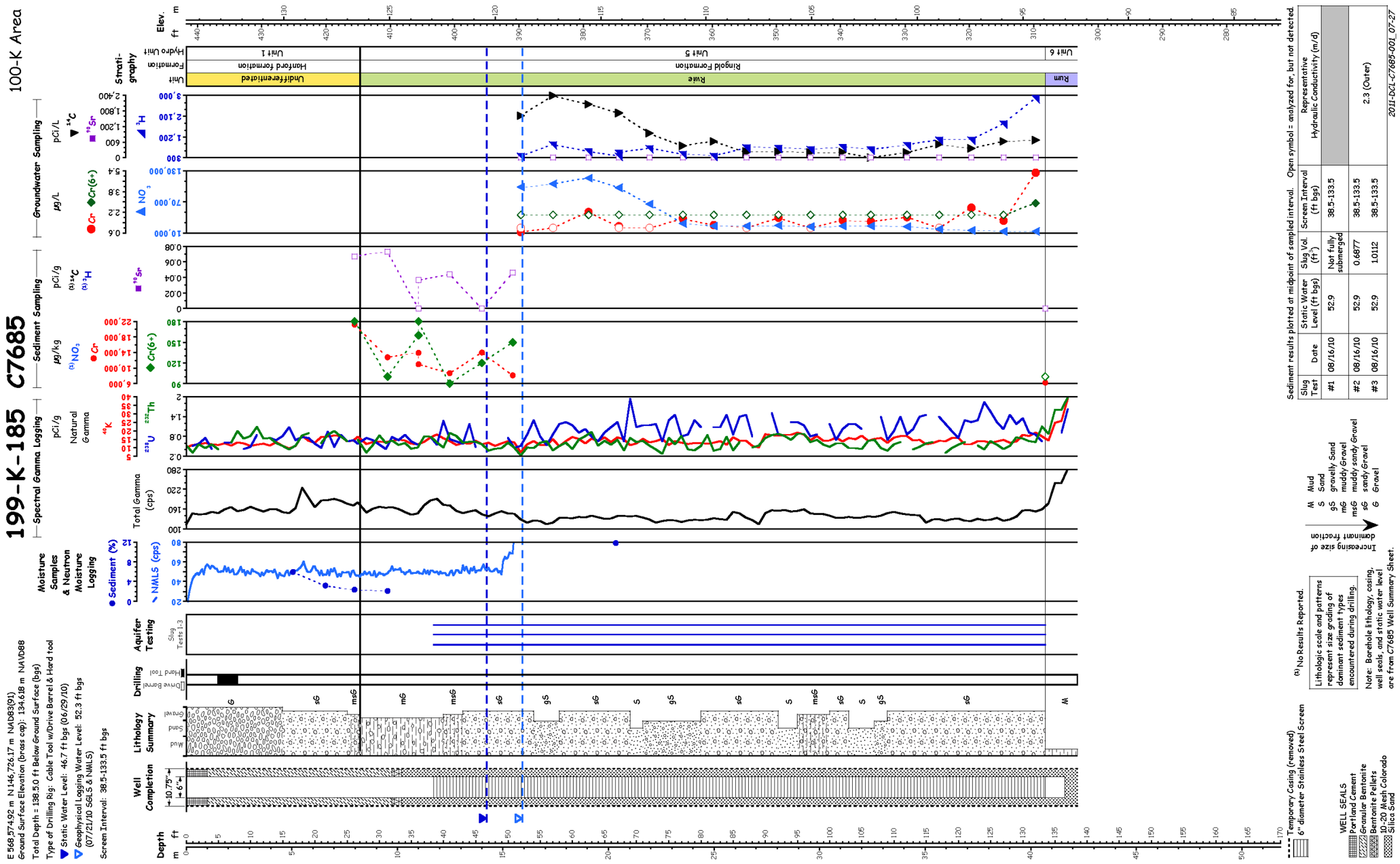
Figure C-12. C7683 (199-K-183)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

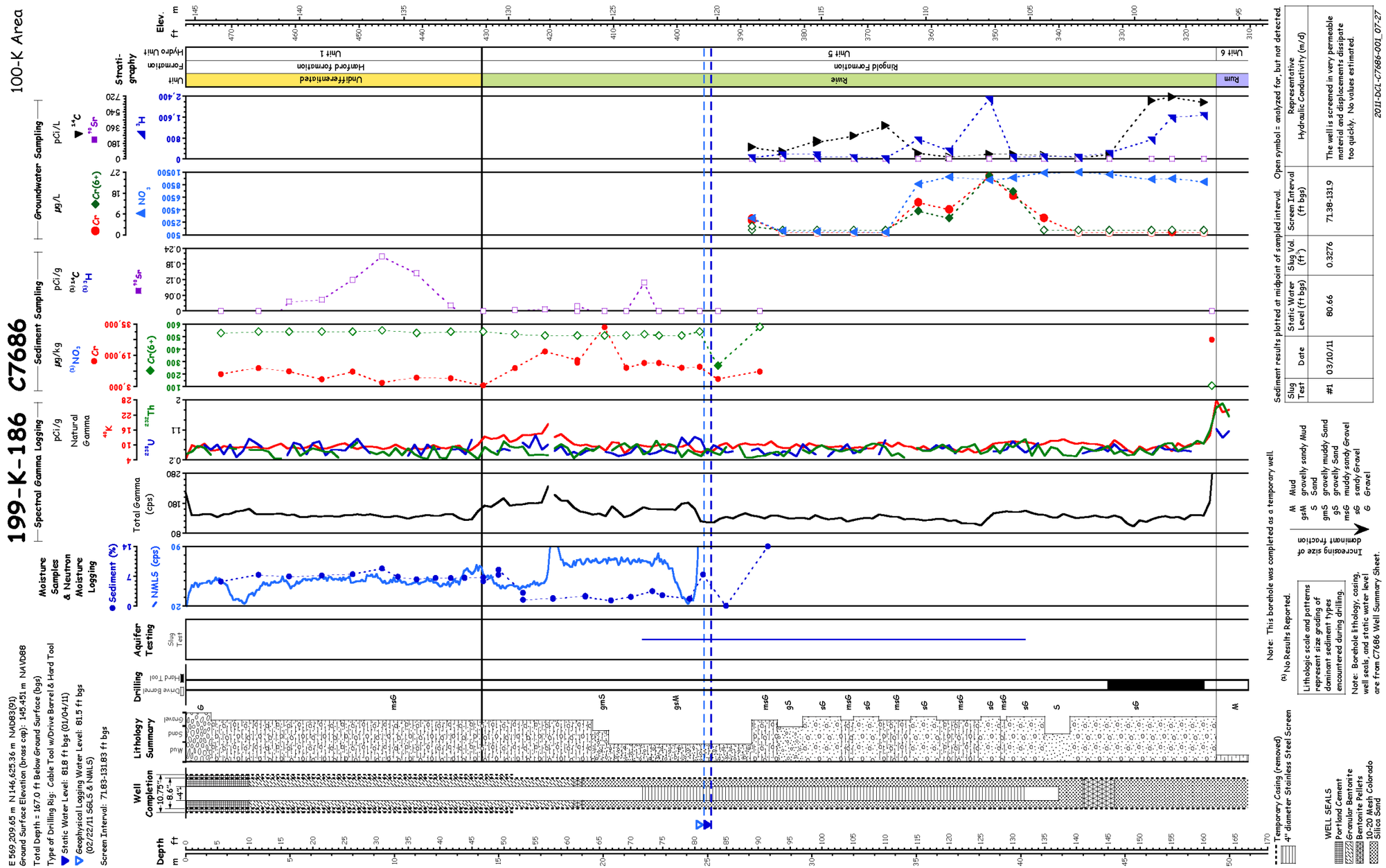
Figure C-13. C7684 (199-K-184)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

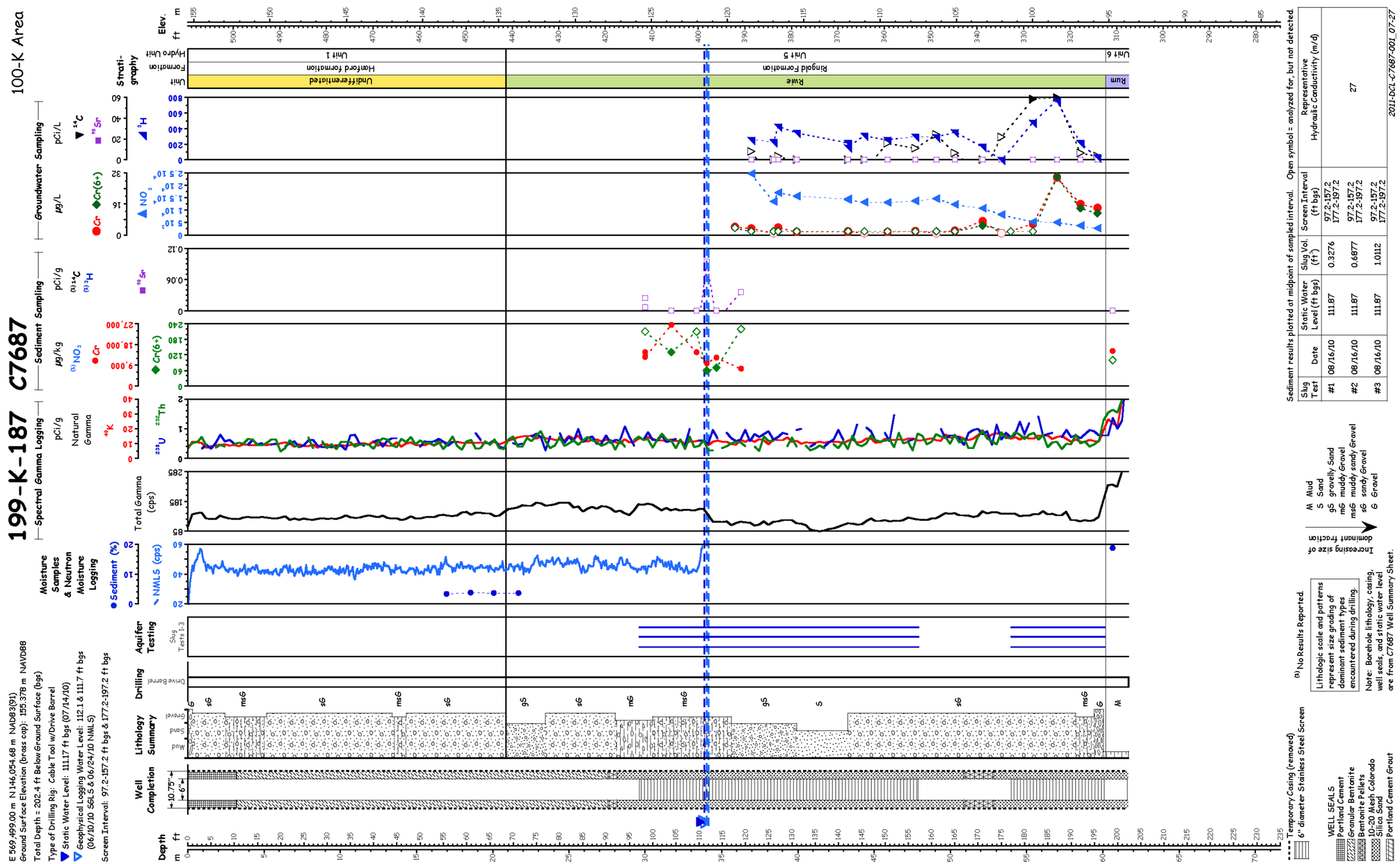
Figure C-14. C7685 (199-K-185)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

Figure C-15. C7686 (199-K-186)

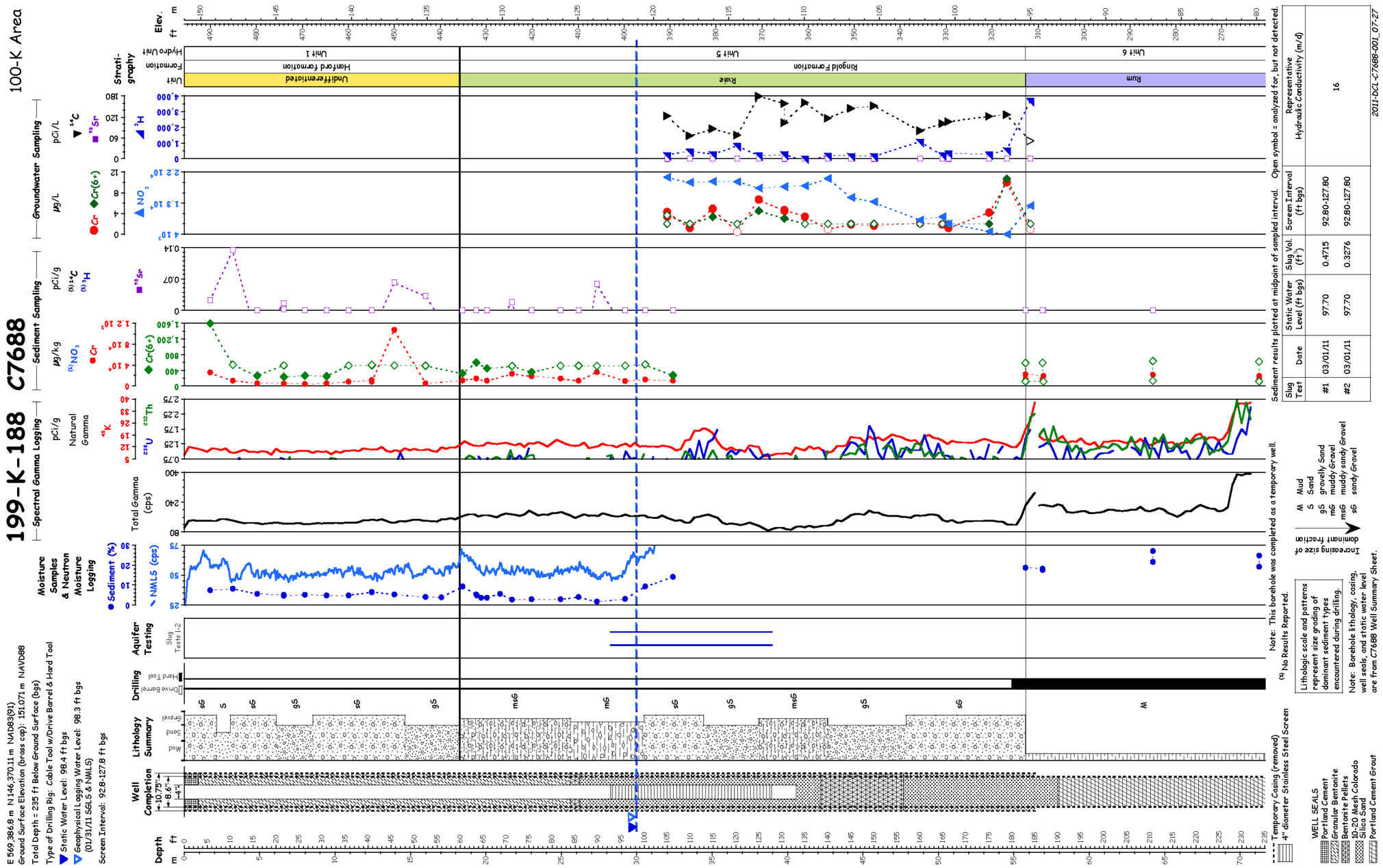


Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

Slug Test	Date	Static Water Level (ft bgs)	Slug Vol. (ft³)	Screen Interval (ft bgs)	Representative Hydraulic Conductivity (m/d)
#1	08/16/10	111.87	0.3276	97.2-157.2 177.2-197.2	27
#2	08/16/10	111.87	0.6877	97.2-157.2 177.2-197.2	
#3	08/16/10	111.87	1.0112	97.2-157.2 177.2-197.2	

References: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

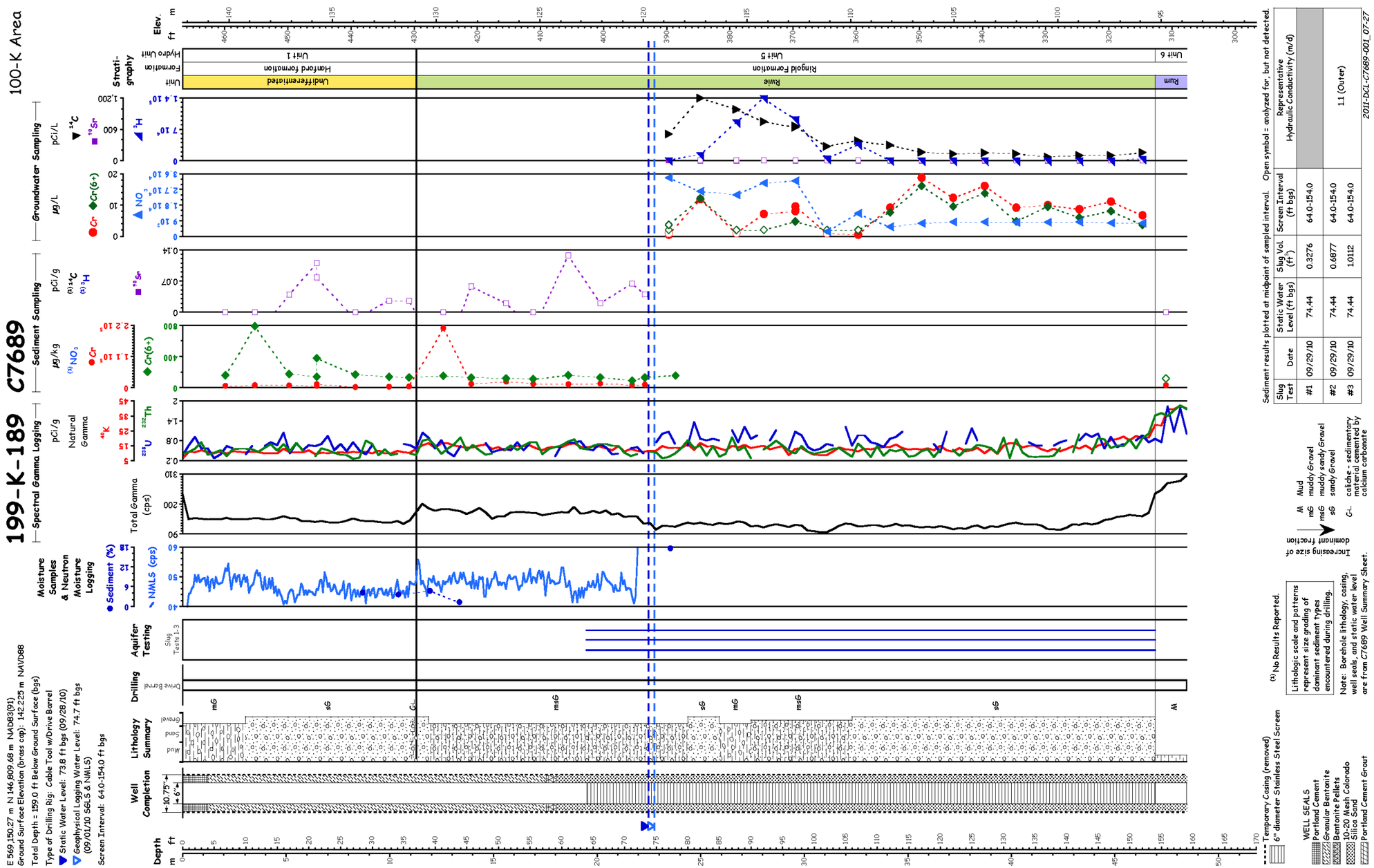
Figure C-16. C7687 (199-K-187)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

Figure C-17. C7688 (199-K-188)

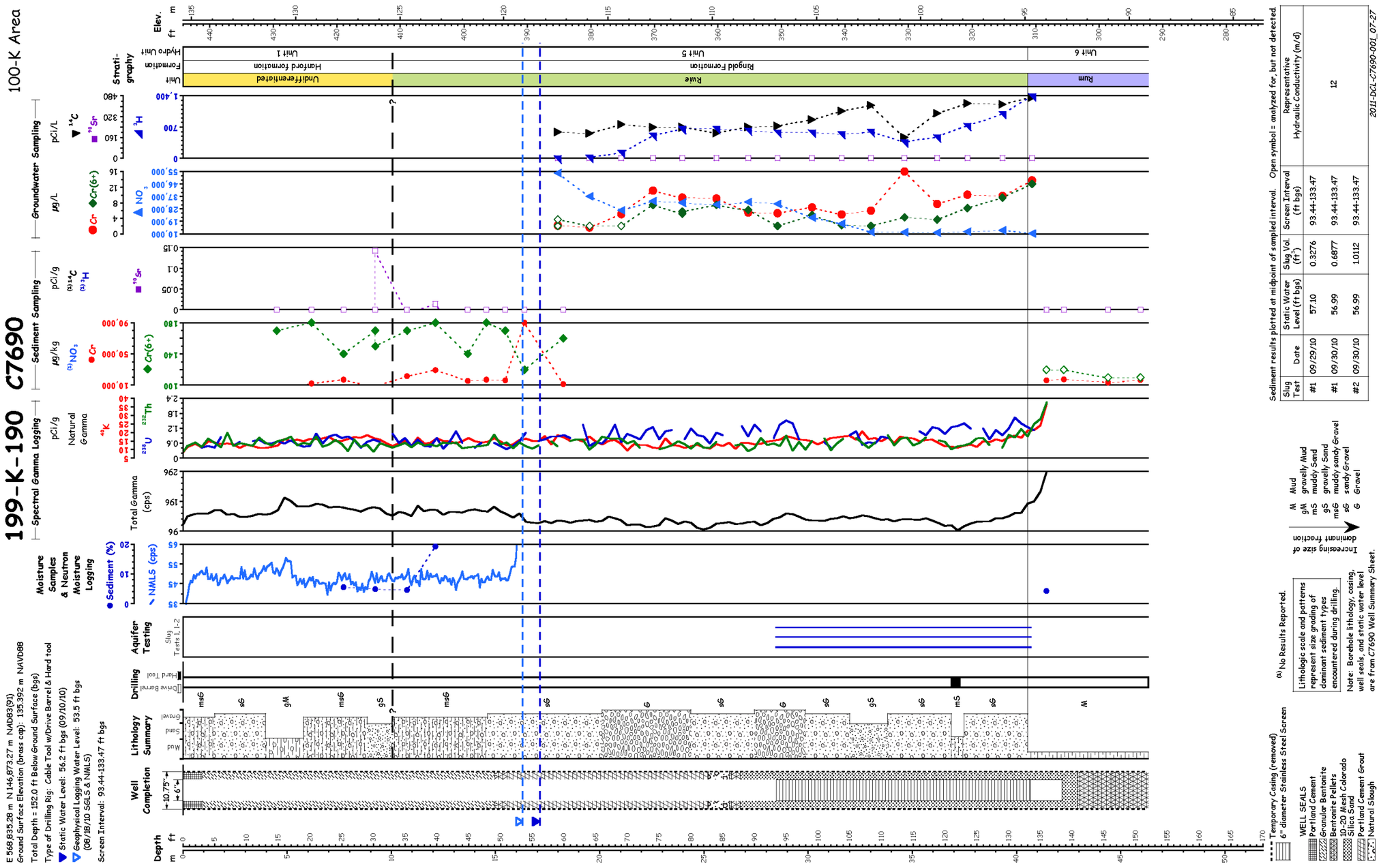


Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

Slug Test	Date	Static Water Level (ft bgs)	Slug Vol. (ft^3)	Screen Interval (ft bgs)	Representative Hydraulic Conductivity (m/d)
#1	09/29/10	74.44	0.3276	64.0-154.0	
#2	09/29/10	74.44	0.6877	64.0-154.0	1.1 (Outer)
#3	09/29/10	74.44	1.0112	64.0-154.0	

References: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

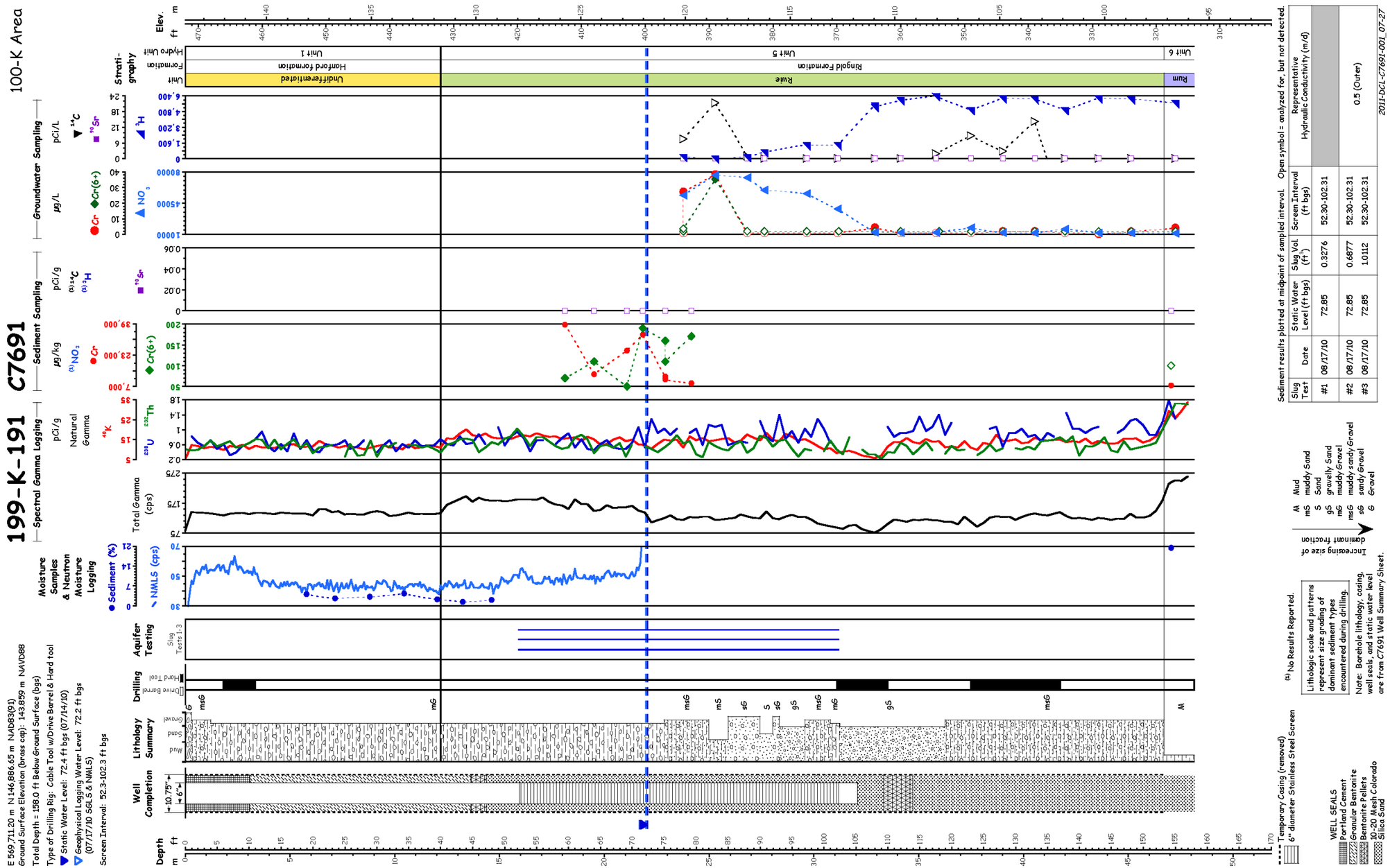
Figure C-18. C7689 (199-K-189)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

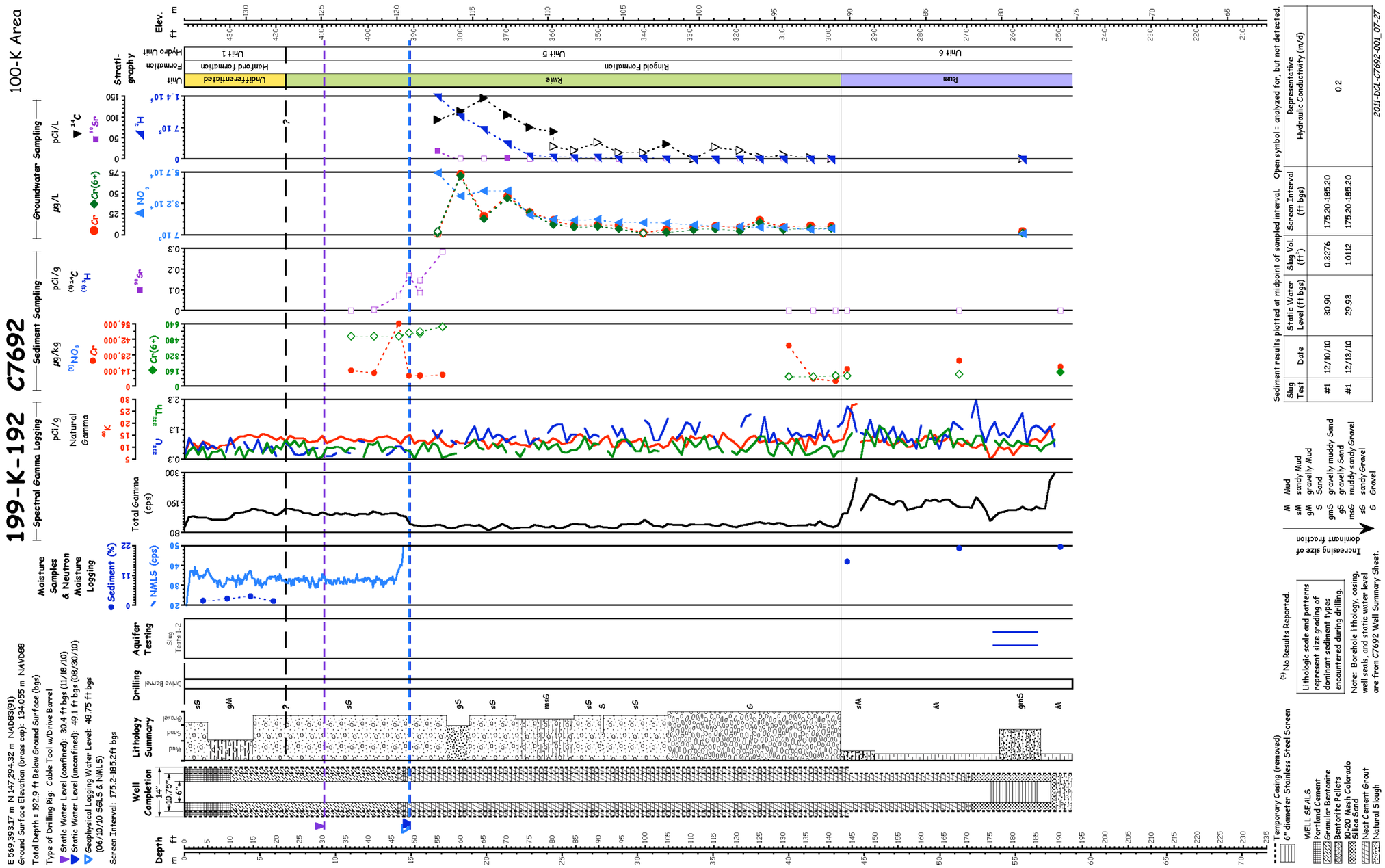
Figure C-19. C7690 (199-K-190)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

Figure C-20. C7691 (199-K-191)



Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

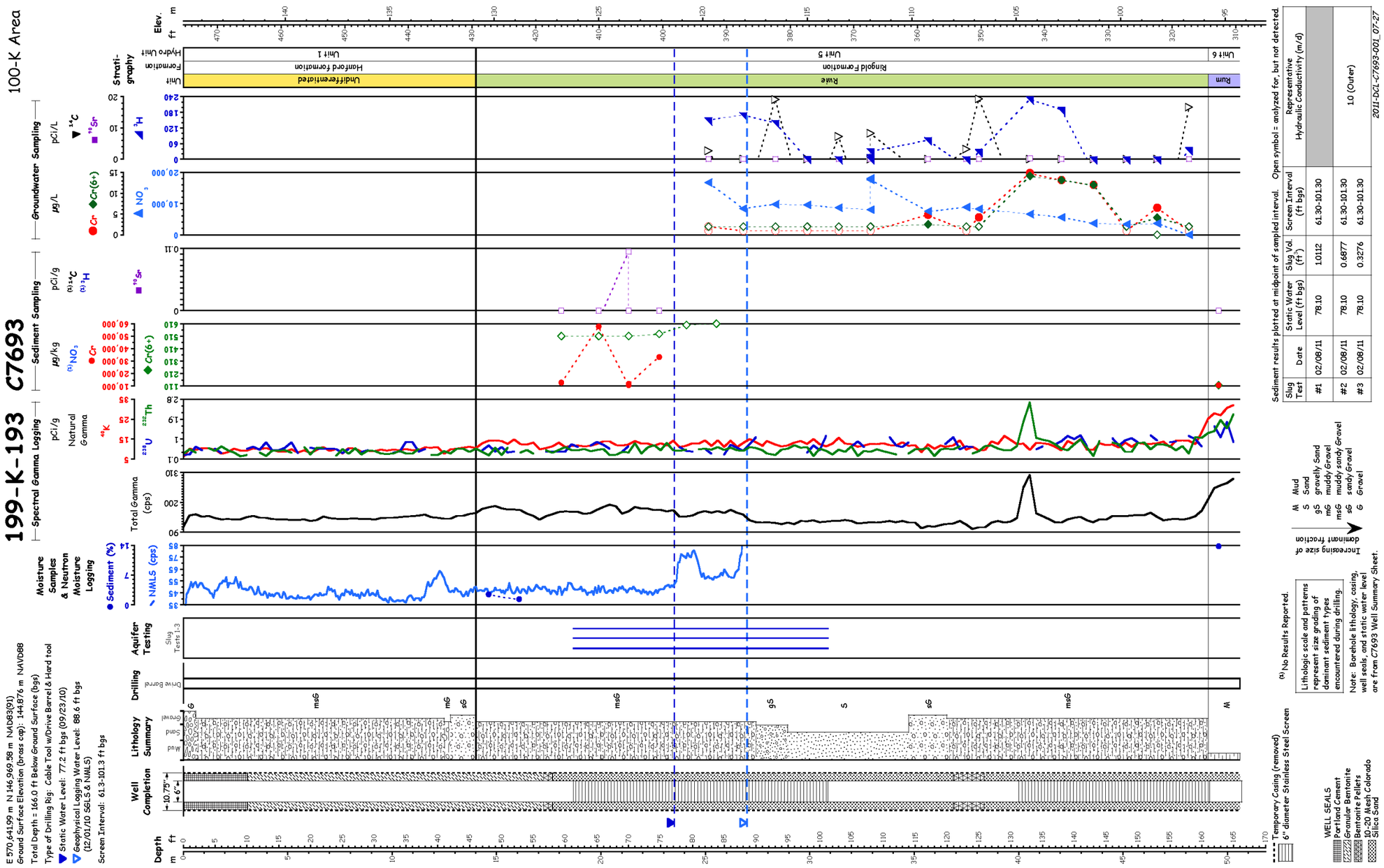
Slug Test	Date	Static Water Level (ft bgs)	Slug Vol. (ft^3)	Screen Interval (ft bgs)	Representative Hydraulic Conductivity (m/d)
#1	12/10/10	30.90	0.3276	175.20-185.20	0.2
#1	12/13/10	29.93	1.0112	175.20-185.20	

(a) No Results Reported.

References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

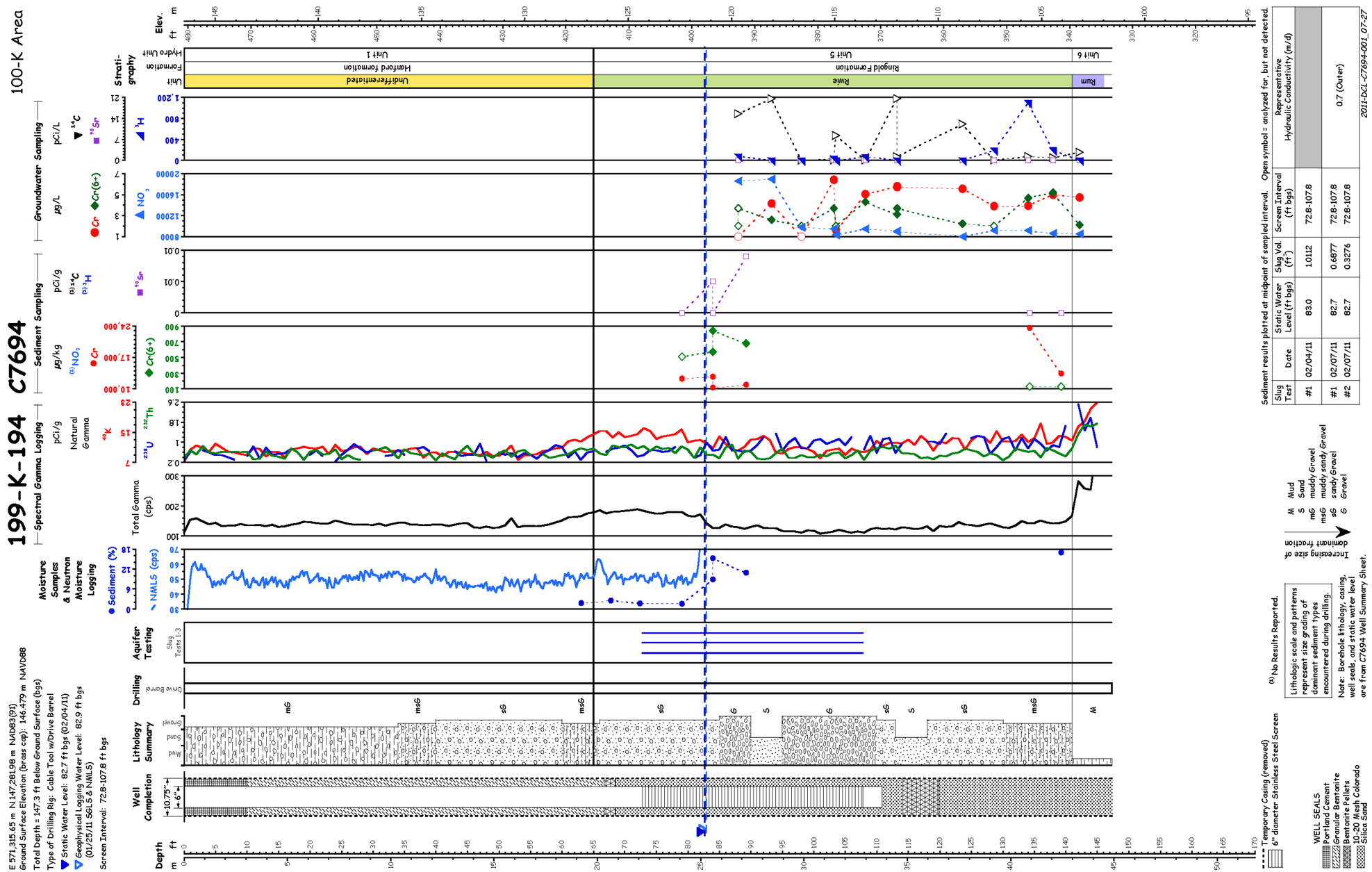
Figure C-21. C7692 (199-K-192)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

Figure C-22. C7693 (199-K-193)

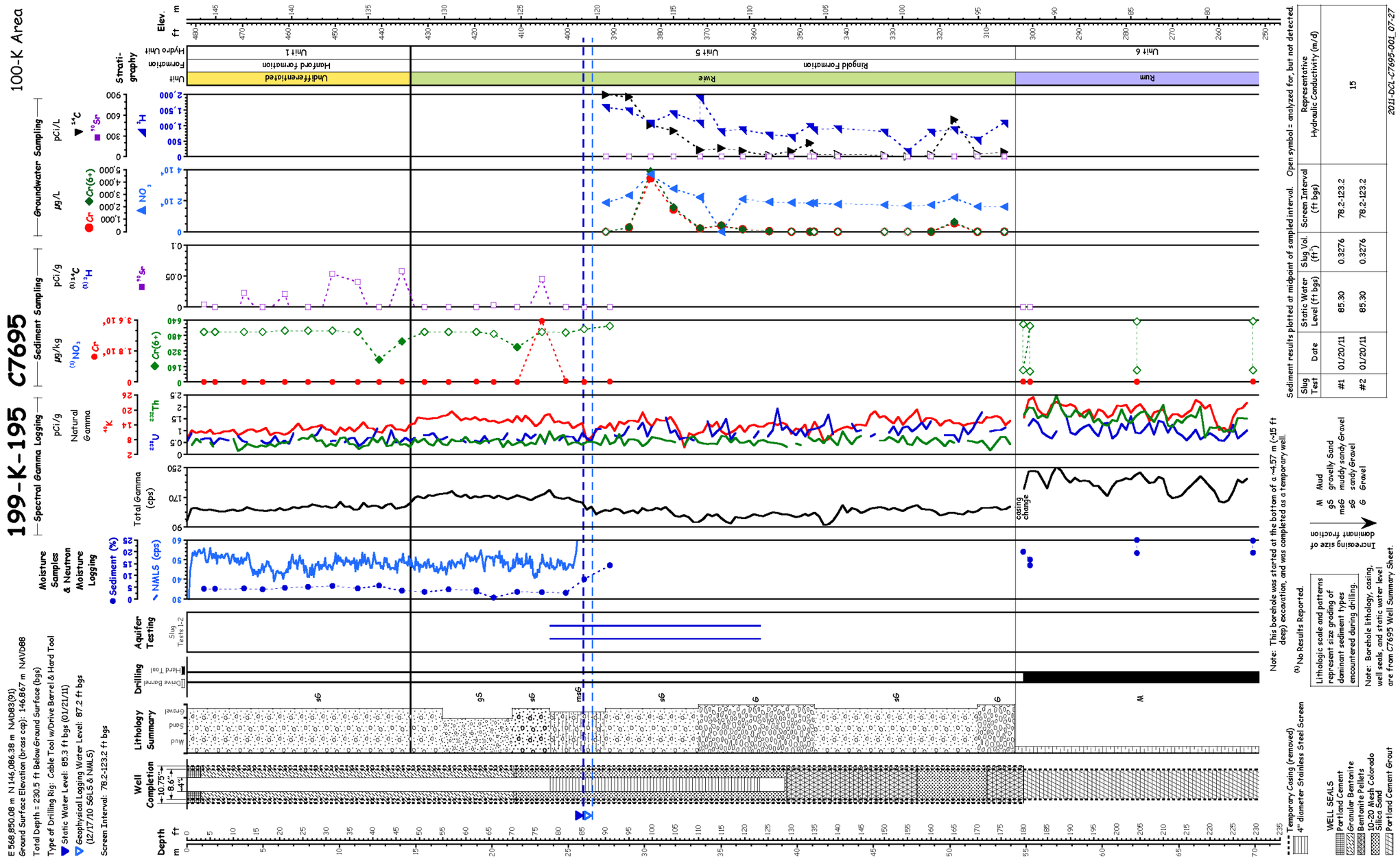


Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

Slug Test†	Date	Static Water Level (ft bgs)	Slug Vol. (ft^3)	Screen Interval (ft bgs)	Representative Hydraulic Conductivity (m/d)
#1	02/04/11	83.0	1.0112	72.8-107.8	
#1	02/07/11	82.7	0.6877	72.8-107.8	0.7 (Outer)
#2	02/07/11	82.7	0.3276	72.8-107.8	

References: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

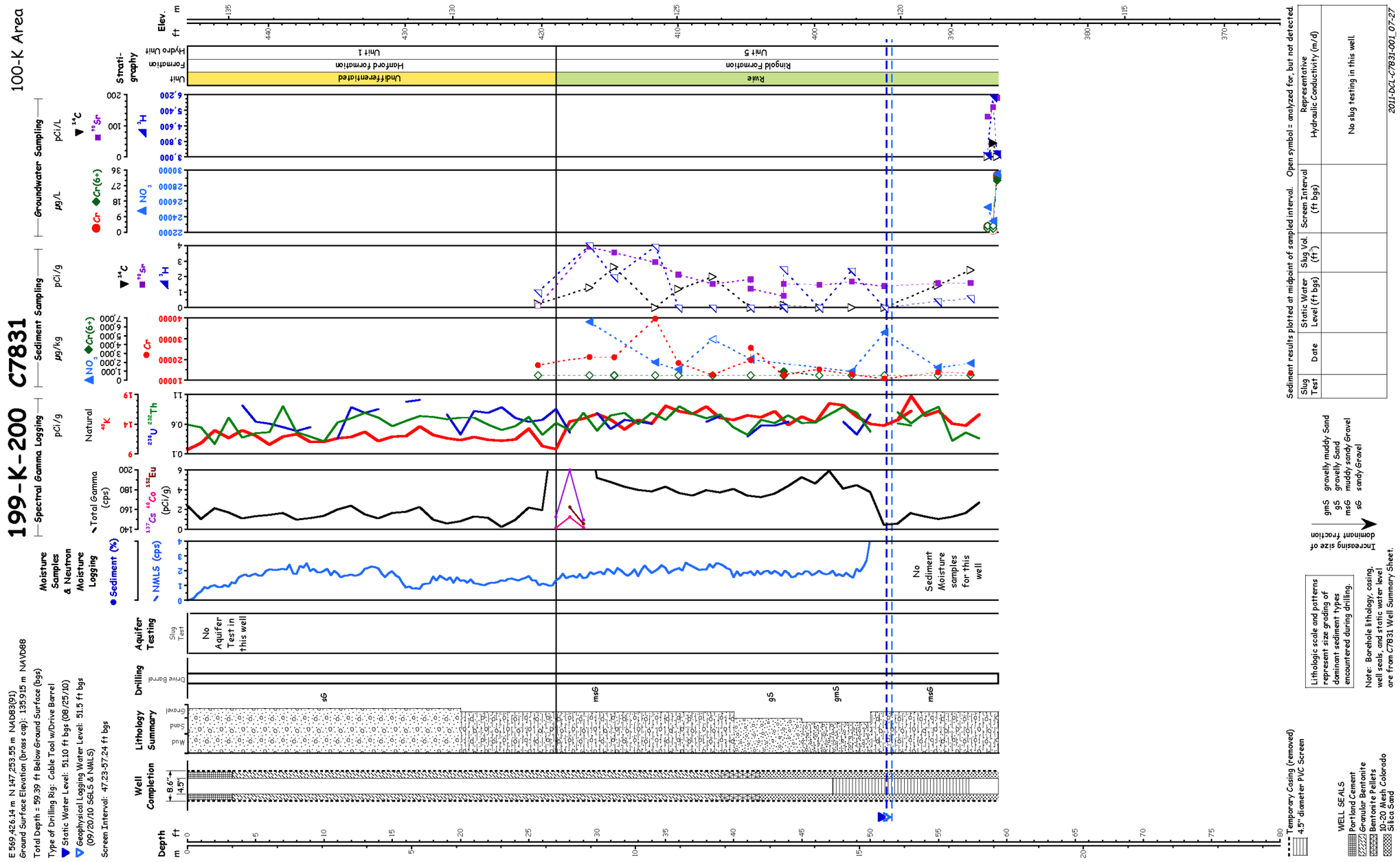
Figure C-23. C7694 (199-K-194)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

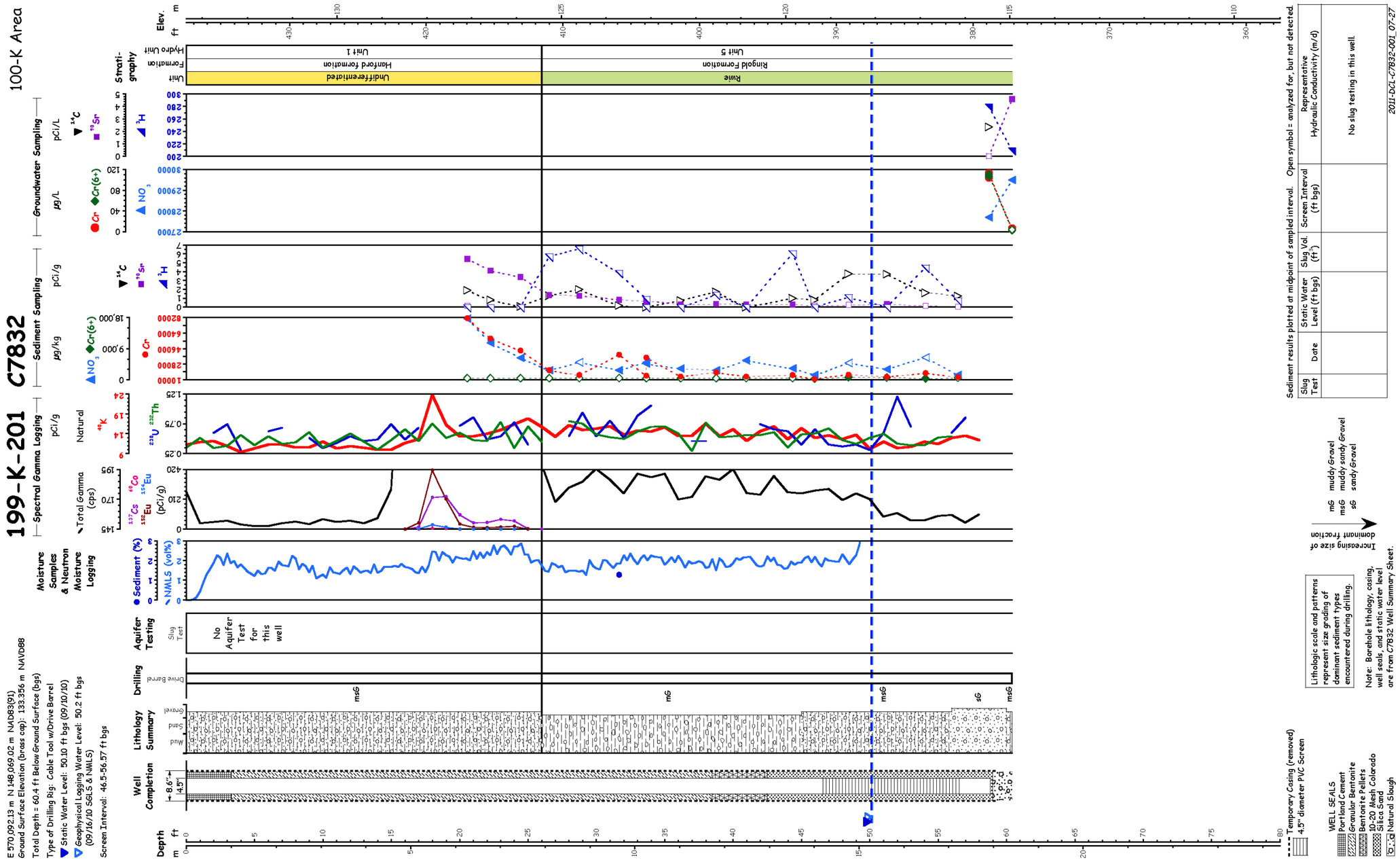
Figure C-24. C7695 (199-K-195)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

Figure C-25. C7831 (199-K-200)



References: NAD83, *North American Datum of 1983*.

NAVD88, *North American Vertical Datum of 1988*.

Figure C-26. C7832 (199-K-201)

Table C-3. Physical Property Results for 100-K Soil Samples

Well ID (Borehole)	Sample Interval	Depth (m bgs)	Depth (ft bgs)	Geologic Unit	Moisture (%)	Calculated Porosity (%)	Bulk Density (kg/m^3)		Grain Size (% Passing Sieve)												Size Classification (%)		
							Wet	Dry	3 in.	1.5 in.	0.75 in.	0.375 in.	#4	#10	#20	#40	#60	#100	#140	#200	Gravel	Sand	Silt/Clay
199-K-183 (C7683)	I-001	4.5	14.75	Hanford	3.12	7.8	2050	1994	100	100	89.9	71.8	47.3	24.7	14.1	9.1	7.2	5.8	5.1	4.5	52.7	42.8	4.5
	I-002	5.9	19.5	Hanford	4.19	8.8	2161	2119	100	89.6	68.5	52.4	43.2	31.4	20.6	13.2	9.5	7.3	6.3	5.4	56.8	37.8	5.4
	I-003	7.6	25	Ringold	2.05	9.8	1764	1724	100	100	100	99.6	99.6	99	93.8	62.2	34.9	22.9	18.4	14.7	0.4	84.9	14.7
	I-004	9.1	30	Ringold	1.15	10.8	2308	2276	100	100	97.1	90.4	83	73.3	62.7	51.7	43.6	36.7	33	29.4	17.0	53.6	29.4
199-K-184 (C7684)	I-004	6.0	19.8	Hanford	19.2	11.8	2335	1999	100	100	100	100	100	100	100	100	99.8	93.5	79.6	64.7	0.0	35.3	64.7
	I-005	7.8	25.7	Hanford	4.29	30.5	1839	1664	100	100	100	100	100	100	99.7	89.3	56.2	34.1	27.9	23.1	0.0	76.9	23.1
	I-006	9.2	30.1	Hanford	3.98	33.9	1749	1677	100	100	100	100	100	98.5	67.2	29.2	12.6	7.5	6.4	5.6	0.0	94.4	5.6
	I-007	10.8	35.4	Hanford	6.10	31.6	1810	1727	100	100	88.5	82.2	78.5	75.9	62.5	43.2	23.3	9	6.6	5.4	21.5	73.1	5.4
199-K-185 (C7685)	I-001	4.6	15	Hanford	6.02	17.0	2198	2092	100	84.8	69.6	56.1	45.7	33.6	25.3	19.8	17.5	15.3	13.6	11.5	54.3	34.2	11.5
	I-002	6.2	20.35	Hanford	3.22	19.5	2132	2095	100	100	54.3	41.9	35.3	30.7	27.4	21.1	13.9	8.5	6.7	5.3	64.7	30.0	5.3
	I-003	7.6	24.9	Ringold	2.39	23.6	2022	1983	100	90.7	81.2	68.6	55.5	45.6	38.1	33.3	27.2	20	17.1	14.7	44.5	40.8	14.7
	I-004	9.2	30.05	Ringold	2.13	17.9	2174	2134	100	100	93.4	87.6	78.6	67.3	57.6	50.6	45.1	38.4	34.7	31.1	21.4	47.5	31.1
199-K-186 (C7686)	I-007	9.8	32.1	Hanford	6.91	7.9	2438	2313	100	100	71.8	53.8	40.2	28.8	15.5	10.3	8.9	7.9	7.4	6.9	59.8	33.3	6.9
	I-009	11.6	38.0	Hanford	6.60	24.2	2006	1913	100	100	77.8	44.4	28.8	15.6	6.5	4.4	3.7	3.2	3	2.8	71.2	26.0	2.8
	I-011	13.0	42.6	Hanford	6.76	23.2	2033	1956	100	100	89	74	58.2	37.8	21.5	15.1	12.7	10.7	9.7	8.7	41.8	49.5	8.7
	I-013	14.6	47.9	Hanford/ Ringold	8.59	19.8	2124	2022	100	89.3	74.9	58	44.5	34.1	25.6	19.8	17.4	15.4	14.1	12.7	55.5	31.8	12.7
199-K-187 (C7687)	I-001	16.6	54.4	Hanford	3.32	26.7	2396	1873	100	92.6	79.3	69.9	59.6	41.3	21.1	11.4	8.6	6.6	5.7	4.9	41.9	51.2	6.8
	I-002	18.2	59.6	Hanford	3.80	20.9	1940	2028	100	92.7	80.9	72.6	62.9	41	18.8	8.7	6.5	5	4.2	3.7	40.4	54.7	4.9
	I-003	19.7	64.6	Hanford	3.68	29.7	2095	1800	100	100	100	100	99.2	90.9	54.9	23.6	14	8.3	6.4	5.1	37.1	59.2	3.7
	I-004	21.3	69.9	Ringold	3.71	9.5	1860	2332	100	100	80.4	67.7	58.1	40.3	24.5	16	11.6	9	7.8	6.8	0.8	94.1	5.1
199-K-188 (C7688)	I-011	16.7	54.7	Hanford	3.88	17.3	2190	2113	100	100	79.6	70.6	60.2	37.5	17.1	9.3	7.1	5.8	5.2	4.7	39.8	55.6	4.7
	I-013	19.0	62.4	Ringold	4.90	9.7	2390	2308	100	88	80.4	70.4	61.7	51.9	43.3	34.4	30.4	26.8	24.7	22.6	38.3	39.1	22.6
	I-015	19.3	63.3	Ringold	3.85	12.2	2324	2244	100	100	91	81.9	71.3	62.2	54.9	47.1	42.4	37.8	35	32.2	28.7	39.1	32.2
	I-017	20.6	67.7	Ringold	5.70	27.5	1919	1882	100	91.3	82.8	68.8	57.4	48.1	34.8	25.6	21.3	17.9	15.9	14	42.6	43.4	14.0
199-K-189 (C7689)	I-006	8.4	27.5	Hanford	4.29	21.1	2089	2025	100	89.6	81.2	69.9	55.8	40.9	26.2	17	13.7	11.1	9.8	8.7	44.2	47.1	8.7
	I-008	10.0	32.9	Hanford	3.64	24.4	2001	1940	100	100	85.8	64.4	46.9	31.6	17.5	9.7	7.5	6	5.3	4.7	53.1	42.1	4.7
	I-010	11.6	37.9	Hanford/ Ringold	4.76	23.3	2030	1981	100	100	70.8	60.3	50.8	41.7	32.4	27	23.3	19.6	17.5	15.3	49.2	35.5	15.3
	I-012	13.0	42.6	Ringold	1.39	27.8	1911	1882	100	100	92.1	86.3	76.8	66.4	56.3	49.6	44.6	37.3	33.1	29.4	23.2	47.4	29.4
199-K-190 (C7690)	I-003	7.3	24.0	Hanford	1.73	17.8	2175	2142	100	94.3	80.6	71.7	64	55.4	46.7	41.3	35.4	28.2	24.5	21.4	36.0	42.6	21.4
	I-004	8.8	29.0	Hanford	2.48	31.5	1812	1773	100	80.1	63	56.8	54	52.2	51.2	46.7	29.8	14.7	10.4	7.8	46.0	46.2	7.8
	I-005	10.4	34.0	Hanford	1.40	19.0	2145	2113	100	100	93.4	84.8	78.4	69.6	59.5	52.5	45.9	38.1	34	30.2	21.6	48.1	30.2
	I-006	11.9	39.0	Hanford	1.78	36.9	1669	1520	100	100	94.2	86.8	74.1	59.6	49.5	43.2	36.1	27.5	23.4	20.1	25.9	54.0	20.1

Table C-3. Physical Property Results for 100-K Soil Samples

Well ID (Borehole)	Sample Interval	Depth (m bgs)	Depth (ft bgs)	Geologic Unit	Moisture (%)	Calculated Porosity (%)	Bulk Density (kg/m^3)		Grain Size (% Passing Sieve)												Size Classification (%)		
							Wet	Dry	3 in.	1.5 in.	0.75 in.	0.375 in.	#4	#10	#20	#40	#60	#100	#140	#200	Gravel	Sand	Silt/Clay
199-K-191 (C7691)	I-001	5.4	17.7	Hanford	4.19	19.3	2135	2073	100	64.9	52.6	42.3	31.6	20.6	11.6	8.5	7.3	6.3	5.8	5.2	68.4	26.4	5.2
	I-002	6.8	22.2	Hanford	2.73	16.7	2206	2150	100	89.9	77.2	64.7	56.6	48.8	32.8	20.7	16.9	14	12.6	11.2	43.4	45.4	11.2
	I-003	8.4	27.6	Hanford	3.35	25.4	1975	1917	100	89	67.5	58.5	51.4	45.6	31.7	21.7	18.1	14.8	13.1	11.5	48.6	39.9	11.5
	I-004	10.1	33.0	Hanford	4.47	14.6	2260	2187	100	94.7	82.7	64	45.6	31.4	12.8	6.3	4	3.2	2.8	2.5	54.4	43.1	2.5
	Add-on 1	11.6	38.2	Hanford	2.38	15.7	2231	2191	100	71	58.2	47.7	42.8	37.1	15.4	7.4	5.6	4.4	3.7	3.2	57.2	39.6	3.2
	Add-on 2	12.9	42.2	Ringold	2.19	19.3	2137	2111	100	73.4	61.4	44.1	34.1	28.3	23.2	18.1	12.4	8.8	7.5	6.4	65.9	27.7	6.4
	Add-on 3	14.2	46.7	Ringold	1.49	17.3	2190	2167	100	92.9	72.1	44.1	27.5	20.1	16.3	14.5	10.9	6.3	4.6	3.5	72.5	24.0	3.5
199-K-192 (C7692)	I-001	0.9	3.0	Hanford	1.74	18.0	2171	2134	100	75.6	51.3	36.8	31.9	27.5	23.9	20.1	17.6	15.1	13.2	10.9	68.1	21.0	10.9
	I-002	2.4	8.0	Hanford	2.47	0.6	2632	2581	100	100	57	36.8	27.5	19.5	12.3	9	7.7	6.4	5.5	4.5	72.5	23.0	4.5
	I-003	4.0	13.1	Hanford	3.25	15.8	2228	2171	100	85.6	78.2	65.6	56.6	49.9	41.7	36.7	32.7	27.6	25.2	22.8	43.4	33.8	22.8
	I-004	5.5	18.1	Hanford	1.53	22.1	2062	2044	100	80.4	63	51.5	43.3	37.2	32.9	29.8	25.9	17.2	14.2	12.1	56.7	31.2	12.1
199-K-193 (C7693)	I-003	14.2	46.7	Ringold	2.45	27.5	1919	1890	100	100	77.7	58.3	45.1	38.4	33.8	29	22.1	15.6	13.1	11	54.9	34.1	11.0
	I-004	15.7	51.5	Ringold	1.40	21.6	2076	2049	100	90.1	82	62.6	52	42	32.2	26.1	20.8	15.4	13.3	11.6	48.0	40.4	11.6
199-K-194 (C7694)	I-001	18.8	61.8	Hanford	1.90	18.4	2159	2126	100	100	96.7	90.6	82.4	72.7	62.1	54.1	48.1	40.7	36.7	33	17.6	49.4	33.0
	I-002	20.3	66.5	Ringold	2.60	16.5	2210	2161	100	100	88.8	80.8	73	64.5	54.1	45.9	38.3	32.1	29	26.2	27.0	46.8	26.2
	I-003	21.9	71.9	Ringold	1.70	22.3	2057	2033	100	100	83.3	69.6	58	47.4	39.6	35.2	30.2	23.5	20.1	17.2	42.0	40.8	17.2
	I-004	23.7	77.8	Ringold	1.60	16.3	2215	2188	100	100	85.1	73	66.1	58.5	51.2	45.6	34.2	26.1	23	20.3	33.9	45.8	20.3
199-K-195 (C7695)	I-006	4.6	15.0	Hanford	4.18	29.6	1863	1813	100	78.8	64.6	55.4	47	36.8	27.5	16.4	11.9	9.2	7.9	6.9	53.0	40.1	6.9
	I-007	6.0	19.8	Hanford	4.84	18.8	2148	2057	100	88.4	86.8	80.7	61.1	21.6	7.1	4.5	3.7	3.2	3	2.7	38.9	58.4	2.7
	I-008	7.6	24.8	Hanford	5.32	15.7	2231	2158	100	78.6	66	47	33.9	24.1	14.4	9.4	7.9	6.7	6.1	5.6	66.1	28.3	5.6
	I-009	9.1	30.0	Hanford	5.63	18.0	2171	2095	100	90.5	71.3	56.4	42.8	29.7	17.6	7.3	4.8	3.8	3.4	3	57.2	39.8	3.0
	I-011	12.2	40.1	Hanford	5.78	13.5	2289	2219	100	100	65.3	46.7	31.4	17.9	8.9	4.1	2.9	2.3	2	1.8	68.6	29.6	1.8
199-K-200 (C7831)	I-003	9.1	30.0	Ringold	4.57	21.0	2090	2063	100	67.7	51.6	38.5	30	24.8	21.2	18.8	15.9	9.7	6.7	4.9	70.0	25.1	4.9
199-K-201 (C7832)	I-003	9.3	30.4	Ringold	1.28	20.7	2100	2063	100	100	91.3	86	81.3	72.6	63	56	47.5	38.8	34.5	30.5	18.7	50.8	30.5

Notes: Includes some samples from below the water table.

Depth refers to the top of the sample interval.

To convert from kg/m^3 to lb/ft^3, multiply by 0.0625.

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Table C-4. Horizontal Saturated Hydraulic Conductivity in 100-K, Historical and RI Data

Well Number	Northing (m)	Easting (m)	Ks (ft/day)	Ks (m/day)	Ks (cm/sec)	Formation	Test Type/ Analysis Method	Reference
199-K-10	146628.1	568912.8	52	16	0.0185	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	PNL-10886
199-K-10	146628.1	568912.8	53	16.16	0.0187	Not reported	Pumping/Cooper and Jacob (1946)	PNL-8337
199-K-106A	146502.4	568697.4	9	2.68	0.0031	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-107A	146468.8	568579.9	5	1.55	0.0018	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-108A	146396.1	568687.2	3	0.98	0.0011	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-110A	146677.9	569230	4	1.1	0.0013	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-110A	146677.9	569230	32	9.79	0.0113	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-T1-221
199-K-111A	146968.9	569308.2	26	8	0.0093	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-DP-090
199-K-111A	146968.9	569308.2	27	8.35	0.0097	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	WHC-SD-EN-TI-221
199-K-18	147400.8	569353.7	9	2.8	0.0032	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-19	147368.6	569458.5	6	1.83	0.0021	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-20	147687.2	569520.5	111	33.84	0.0392	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566

Table C-4. Horizontal Saturated Hydraulic Conductivity in 100-K, Historical and RI Data

Well Number	Northing (m)	Easting (m)	Ks (ft/day)	Ks (m/day)	Ks (cm/sec)	Formation	Test Type/ Analysis Method	Reference
199-K-21	147932.1	569769.9	16	5	0.0058	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-22	148097.4	570023.7	3	0.88	0.0010	Ringold Formation unit E	Pumping/Cooper and Jacob (1946)	CCN 024566
199-K-32A	147006.7	569024.2	80	24.38	0.0282	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-33	146713.3	568573.7	19	5.79	0.0067	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-34	146501.9	568605.8	68	20.73	0.0240	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-35	146110.7	568832.3	124	37.8	0.0438	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-36	146390.7	569373.8	87	26.52	0.0307	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-37	148226.5	570216.2	145	44.2	0.0512	Ringold Formation unit E	Slug/Bouwer and Rice (1976)	DOE/RL-93-79
199-K-183	568302.28	146439.70	42.6	13	0.0150	Ringold Formation unit E	Slug/KGS	RI Well
199-K-184 [a]	568618.68	146366.32	22.3	6.8	0.0079	Ringold Formation unit E	Slug/KGS	RI Well
199-K-185	568574.92	146726.17	75	23	0.0266	Ringold Formation unit E	Slug/KGS	RI Well
199-K-186	568209.65	146625.36	No data [b]	No data [b]	No data [b]	Ringold Formation unit E	Slug/KGS	RI Well
199-K-187	569499.00	146054.68	92	28	0.0324	Ringold Formation unit E	Slug/KGS	RI Well

Table C-4. Horizontal Saturated Hydraulic Conductivity in 100-K, Historical and RI Data

Well Number	Northing (m)	Easting (m)	Ks (ft/day)	Ks (m/day)	Ks (cm/sec)	Formation	Test Type/ Analysis Method	Reference
199-K-188 [a]	569386.80	146370.11	53	16	0.0185	Ringold Formation unit E	Slug/KGS	RI Well
199-K-189	569150.27	146809.68	2.9	0.9	0.0010	Ringold Formation unit E	Slug/KGS	RI Well
199-K-190	568835.28	146873.27	39	12	0.0139	Ringold Formation unit E	Slug/KGS	RI Well
199-K-191	569711.20	146886.65	3.3	1	0.0012	Ringold Formation unit E	Slug/KGS	RI Well
199-K-192	569393.27	147294.32	0.7	0.2	0.0002	RUM/sand	Slug/KGS	RI Well
199-K-193	570641.99	146969.58	3.6	1.1	0.0013	Ringold Formation unit E	Slug/KGS	RI Well
199-K-194	571315.65	14281.98	2.3	0.7	0.0008	Ringold Formation unit E	Slug/KGS	RI Well
199-K-195 [a]	568850.08	146086.38	49.2	15	0.0174	Ringold Formation unit E	Slug/KGS	RI Well

References: Bouwer and Rice, 1976, "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells."

CCN 024566, "Field Summary Report 100-H Area Well Production Testing."

Cooper and Jacob, 1946, "A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well Field History."

DOE/RL-93-79, *Limited Field Investigation Report for the 100-KR-4 Operable Unit.*

PNL-8337, *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System*.

PNL-10886, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*.

WHC-SD-EN-DP-090, *Borehole Data Package for the 100-K Area Groundwater Wells for CY 1994.*

WHC-SD-EN-TI-221, *Geology of the 100-FR-3 Operable Unit, Hanford Site South-Central Washington.*

a. Well drilled into the RUM, but was completed and screened in the unconfined aquifer above the RUM.

b. Water level dropped too fast during test to record data, indicates high hydraulic conductivity.

RUM = Ringold Formation upper mud

C7 Geochemical Analysis Charts

Groundwater data were evaluated for the major ions distribution in various 100-K wells. The major ions include calcium, chloride, sulfate, carbonate, sodium, potassium, and magnesium. The ions distribution was compared between wells with different geology, various levels of contamination, and the water of the Columbia River. To compare the concentrations of the ions, laboratory analytical results are collected. The concentrations are converted from micrograms per liter or milligrams per liter to the milliequivalent per liter of the ion, based on its atomic weight.

As presented in Table C-5, the milliequivalent per liter concentrations vary greatly across 100-K, but when plotted as a stiff diagram, patterns develop. Stiff diagrams for various wells based on the data in Table C-5, and the Columbia River, are presented in Figure C-27. Groundwater monitoring wells were evaluated from near the KE and KW Reactors and the 116-K-2 trench. Not all wells had adequate data to conduct analyses. Several groups with a similar chemistry/ion pattern or distribution emerged during evaluation.

Two major groupings can be distinguished in 100-K. Monitoring wells within these groups tend to exhibit a similar ion distribution, or pattern, to some varying degrees. One group is near at the KW Reactor and the other around the 116-K-2 trench. Around the KW Reactor, several monitoring wells show a similar pattern and are identified on Figure C-27 with rust coloring. Monitoring well 199-K-35 is the representative stiff diagram. The distinguishing feature in the geochemistry is the lack of chloride in the groundwater from those wells, which still has a relatively moderate level of magnesium and sodium plus potassium. The other major pattern at 100-K is present near the 116-K-2 trench. Groundwater in this area has slightly more chloride and sulfate than the first group, with less sodium and potassium. The resulting pattern appears to “pinch” towards the middle between the chloride and the sodium plus potassium axis. These wells are purple on Figure C-27, with well 199-K-152 used as a representative diagram. The distribution pattern in this group of wells is closest to that of the Columbia River, also presented on Figure C-27.

Three wells have a more distinct and unusual pattern: wells 199-K-186, 199-K-29, and 199-K-135. Monitoring wells 199-K-186 and 199-K-29 are proximal to each other near the KW Reactor, upgradient from the Cr(VI) plume. These three wells are in Figure C-27 in orange, with well 199-K-186 presented as a representative diagram. Well 199-K-29 is located downgradient from the KE Reactor, and well 199-K-186 is on the opposite side. These two wells have a high level of calcium and carbonate, with very little sodium plus potassium or sulfate and no other apparent similarities. Monitoring well 199-K-135 is located to the north of the 116-K-2 trench. The well 199-K-135 geochemistry was altered by the calcium polysulfide injection(s) during a remediation test conducted in 2005 (DOE/RL-2006-17, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*). The groundwater signature is very similar to well 199-K-186; however, the ratio of calcium to the other ions is exaggerated.

Table C-5. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-106A		199-K-107A		199-K-108A		199-K-11		199-K-110A		199-K-111A		199-K-132	
Sampling Date	6/13/2010		10/18/2009		6/13/2010		6/11/2010		4/15/2010		6/11/2010		6/15/2010	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	160	3.2	120	2.4	140	.8	120	2.4	130	2.6	140	2.8	120	2.4
Ca	73,900	4	48,400	2	57,800	3	39,700	2	71,000	4	50,300	3	56,000	3
Cl	26,500	0.7	14,300	0.4	10,800	0.3	8,240	0.2	51,300	1.4	7,870	0.2	13,100	0.4
Mg	17,400	1	9,860	1	12,500	1	10,800	1	11,300	1	11,700	1	6,450	1
pH	7.64		7.75		7.72		7.91		7.52		7.91		7.5	
K	7,790	0.2	5,040	0.1	6,010	0.2	5,210	0.1	3,830	0.1	5,960	0.2	3,000	0.1
+Na	23,000	1.0	15,500	0.7	21,300	0.9	14,400	0.6	7,600	0.3	14,000	0.6	15,500	0.7
SO_4	40,700	1	35,700	1	36,200	1	37,700	1	15,900	0	37,000	1	33,600	1
Well ID	199-K-152		199-K-157		199-K-18		199-K-182		199-K-20		199-K-22		199-K-31	
Sampling Date	6/22/2010		3/8/2010		6/11/2010		6/22/2010		6/16/2010		6/11/2010		6/11/2010	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	94	1.9	110	2.2	63	1.3	91	1.8	91	1.8	91	1.8	120	2.4
Ca	35,600	2	67,400	3.4	71,100	3.5	39,600	2	42,200	2	60,500	3	46,000	2
Cl	6,530	0.2	16,200	0.5	14,000	0.4	11,200	0.3	17,500	0.5	20,400	1	15,000	0.4
Mg	10,400	1	10,500	0.9	11,700	1.0	12,300	1	9,360	1	10,400	1	10,600	1
pH	8.03		7.93		8.3		8.03		7.67		8.06		7.71	
K	4280	0.1	4,800	0.1	4,180	0.1	4,390	0.1	4,330	0.1	2,770	0.1	5,220	0.1
+Na	9,600	0.4	15,500	0.7	4,680	0.2	10,500	0.5	7,620	0.3	8,470	0.4	15,400	0.7
SO_4	36,600	1	80,100	1.7	94,800	2.0	45,300	1	37,700	1	74,500	2	37,000	1

Table C-5. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-135 CaS(1-X)		199-K-142		199-K-34		199-K-37		699-73-61		199-K-32B		199-K-192	
Sampling Date	10/18/2009		6/11/2010		6/30/2010		6/24/2010		6/18/2010		6/24/2010		6/24/2010	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	490	9.8	94	1.9	140	2.8	97	1.9	110	2.2	134	2.7	146	2.9
Ca	225,000	11.2	28,000	1.4	59,600	3	38,800	2	34,100	2	25,500	1	25,500	1
Cl	18,900	0.5	6,280	0.2	18,200	0.5	10,500	0.3	6,620	0.2	4,590	0.1	3,900	0.1
Mg	26,800	2.2	5,590	0.5	10,700	1	8,570	1	9,480	1	14,500	1	18,000	1
pH	7.05		8.16		7.72		8.25		8.13					
K	5,650	0.1	3,710	0.1	2,180	0.1	3,700	0.1	4,930	0.1	4,270	0.1	5,120	0.1
+Na	10,200	0.4	7,250	0.3	17,300	0.8	9,370	0.4	15,000	0.7	29,700	1.3	25,800	1.1
SO_4	11,800	0.2	10,400	0.2	20,000	0	42,100	1	34,900	1	38,600	1	38,600	1
Well ID	199-K-35		199-K-19		199-K-21		199-K-23		199-K-29		199-K-30		Col. Rvr. Below PR Dam	
Sampling Date	3/19/1993		6/15/1993		6/25/1993		10/10/2011		12/2/2010		12/2/2010		5/1/1994	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	120	2.4	86	1.7	68	1.4	210	4.2	110	2.2	120	2.4	52	1.0
Ca	34,800	2	45,500	2	39,700	2	67,900	3	50,200	3	50,400	3	18300	1
Cl	6,200	0.2	6,200	0.2	5,900	0.2	26,800	0.8	20,500	0.6	23,500	0.7	1300	0.0
Mg	9,480	1	6,460	1	7,830	1	17,300	1	11,500	1	9,860	1	4470	0
pH			7.60		7.90		7.85		7.77		7.87			
K	5,040	0.1	3,120	0.1	1,540	0.0	15,900	0.4	4,830	0.1	4,820	0.1	645	0.0
+Na	13,300	0.6	5,370	0.2	3,250	0.1	25,200	1.1	9,360	0.4	11,000	0.5	2470	0.1
SO_4	22,000	0	53,400	1	53,700	1	33,600	1	19,100	0	28,400	1	9900	0

Table C-5. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-184		199-K-186		199-K-189		199-K-200	
Sampling Date	7/20/2011		5/11/2011		10/10/2011		7/19/2011	
Concentration Units	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)	(µg/L)	(meq/L)
Alkalinity	110	2.2	170	3.4	100	2.0	98	2.0
Ca	41,600	2	53,400	3	49,100	2	63,200	3
Cl	11,300	0.3	15,000	0.4	38,200	1.1	20,700	0.6
Mg	11,500	1	11,000	1	11,600	1	11,000	1
pH	8.15		7.38		7.86		7.73	
K	5,930	0.2	4,720	0.1	6,590	0.2	2,980	0.1
+Na	15,200	0.7	7,340	0.3	10,900	0.5	10,700	0.5
SO_4	32,800	1	11,800	0	23,500	0	74,700	2
Well ID	199-K-36	Time Series						
Sampling Date	3/19/1993		12/4/1996		10/23/2003		6/10/2010	
Concentration Units	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L
Alkalinity	127	2.5	140	2.8	120	2.4	130	2.6
Ca	45,000	2	136,000	7	47,400	2	49,200	2
Cl	3,900	0.1	147,000	4.1	27,500	0.8	24,400	0.7
Mg	11,400	1	34,100	3	12,300	1	12,400	1
K	5,180	0.1	7,150	0.2	6,850	0.2	5,810	0.1
+Na	13,200	0.6	21,600	0.9	31,300	1.4	21,300	0.9
SO_4	52,000	1	160,000	3	47,800	1	53,800	1

Table C-5. 100-KR-4 OU Major Ion Chemistry Data

Well ID	199-K-107A	Time Series												
Sampling Date	4/28/1999		10/3/2005		10/12/2006		10/19/2007		4/15/2009		8/12/2009		12/3/2010	
Concentration Units	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L
Alkalinity	126	2.5	115	2.3	110	2.2	120	2.4	120	2.4	120	2.4	120	2.4
Ca	44,800	2	44,400	2	42,000	2	46,900	2	45,100	2	46,200	2	49,200	2
Cl	8,030	0.2	7,600	0.2	6,680	0.2	10,200	0.3	11,900	0.3	11,500	0.3	19,300	0.5
Mg	9,760	1	8,910	1	9,240	1	8,970	1	9,540	1	8,780	1	10,600	1
K	6,490	0.2	4,850	0.1	4,670	0.1	5,290	0.1	4,970	0.1	4,390	0.1	4,590	0.1
+Na	19,100	0.8	16,000	0.7	17,300	0.8	15,600	0.7	16,400	0.7	13,900	0.6	17,000	0.7
SO_4	39,600	1	32,500	1	33,900	1	37,200	1	35,200	1	35,500	1	40,500	1
Well ID	199-K-108A	Time Series												
Sampling Date	4/28/1999		10/12/2006		4/1/2008		10/6/2008		4/15/2009		10/22/2009		12/8/2010	
Concentration Units	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L	(µg/L)	meq/L
Alkalinity	162	3.2	110	2.2	160	3.2	150	3.0	170	3.4	140	2.8	140	2.8
Ca	64,200	3	61,300	3	69,700	3	67,800	3	63900	3	62,800	3	53,800	3
Cl	9,880	0.3	26,000	0.7	20,700	0.6	22,900	0.6	17200	0.5	8,070	0.2	10,800	0.3
Mg	14,500	1	13,900	1	13,800	1	13,300	1	13700	1	12,800	1	11,900	1
K	7,650	0.2	4,520	0.1	6,090	0.2	4,530	0.1	6010	0.2	6,010	0.2	6,080	0.2
+Na	24,500	1.1	16,600	0.7	23,200	1.0	25,800	1.1	25500	1.1	22,000	1.0	21,900	1.0
SO_4	60,600	1	30,300	1	70,700	1	33,700	1	37100	1	54,100	1	35,400	1

Note: Alkalinity = mg/L as $CaCO_3$.

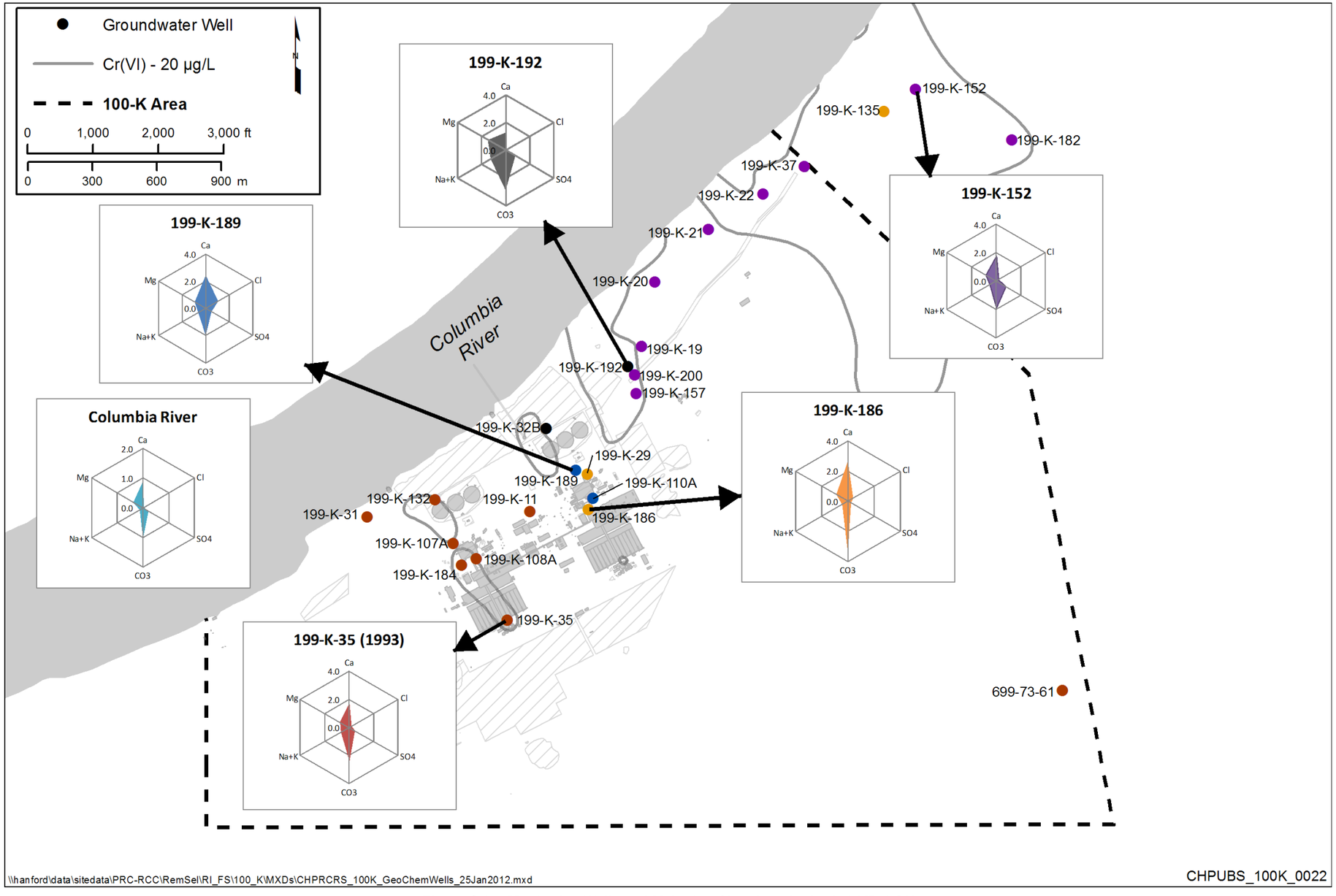

Figure C-27. Monitoring Wells and Major Ion Chemistry in the 100-KR-4 OU

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Two of the wells in 100-K are completed in the first water-bearing unit of the RUM (wells 199-K-192 and 199-K-32B), and both had adequate data for geochemistry analysis. The geochemical signature for both wells is similar, as expected for wells screened within the same geologic unit. The stiff diagram for well 199-K-192 is representative of both wells and presented in Figure C-27. Unlike other wells screened in the RUM, low Cr(VI) levels have been identified in well 199-K-32B. As shown in cross section H-H' (Figure C-9), if the water-bearing unit encountered in well 199-K-32B is in the same unit and extends northeast, it would intersect the same groundwater identified in well 199-K-162. Well 199-K-162 had Cr(VI) levels ranging from 8 to 25 µg/L during 2010. A connection between the sand layer identified and screened in wells 199-K-162 (located in a dip in the RUM) and 199-K-32B is a possible explanation for the low levels of Cr(VI) identified in well 199-K-32B.

Monitoring wells 199-K-110A and 199-K-189 show a similar chemical signature, but differ from other 100-K wells (shown in dark blue in Figure C-27). The Cl^- component is greater in these two wells, with low levels of sulfate and sodium plus potassium. Within 100-K, there are several other wells where the chemical signature could be with one group or another, but the pattern is not clear.

To evaluate the potential effect of contamination and/or remediation activities on the groundwater geochemical signature, wells 199-K-36, 199-K-107A, and 199-K-108A were evaluated over a time series. Monitoring wells 199-K-108A and 199-K-107A are proximal to each other, near the KW Reactor. The groundwater geochemistry signature of well 199-K-107A from 1999 through 2009 reveals little change and remains similar to well 699-73-61. The Cr(VI) concentrations in well 199-K-107A during that period ranges from about 600 µg/L in 1999 to 50 µg/L in August 2009; however, well 699-73-61, which has a similar major ions pattern, has Cr(VI) concentration levels below detection. The Cr(VI) concentrations in monitoring well 199-K-108A fluctuate between levels from 250 µg/L to below detection.
The geochemical signature, however, is not consistent through any periods. The ion distribution pattern in well 199-K-36 is lacking a distinctive pattern, consistent with the other two wells. There is no apparent correlation between a particular ion distribution and a related contamination level.

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Appendix D

Analytical Data

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Supporting Information

The following supporting information is contained on the removable media.

Groundwater Data

100K_WellData_GW	Groundwater data collected from wells between January 1, 1990 to April 30, 2017.

Soil Data

qry_100K_LFI_Data_fromJumbo.xlsx	Includes historical data collected at 100-K and the Limited Field Investigation.
100K_2017_SOILDATA_22Jan2018.xlsx	RSVP and CVP data collected at 100-K

100K_ADDLSITES_SOILDATA.xlsx	Soil data collected from river shore waste sites
100K_WellData_SO.xlsx	Soil data collected from pre-RI, RI, and post RI characterization wells.
Water Levels and River Stage Data	
100K_AWLN_1of8.xlsx 100K_AWLN_2of8.xlsx 100K_AWLN_3of8.xlsx 100K_AWLN_4of8.xlsx 100K_AWLN_5of8.xlsx 100K_AWLN_6of8.xlsx 100K_AWLN_7of8.xlsx 100K_AWLN_8of8.xlsx	Hourly water-level data from automated water level network for 100-K wells, January 2004 through December 2017.
100K_ManualWL.xlsx	Historic, manual water level data for wells in 100-K.
River_Stage_100K.xlsm	Hourly and daily average river stage at 100-K, calculated from Priest Rapids Dam data (October 2007 to July 2017).

Terms

AWQC	ambient water quality criteria
COPC	contaminant of potential concern
DWS	drinking water standards
HQ	hazard quotient
ICP	inductively coupled plasma
MCL	maximum contaminant level
MDL	method detection limit
MS	mass spectrometry
MTCA	“Model Toxics Control Act—Cleanup”
OU	operable unit
RBC	risk-based concentration
RUM	Ringold upper mud
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbon
VOC	volatile organic compound

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D1 Introduction

This appendix summarizes the data set compiled to support the 100-K remedial investigation (RI) and associated feasibility study (FS). It includes data from ongoing site programs (e.g., annual groundwater monitoring); waste site remediation, previous soil and groundwater investigations conducted in 100-K; and data collected specifically for the RI/FS as described in DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*, and the companion sampling and analysis plan (DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units Remedial Investigation/Feasibility Study*). The following is a list of the available data:

- Waste site interim remedial soil analytical data
- Soil analytical data
- Groundwater analytical data (October 2009 to April 2017)
- Fate and transport parameters (e.g., geochemical parameters, hydrogeologic parameters, soil physical properties)
- Groundwater levels and Columbia River stage (to April 2017)
- Soil physical properties (grain size, moisture content, and porosity[1])

The data compiled for this RI/FS are recorded on the attached USB card, unless incorporated by reference as described in this appendix.

D1.1 Assessments of Data Quality

An assessment of data quality was prepared to support the vadose zone characterization component of the 100-K RI and FS (WCH-489, *100-K Remedial Investigation/Feasibility Study Data Quality Assessment Report*). The assessment addressed laboratory quality control (QC) results. The laboratory QC results were evaluated against the requirements and guidelines provided in DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*, and the associated Tri-Party Agreement (Ecology et al. 1989, Hanford Federal Facility Agreement and Consent Order) Change Notices (TPA-CN-357, TPA-CN-384, and TPA-CN-405). Based on the assessment results, the laboratory analytical results that were not qualified as rejected are considered useable for their intended purpose (WCH-489). An assessment was also performed on the groundwater data collected in support of the 100-K RI/FS Work Plan (DOE/RL-2008-46ADD2), and is documented in Attachment D1.

Subsequent assessments were performed on additional data collected after 2012, the results of which are documented in:

- SGW-60149, *Report for Soil Borings and Well installations in the UPR-100-K-1 and 116-KE-3 Waste Sites*
- SGW-61212, *Data Quality Assessment for 100-KR-4 Groundwater Operable Unit Wells Installed in Calendar Year 2014 and 2015*

[1] Included in Appendix C.

- SGW-61544, Data Usability Assessment for 100-KR-4 Groundwater Operable Unit Wells Installed in Calendar Year 2014 and 2016
- Soil Data

Historical, RI, and interim remedial action data are included in the soils data. The following types of data are not included in the waste site post-remedial action soil analytical data:

- Quality control (QC) samples (e.g., equipment blanks, field trip blanks)
- Variance Samples
- In-Process Samples

Historical and RI soil data include analytical data from Limited Field Investigation (LFI) reports and other investigation activities not directly related to waste site remediation. Available soil analytical data to December 31, 2010 in HEIS were exported from HEIS on February 11, 2010 (qry_100K_LFI_Data_fromJumbo.xlsx) The following references provided sample identifications for data within 100-K:

- DOE/RL-93-78, *Limited Field Investigation Report for the 100-KR-1 Operable Unit*
- DOE/RL-93-79, *Limited Field Investigation Report for the 100-KR-4 Operable Unit*
- UNI-946, *Radiological Characterization of the Retired 100 Areas*
- SGW-39635, *Borehole Summary Report for the Installation of Four Groundwater Wells at 100-KW, FY 2008*
- SGW-48760, *Borehole Summary Report for Two Characterization Boreholes in the K2 Trench in the 100-KR-4 Operable Unit to Support WCH in FY 2010*
- SGW-49459, *Borehole Summary Report for the Drilling and Installation of RI/FS Wells in the 100-KR-4 Operable Unit*
- SGW-58157, *Borehole Summary Report for the Installation of Three Wells in the 100-KR-4 Operable Unit, FY2013*
- SGW-59027, *Borehole Summary Report for the Installation of Two Wells in the 100-KR-4 Operable Unit, with and option of Three Wells, FY2014*
- SGW-59494, *Borehole Summary Report for the Installation of Two Characterization, Monitoring, and Extraction Wells in the 100-KR-4 Operable Unit, FY2015*
- SGW-60149, *Report for Soil Borings and Well Installations in the UPR-100-K-1 and 116-K-3 Waste Sites*
- SGW-60241, *Borehole Summary Report for the Installation of Four 100-KR-4 Operable Unit Extraction Wells, FY16*

The 100-K interim remedial action data were compiled based on the following CVP and RSVP reports related to waste site remedial actions:

- CVP-2003-00024, *Cleanup Verification Package for the 116-K-1 Crib*

- CVP-2004-00001, *Cleanup Verification Package for the 116-KW-3 Retention Basin*
- CVP-2005-00002, *Cleanup Verification Package for the 116-KE-4 Retention Basin*
- CVP-2005-00006, *Cleanup Verification Package for the 100-K-55:1 and 100-K-56:1 Pipelines and the 116-KW-4 and 116-KE-5 Heat Recovery Stations*
- CVP-2006-00001, *Cleanup Verification Package for the 116-K-2 Effluent Trench*
- WSRF 2003-036, *Waste Site Reclassification Form, Operable Unit 100-KR-2, Waste Site ID 100-K-30*
- WSRF 2004-038, *Waste Site Reclassification Form, Operable Unit 100-KR-2, Waste Site ID 100-K-31*
- WSRF 2004-039, *Waste Site Reclassification Form, Operable Unit 100-KR-2, Waste Site ID 100-K-32*
- WSRF 2004-040, *Waste Site Reclassification Form, Operable Unit 100-KR-2, Waste Site ID 100-K-28*
- WSRF 2004-041, *Waste Site Reclassification Form, Operable Unit 100-KR-2, Waste Site ID 100-K-33*
- WSRF 2004-042, *Waste Site Reclassification Form, Operable Unit 100-KR-2, Waste Site ID 128-K-1*

QC samples (e.g., equipment blanks, field trip blanks) are not included in the soil analytical data.

Analytical data from soil samples collected as part of the RI between May 2010 and February 2011 and from March 2015 through April 2017 are included in the following excel files:

- 100K_2017_SOILDATA_22Jan2018.xlsx
- 100K_ADDLSITES_SOILDATA.xlsx
- 100K_WellData_SO.xlsx

The samples were collected from vadose zone boreholes and monitoring wells. Data include chemicals, radionuclides, and physical properties.

D2 Evaluation of Measured Groundwater Concentrations

This section presents a comprehensive interpretation of the groundwater monitoring results used to identify analyte concentrations that are greater than action levels. Action levels are defined as screening levels derived from chemical-specific drinking water standards (DWSs), ambient water quality criteria (AWQC), state surface water quality standards, or risk-based concentrations (RBCs) using default exposure assumptions. The results of this evaluation will be used to support the contaminant of potential concern (COPC) identification process that is provided in the groundwater baseline risk assessment, which is presented in Chapter 6. The groundwater baseline risk assessment provides a comprehensive evaluation of cumulative cancer risks and noncancer hazards.

The purpose of evaluating the groundwater data is to determine the specific well and aquifer tube where a COPC is present above an action level. Subsequently, this information can be used in the feasibility study to evaluate groundwater remedial alternatives.

A total of 82 monitoring and extraction wells are included in this evaluation; this data set is consistent with the data set used in the groundwater baseline risk assessment. Well 199-K-109A was originally included to define strontium-90 contamination near the KE Fuel Storage Basin; however, no samples were collected from this well during the time period evaluated, therefore it is not included in the well dataset. Monitoring and extraction wells are evaluated in this appendix based on the screen depth. Twenty monitoring wells and one extraction well are screened at the top of the unconfined aquifer, 20 monitoring wells and nine extraction wells are screened across the upper unconfined aquifer, three monitoring wells are screened across the lower unconfined aquifer, one monitoring well is screened in the upper and lower unconfined aquifer, nine monitoring wells and 14 extraction wells are screened across the entire aquifer, and two monitoring wells are screened in the Ringold upper mud (RUM) unit. Additionally, groundwater data from 52 aquifer tubes are evaluated. The groundwater evaluation is based on samples collected between October 2009 and April 2017, which were considered representative of current groundwater conditions. The groundwater data set that is included in this appendix (100K_WellData_GW.xlsx) includes data collected between January 1, 1990 and April 30, 2017. A list of the wells and aquifer tubes included in this evaluation is provided in Table D-1, and well locations within the 100-KR-4 operable unit (OU) are shown in Figure 4-27 of Chapter 4.

Groundwater data from all wells with a specified screen interval and data from each individual well were compiled, statistically analyzed, and summarized. Section 6.3.2.3 of the main text describes data processing and reduction steps. Constituents included those identified in the 100-K Work Plan (DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*) as COPCs and all additional constituents analyzed during the monitoring period for which action levels have been identified. Results are compared to the lower of the DWSs and the 2013 WAC 173-340, "Model Toxics Control Act-Cleanup," hereinafter called MTCA, WAC 173-340-720, "Groundwater Cleanup Standards" (see Section D.1 for the definition of action levels). Similarly, results are compared to the lower of the federal AWQC and the State surface water quality standards (WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"). Groundwater data collected from aquifer tubes are evaluated using the same approach as groundwater data collected from monitoring wells.

D2.1 Action Levels

For the purpose of this evaluation, action levels are defined as screening levels derived from chemical-specific DWSs, AWQC, state surface water quality standards, or RBCs using default exposure assumptions. The comparisons discussed further in this section identify the screening levels that are relevant.

The sources of action levels from federal regulations are as follows:

- 40 CFR 141, "National Primary Drinking Water Regulations"; maximum contaminant levels[2] (MCLs); secondary MCLs; and nonzero MCL goals established under the *Safe Drinking Water Act of 1974*
- National recommended water quality criteria and AWQC established under Section 304 of the *Clean Water Act of 1977* (CWA) (*Federal Water Pollution Control Act*)
- 40 CFR 131, "Water Quality Standards," for states not complying with Section 304 of the CWA

[2]For the purposes of this appendix, the terms MCL (maximum contaminant levels for drinking water) and DWS are used interchangeably.

The sources of action levels from Washington State regulations are as follows:

- WAC 173-201A
- WAC 173-340-720, based on a target risk level of 1×10^{-6} or a hazard quotient (HQ) of 1
- WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)"

While surface water standards and AWQC are considered when identifying action levels, it must be noted that these standards only apply to groundwater where it enters the Columbia River. Although groundwater concentrations were compared to AWQC or state surface water quality standards, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Table D-2 provides a summary of the action levels used for comparison of groundwater that could potentially discharge into the Columbia River. Table D-3 provides a summary of the DWSs and 2007 MTCA (WAC 173-340-720) groundwater cleanup levels (also known as the 2013 MTCA RBC) used for comparison of groundwater.

Note that Tables D-2 and D-3 include constituents analyzed for and detected during the monitoring period for which groundwater or surface water action levels have been identified. Similarly, the tables in Sections D.1.2 through D.1.8 list only those constituents that were detected in at least one sample.

D2.2 Comparison Results for Wells Screened at the Top of the Unconfined Aquifer

A total of 21 wells are screened at the top of the unconfined aquifer. Groundwater data from all wells screened at the top of the unconfined aquifer and data from each individual well were compiled, statistically analyzed, and summarized in Tables D-4 through D-7. Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Table D-4 and Table D-5, respectively. Results are also compared to federal AWQC and the State surface water quality standards (WAC 173-201A) and presented in Table D-6 and Table D-7. Each set of tables presents the summary statistics for each analyte detected, the background concentrations in Hanford Site groundwater (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, pesticides, radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and total petroleum hydrocarbon (TPH)-diesel range organics and TPH-gasoline range organics.

D2.2.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: All but one well (199-K-110A) was analyzed for carbon-14, gamma-emitting isotopes, and strontium-90. All but well 199-K-36 was analyzed for gross alpha and gross beta. All wells were analyzed for tritium. Six wells (199-K-106A, 199-K-18, 199-K-19, 199-K-22, 199-K-29, and 199-K-30) were analyzed for nickel-63. All but two wells (199-K-110A and 199-K-140) were analyzed for technetium-99. Two wells (199-K-132 and 699-73-61) were analyzed for isotopic uranium. As shown in Table D-4, carbon-14, cobalt-60, nickel-63, gross alpha, gross beta, strontium-90, technetium-99, and tritium were detected at least once in groundwater. Concentrations of cobalt-60, nickel-63, and technetium-99 were less than their respective DWS; therefore, they are not retained as COPCs.

Carbon-14, gross alpha, strontium-90, and tritium concentrations were greater than their respective DWS and are discussed below:

- As shown in Table D-4, carbon-14 was detected in 273 of 308 (89% frequency), with concentrations ranging between 8.4 and 40,100 pCi/L. As shown in Table D-5, six wells reported carbon-14 above the DWS and include 199-K-106A, 199-K-132, 199-K-139, 199-K-29, 199-K-30, and 199-K-34.
  - Detected in the single sample from well 199-K-29 (3,120 pCi/L) collected December 2010.
  - Detected in both samples from well 199-K-30 (3,510 to 4,110 pCi/L); collected in April and December 2010.
  - Detected in all 24 samples from well 199-K-34 (654 to 8,210 pCi/L); all samples collected after November 2015 were less than DWS. Carbon-14 is not retained as a COPC at this well due to the downward concentration trend.
  - Detected in all 29 samples from well 199-K-106A (3,970 to 40,100 pCi/L); all 29 samples above the DWS.
  - Detected in all 30 samples from well 199-K-132 (1,570 to 10,900 pCi/L); 27 samples above DWS.
  - Detected in all 11 samples from 199-K-139 (347 to 2,370 pCi/L in 2013); 1 sample from 11/19/14 was above DWS. Carbon-14 is not retained as a COPC at this well due to the sporadic nature of the detection.
- As shown in Table D-4, gross alpha was detected in 116 of 264 (44% frequency), with concentrations ranging between 1.4 and 18 pCi/L. As shown in Table D-5, well 199-K-111A reported gross alpha above the DWS in one of 31 samples. Gross alpha is not retained as a COPC because the single occurrence above the DWS was measured in June 2010 and did not occur again over the DWS.
- As shown in Table D-4, strontium-90 was detected in 146 of 276 groundwater samples (53% frequency), with concentrations ranging between 0.88 and 251 pCi/L. As shown in Table D-5, seven wells reported strontium-90 above the DWS (199-K-107A, 199-K-139, 199-K-19, 199-K-200, 199-K-201, 199-K-22, and 199-K-34). Strontium-90 is retained as a COPC due to the following results exceeding the DWS.
  - Detected in all seven samples from 199-K-19 (12 to 15 pCi/L); all samples were above the DWS.
  - Detected in 9 of 10 samples from well 199-K-22 (4 to 15 pCi/L); concentrations show downward trend where concentrations are less than the DWS since November 2015 and is not retained as a COPC at this well.
  - Detected in all 24 samples from well 199-K-34 (15 to 66 pCi/L); all samples were above the DWS.
  - Detected in all 24 samples from well 199-K-107A (9.2 to 32 pCi/L); all samples were above the DWS.
  - Detected in all 12 samples from well 199-K-139 (4.7 to 22 pCi/L); 6 samples collected after November 2015 were above the DWS.

- Detected in all 22 samples from well 199-K-200 (137 to 251 pCi/L); all samples were above the DWS.
- Detected in all 22 samples from well 199-K-201 (5.2 to 18 pCi/L); 21 of 22 samples above the DWS.

- As shown in Table D-4, gross beta was detected in 259 of 264 groundwater samples (98% frequency), with concentrations ranging between 2.9 pCi/L and 426 pCi/L. The presence of gross beta is generally consistent with that of strontium-90 and tritium. Note that the sum-of-fractions approach is used to determine whether the contribution of each beta- and photon-emitting radionuclide is greater than the cumulative annual dose equivalent of 4 mrem to the total body or any internal organ. This evaluation is presented in Section 6.3.5.

- As shown in Table D-4, tritium was detected in 339 of 383 groundwater samples (89% frequency), with concentrations ranging between 129 and 379,000 pCi/L. As shown in Table D-5, five wells reported concentrations greater than the DWS of 20,000 pCi/L. Wells that reported tritium above the DWS included 199-K-106A, 199-K-111A, 199-K-18, 199-K-29 and 199-K-30. Although tritium concentrations were above the DWS during 2010 and 2011, tritium concentrations had declined below the DWS in 2013 through 2015. Tritium is retained as a COPC for monitoring based on the DWS exceedances listed below:

  - Detected in all 16 samples from well 199-K-18 (3,050 to 290,000 pCi/L); 11 of 16 samples above DWS through October 2014, concentrations show downward trend below the DWS after that date.
  - Detected in a single sample collected on December 2, 2010 from well 199-K-29 (130,000 pCi/L) prior to the well being decommissioned in early 2011.
  - Detected in all four samples from well 199-K-30 (16,000 to 280,000 pCi/L); the sample collected December 2010 was less than the DWS, no additional tritium samples have been collected from this location as the well was decommissioned in early 2011.
  - Detected in all 41 samples from well 199-K-106A; 13 samples collected before August 2009 were above DWS and all samples collected afterward were below the DWS. Tritium is not retained as a COPC at this well because of the downward concentration trend below the DWS.
  - Detected in all 34 samples from well 199-K-111A (15,000 to 379,000 pCi/L); 27 of 34 samples above the DWS.

VOCs: VOCs were analyzed in 17 wells. As shown in Table D-4, 2-butanol, 2-butanone, 2-propanol, acetone, bromodichloromethane, bromomethane, carbon disulfide, chlorobenzene, chloroform, methylene chloride, styrene, tetrahydrofuran, toluene, trichloroethene, and xylenes (total) were detected in groundwater. 2-butanol, 2-butanone, 2-propanol, acetone, bromodichloromethane, bromomethane, carbon disulfide, chlorobenzene, styrene, tetrahydrofuran, toluene, and xylenes (total) are not retained as COPCs because all results (detected concentrations and method detection limits [MDLs]) were less than the groundwater action level. Chloroform, methylene chloride, and trichloroethene were detected above the 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and are discussed below. One sample was analyzed for SVOCs and one wells analyzed for pesticides.

- As shown in Table D-4, chloroform was detected in 97 of 161 groundwater samples (60% frequency), with concentrations ranging between 0.11 µg/L and 2.3 µg/L. As shown in Table D-5, three wells (199-K-18, 199-K-32A, and 199-K-106A) had chloroform concentrations above the 2013 MTCA

(WAC 173-340-720) groundwater cleanup level of 1.4 µg/L based on a target risk level of 1×10^{-6} in at least one sample, as discussed below:

- Detected in all three samples collected from well 199-K-18 (2.0 µg/L to 2.1 µg/L) during 2010; no additional chloroform analyses have been performed at this well.
- Detected in all three samples collected from well 199-K-32A (2.1 µg/L to 2.3 µg/L) during 2010; no additional chloroform analyses have performed at this well.
- Detected in 14 of 19 samples (74% frequency) collected from well 199-K-106A (0.13 µg/L to 1.5 µg/L); two of 14 results were greater than the RBC.

Chloroform concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 1.4 µg/L at three wells (199-K-18, 199-K-32A, and 199-K-106A), However, the well-specific risk assessment determined that the cumulative risk level was equal to the MTCA (WAC 173-340-708, "Human Health Risk Assessment Procedures") risk threshold of 1×10-5 in both wells. As a result, chloroform is not retained as a COPC.

- As shown in Table D-4, methylene chloride was detected in 8 of 161 groundwater samples (5.0% frequency), with concentrations ranging between 0.31 µg/L and 14 µg/L. As shown in Table D-5, three wells (199-K-132 and 199-K-200) had methylene chloride concentrations above the DWS of 5 µg/L in at least one sample. Methylene chloride is not considered a COPC because it is a common laboratory contaminant, which is introduced in the laboratory after the sample is collection in the field. Methylene chloride is discussed below:
  - Detected in one of 22 samples from well 99-K-132 (MDL to 14 µg/L). The single detection at this well over a five-year time period suggests its presence is contributed from the laboratory.
  - Detected in two of eight samples from well 99-K-200 (2.2 to 6.3 µg/L). One of eight methylene chloride results were above the DWS. Its low frequency of detection suggests its presence is contributed from the laboratory.
- As shown in Table D-4, trichloroethene was detected in 109 of 161 groundwater samples (68% frequency), with concentrations ranging between 0.22 µg/L and 7.4 µg/L. As shown in Table D-5, nine wells (199-K-34, 199-K-36, 199-K-106A, 199-K-107A, 199-K-108A, 199-K-132, 199-K-137, 199-K-139, 199-K-140) had trichloroethene concentrations above the 2013 MTCA (WAC 173-340-720) RBC of 0.54µg/L in at least one sample, as discussed below:
  - Detected in six of 10 samples from well 199-K-34 (0.39 to 4 µg/L); 5 of 6 detected results were greater than the RBC.
  - Detected in two of three samples from well 199-K-36 (0.54 to 0.6 µg/L); one of two detected results were greater than the RBC.
  - Detected in all 19 samples from well 199-K-106A (0.74 µg/L to 7.4 µg/L); all samples were greater than the RBC.
  - Detected in 15 of 16 samples from well 199-K-107A (2.3 µg/L to 7.4 µg/L); all detected results were greater than the RBC.
  - Detected in all nine samples from well 199-K-108A (1.3 µg/L to 4.2 µg/L); all samples were greater than the RBC.

  - Detected in 21 of 22 samples from well 199-K-132 (1.5 µg/L to 6.4 µg/L); all detected results were greater than the RBC.
  - Detected in all three samples from well 199-K-137 (3.6 µg/L to 4.4 µg/L); all samples were greater than the RBC.
  - Detected in all 17 samples from well 199-K-139 (3.5 µg/L to 6.3 µg/L); all samples were greater than the RBC.
  - Detected in 13 of 14 samples from well 199-K-140 (3.0 µg/L to 5.9 µg/L); all detected results were greater than the RBC.

- Trichloroethene concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 0.54 µg/L at nine wells, However, the well-specific risk assessment determined that the cumulative risk level was less than the MTCA (WAC 173-340-708) risk threshold of 1×10^{-5} in all wells and HQ was greater than 1 at six wells. As a result, trichloroethene is retained as a COPC at wells 199-K-106A, 199-K-107A, 199-K-108A, 199-K-132, 199-K-139, and 199-K-140.

Pesticides: Pesticides were analyzed in one well (699-73-61). Pesticides were not detected in any samples collected from well 699-73-61.

SVOCs: SVOCs were analyzed in one well (699-73-61). SVOCs were not detected in the samples collected from well 699-73-61.

TPH-diesel: TPH-diesel was analyzed in nine wells. As shown in Table D-4, TPH-diesel was detected in 3 of 56 groundwater samples (5.4% frequency). All TPH-diesel results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 500 µg/L. Based on these results, TPH-diesel is not retained as a COPC.

TPH-gasoline: TPH-gasoline was analyzed in eight wells. As shown in Table D-4, TPH-gasoline was detected in 6 of 48 groundwater samples (13% frequency). All TPH-gasoline results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 1,000 µg/L. Based on these results, TPH-gasoline is not retained as a COPC.

TPH-motor oil: TPH-motor oil was analyzed in five wells. As shown in Table D-4, TPH-motor oil was detected in 3 of 5 groundwater samples (60% frequency). All TPH-motor oil results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 1,000 µg/L. Based on these results, TPH-motor oil is not retained as a COPC.

Anions: Anions were analyzed in all 22 wells. As shown in Table D-4, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride and nitrite results (detected concentrations and MDLs) were less than their respective action levels and are not retained as COPCs. Nitrate was detected in all 409 groundwater samples (100% frequency), with concentrations ranging between 797 and 100,931 µg/L. As shown in Table D-5, 11 wells (199-K-18, 199-K-22, 199-K-23, 199-K-29, 199-K-30, 199-K-32A, 199-K-34, 199-K-106A, 199-K-107A, 199-K-108A, and 199-K-132) had nitrate above the DWS of 45,000 µg/L. Nitrate is retained as a COPC for monitoring based on the DWS exceedances listed below:

- Detected in all 26 samples from well 199-K-18 (15,100 to 76,600 µg/L); four of 26 samples collected before December 2010 were above the DWS. Nitrate is not retained as a COPC at this well due to concentrations decreasing below the DWS.

- Detected in all 14 samples from well 199-K-22 (10,300 to 66,400 µg/L); one sample collected June 2012 was above the DWS all other samples were less than the DWS. Nitrate is not retained as a COPC at this well due to the sporadic nature of the detection.
- Detected in all seven samples from well 199-K-23 (797 to 70,800 µg/L); four of seven samples were above the DWS. Note the September 2017 sample shows a spike in concentration.
- Detected in the single sample from well 199-K-29 (46,500 µg /L); no samples were collected from this well after December 2010.
- Detected in all four samples from well 199-K-30 (25,100 to 60,600 µg/L); one of four samples were above the DWS, no samples were collected from this well after December 2010. Nitrate is not retained as a COPC at this well due to the sporadic nature of the detection.
- Detected in all 28 samples from well 199-K-32A (12,400 to 53,100 µg/L); one of 28 samples were above the DWS.
- Detected in all 40 samples from well 199-K-34 (27,900 to 66,800 µg/L); 14 samples collected before May 2015 were above the DWS, a downward trend below the DWS since that date and is not retained as a COPC at this well.
- Detected in all 40 samples from well 199-K-106A (34,100 to 100,931 µg/L); 30 samples were greater than the DWS.
- Detected in all 29 samples from well 199-K-107A (21,900 to 64,200 µg/L); one of 29 samples were above the DWS and is not retained as a COPC at this well.
- Detected in all 31 samples from well 199-K-108A (29,700 to 73,500 µg/L); 10 of 29 samples were above the DWS and has shown a recent increase in concentrations.
- Detected in all 29 samples from well 199-K-132 (29,700 to 75,300 µg/L); 10 of 29 samples were above the DWS.

Cyanide: Cyanide was analyzed in three wells (199-K-106A, 199-K-132, and 699-73-61). As shown in Table D-4, all cyanide results (detected concentrations and MDLs) were less than the action level.

Metals: All wells were analyzed for chromium, hexavalent chromium, and U.S. Environmental Protection Agency (EPA) Method 6010 inductively coupled plasma (ICP) metals from SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update V*. All wells except 199-K-29 were analyzed for ICP/mass spectrometry (MS) metals by either Method 200.8 or 6020, and five wells were analyzed for mercury by Method 7470. With the exception of total chromium, cobalt, hexavalent chromium, lead, nickel, and thallium, all metals results (detected concentrations and MDLs) were less than their respective Hanford Site background values or action levels. Total chromium, cobalt, hexavalent chromium, lead, nickel, and thallium are discussed below.

As shown in Table D-4, total chromium was detected in 358 of 366 unfiltered groundwater samples (98% frequency), with concentrations ranging between 0.83 and 764 µg/L. As shown in Table D-5, 10 wells (199-K-18, 199-K-22, 199-K-23, 199-K-36, 199-K-110A, 199-K-111A, 199-K-137, 199-K-139, 199-K-140, and 199-K-201) had total chromium above the DWS of 100 µg/L.

- Detected in all 26 samples from well 199-K-18 (2.5 to 203 µg/L); four samples collected before December 2010 were above the DWS, remaining sample results show downward concentration trend, as a result total chromium is not retained as a COPC in this well.

- Detected in all nine samples from well 199-K-22 (26 to 125 µg/L); seven samples collected through June 2010 were above the DWS, remaining sample results show downward concentration trend below DWS. Total chromium is not retained as a COPC at this well due to the downward concentration trend.
- Detected in all nine samples from well 199-K-23 (3.1 to 110 µg/L); one sample from June 2012 was above the DWS, remaining sample results show downward concentration trend. Note a concentration increase in September 2017.
- Detected in all 14 samples from well 199-K-36 (26 to 454 µg/L); 10 samples collected before May 2015 were above the DWS, remaining sample results shown downward concentration trend. Total chromium is not retained as a COPC at this well due to the downward concentration trend.
- Detected in all 14 samples from well 199-K-110A (26 to 169 µg/L); three of 14 samples were above the DWS. Note a concentration increase in October 2017.
- Detected in all 29 samples from 199-K-111A (33 to 622 µg/L); 22 of 29 samples were above the DWS.
- Detected in all 22 samples from well 199-K-137 (15 to 133 µg/L); one sample collected June 2010 was above the DWS, remaining sample results show downward concentration trend. Total chromium is not retained as a COPC at this well due to the downward concentration trend.
- Detected in all 19 samples from well 199-K-139 (8.4 to 125 µg/L); one sample collected November 2009 was above the DWS, remaining sample results show downward concentration trend. Total chromium is not retained as a COPC at this well due to the sporadic nature of the detection.
- Detected in all 15 samples from well 199-K-140 (8.2 to 764 µg/L); one sample from May 2012 was above the DWS. All prior and subsequent samples were below the DWS. Total chromium is not retained as a COPC at this well due to the sporadic nature of the detection.
- Detected in all 22 samples from well 199-K-201 (39 to 130 µg//L); six samples collected before September 2012 were above the DWS, remaining sample results show downward concentration trend. Total chromium is not retained as a COPC at this well due concentrations decreasing below DWS.

As shown in Table D-4, cobalt was detected in 66 of 150 groundwater samples (44% frequency), with concentrations ranging between 0.066 and 5.6 µg/L. As shown in Table D-5, two wells (199-K-110A and 199-K-34) had concentrations above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 4.8 µg/L. Cobalt was detected above the groundwater cleanup level in the following samples but is not retained as a COPC due to the sporadic nature of the detections.

- Detected in all 8 samples from 199-K-110A (0.84 to 5.5 µg/L); 1 sample was above the MTCA RBC.
- Detected in 6 of 7 samples from well 199-K-34 (0.26 to 5.6 µg/L); 1 sample was above the MTCA RBC.

As shown in Table D-4, hexavalent chromium was detected in 402 of 438 unfiltered groundwater samples (92% frequency), with concentrations ranging between 1.5 and 571 µg/L. As shown in Table D-5, eight wells (199-K-111A, 199-K-137, 199-K-139, 199-K-18, 199-K-201, 199-K-22, 199-K-23, and 199-K-36) had hexavalent chromium concentrations greater than the 2013 MTCA RBC of 48 µg/L.

Hexavalent chromium was detected above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level in the following samples:

- Detected in all 28 samples from well 199-K-18 (1.5 to 201 µg/L); eight samples collected through October 2011 were above the cleanup level, remaining sample results show downward concentration trend and is not retained as a COPC at this well.
- Detected in all 16 samples from well 199-K-22 (12 to 128 µg/L); 10 samples collected through December 2013 were above the cleanup level, remaining sample results show downward concentration trend and is not retained as a COPC at this well.
- Detected in 7 of 10 samples from well 199-K-23 (2.2 to 115 µg/L); two samples collected through June 2012 were above the cleanup level. Note a concentration spike in samples collected between May and September 2017.
- Detected in all 16 samples from well 199-K-36 (9.3 to 403 µg/L); nine samples collected before May 2015 were above the cleanup level followed by a downward trend. Note a concentration increase since November 2016.
- Detected in all 26 samples from 199-K-111A (30 to 571 µg/L); 23 of 26 samples were above the cleanup level.
- Detected in all 30 samples from well 199-K-137 (13 to 145 µg/L); 4 samples collected during 2017 were above the cleanup level.
- Detected in all 23 samples from well 199-K-139 (5.3 to 117 µg/L); three samples collected in 2010 were above the cleanup level. Remaining sample results show downward concentration trend and is not retained as a COPC at this well.
- Detected in all 23 samples from well 199-K-201 (30 to 131 µg/L); 21 samples collected before August 2016 were above the cleanup level. Remaining sample results show downward concentration trend and is not retained as a COPC at this well.

As shown in Table D-4, lead was detected in 39 of 140 unfiltered groundwater samples (28% frequency), with concentrations ranging between 0.067 and 16 µg/L. As shown in Table D-5, one well (699-73-61) had one of six samples (16 µg/L) greater than the DWS. Lead is not retained as a COPC due to the single sporadic occurrence above the DWS.

As shown in Table D-4, nickel was detected in 153 of 348 unfiltered groundwater samples (44% frequency), with concentrations ranging between 0.72 and 300 µg/L. As shown in Table D-5, four wells (199-K-108A, 199-K-110A, 199-K-34, and 199-K-36) had nickel concentrations greater than the DWS of 100 µg/L. Nickel was detected above the DWS in the following samples but is not retained as a COPC due to the sporadic nature of the detections.

- Detected in 17 of 22 samples from well 199-K-34 (12 to 300 µg/L); 3 samples were above the DWS, which is likely the result of well corrosion.
- Detected in all 14 samples from well 199-K-36 (5.3 to 115 pCi/L); 3 samples were above the DWS.
- Detected in 24 of 31 samples from well 199-K-108A (2.3 to 126 µg/L); 1 sample was above the DWS.
- Detected in all 13 samples from 199-K-110A (10 to 108 µg/L); one sample was above the DWS.

As shown in Table D-4, thallium was detected in 5 of 140 unfiltered groundwater samples (3.6% frequency), with concentrations ranging between 0.5 and 2.2 µg/L. As shown in Table D-5, thallium was detected above the 90th percentile Hanford Site value of 1.67 µg/L in well 199-K-23. Thallium was detected in 1 of 6 samples from well 199-K-23 (2.2 µg/L) The range of thallium background concentrations (minimum, maximum, and 90th percentile) is 0.883, 1.73, and 1.67 µg/L in filtered groundwater samples. All filtered thallium samples were less than the 90th percentile value. Thallium is not retained as a COPC due to the sporadic detections in unfiltered samples and because all filtered samples were less than background.

D2.2.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once are as follows:

Anions: As shown in Table D-6, chloride was detected in all groundwater samples. All of the chloride results (detected concentrations and MDLs) were less than the AWQC.

Metals: Total concentrations of hexavalent chromium and dissolved concentrations of aluminum, cadmium, total chromium, copper, lead, mercury, nickel, silver, and zinc were detected above their respective Hanford Site background values and/or surface water action levels. All total cyanide and dissolved arsenic, iron, and selenium (detected concentrations and MDLs) were less than their respective Hanford Site background values and/or surface water action levels.

- As shown in Table D-6, dissolved aluminum was detected in 26 of 141 filtered groundwater samples (18% frequency), with concentrations ranging between 6.9 and 204 µg/L. As shown in Table D-7, aluminum was measured in three wells at concentrations greater than the AWQC of 87 µg/L. Dissolved aluminum was reported above the AWQC in wells 199-K-111A and 199-K-19; however, these results were flagged with a “C” by the laboratory indicating it was both the sample and the laboratory preparation blank and is the result of laboratory contamination. Dissolved aluminum was reported above the AWQC but is not retained as a COPC due to the sporadic nature of the detections. Aluminum is a common element in clay minerals and its presence in unfiltered groundwater samples is likely a result of sediment particles in the samples. Dissolved aluminum was reported above the AWQC in the following samples:
  - Detected in 1 of 6 samples from 699-73-61 at a concentration of 209 µg/L
- As shown in Table D-6, dissolved cadmium was detected in four of 151 filtered groundwater samples (2.7% frequency), with concentrations ranging between 0.12 and 3.7 µg/L. As shown in Table D-7, dissolved cadmium was detected in one of six samples from well 199-K-110A at a concentration (3.7 µg/L) above the AWQC of 0.72 µg/L. Dissolved cadmium is not retained as a COPC due to the sporadic nature of the detection.
- As shown in Table D-6, dissolved total chromium was detected in 346 of 369 filtered groundwater samples (94% frequency) where concentrations ranged between 0.68 µg/L and 541 µg/L. As shown in Table D-7, dissolved total chromium was measured in 8 wells at concentrations greater than the AWQC of 74 µg/L. Dissolved total chromium was reported above the AWQC in the following filtered samples:
  - Detected in 25 of 26 samples from well 199-K-18 (2 to 188 µg/L); 5 samples collected before May 2011 were above the AWQC, as a result dissolved total chromium is not retained as a COPC at this well.

- Detected in all 9 samples from well 199-K-22 (22 to 122 µg/L); 3 samples collected before April 2011 were above the AWQC. Dissolved total chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in 7 of 9 samples from well 199-K-23 (3 to 97 µg/L); 2 samples before July 2012 were above the AWQC. Note that dissolved chromium increased to 641 µg/L September 2017.
- Detected in all 15 samples from well 199-K-36 (19 to 427 µg/L); 10 samples collected before June 2016 were above the AWQC. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in 28 of 29 samples from well 199-K-111A (29 to 541 µg/L); 24 samples were above the AWQC.
- Detected in all 22 samples from well 199-K-137 (13 to 128 µg/L); 2 samples collected before February 2011 were above the AWQC. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 19 samples from well 199-K-139 (7.9 to 128 µg/L); 1 sample collected before December 2009 was above the AWQC. Dissolved total chromium is not retained as a COPC at this well because of the sporadic nature of the detection.
- Detected in all 22 samples from well 199-K-201 (38 to 125 µg/L); 17 samples collected before March 2016 were above the AWQC. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.

• As shown in Table D-6, dissolved copper was detected in 66 of 151 filtered groundwater samples (44% frequency) where concentrations ranged between 0.16 µg/L and 20 µg/L. As shown in Table D-7, dissolved copper was detected above the AWQC of 9.9 µg/L in two wells (199-K-132 and 199-K-140). Dissolved copper was reported above the AWQC, but it is not retained as a COPC due to the sporadic nature of the detections. Dissolved copper was reported above the AWQC at the following locations:

  - Detected in all 4 samples from well 199-K-132 (0.6 to 10 µg/L); 1 sample was above the AWQC.
  - Detected in 8 of 11 samples from well 199-K-140 (0.16 to 20 µg/L); 1 sample was above the AWQC.

• As shown in Table D-6, hexavalent chromium was detected in 402 of 438 groundwater samples (92% frequency) where concentrations ranged between 1.5 µg/L and 571 µg/L. As shown in Table D-7, hexavalent chromium was measured in 16 wells at concentrations greater than the State surface water quality standard (WAC 173-201A) of 10 µg/L. Hexavalent chromium was identified as a COPC and reported above the Washington State surface water quality standard (WAC 173-201A) of 10 µg/L in the following filtered samples:

  - Detected in all 28 samples from well 199-K-18 (1.5 to 201 µg/L); 16 samples collected through October 2013 were above the state standard, remaining sample results show downward concentration trend and as a result is not retained as a COPC at this well.
  - Detected un 12 of 13 samples from well 199-K-19 (1.8 to 11 µg/L); 1 sample from July 2010 was above the state standard, remaining sample results show downward concentration trend and is not retained as a COPC at this well.

- Detected in all 16 samples from well 199-K-22 (12 to 128 µg/L); all 16 samples were above the state standard.
- Detected in 7 of 10 samples from well 199-K-23 (2.2 to 115 µg/L); 5 samples collected before June 2014 were above the state standard. However, a concentration increase above the standard occurred May through September 2017.
- Detected in all 23 samples from well 199-K-32A (8.2 to 17 µg/L); 15 samples collected through December 2016 were above the state standard.
- Detected in all 30 samples from well 199-K-34 (2 to 47 µg/L); five samples collected before July 2012 were above the state standard, all remaining samples are less than the state standard. Hexavalent chromium is not retained as a COPC in this well due to the downward concentration trend.
- Detected in all 16 samples from well 199-K-36 (9.3 to 403 µg/L); 15 samples were above the state standard.
- Detected in all 30 samples from well 199-K-107A (5.6 to 27 µg/L); 11 samples collected before December 2014 were above the state standard, remaining sample results show downward concentration trend.
- Detected in 12 of 13 samples from well 199-K-110A (1.5 to 13 µg/L); 2 samples collected before June 2014 were above the state standard, all remaining samples are less than the state standard.
- Detected in all 26 samples from well 199-K-111A (30 to 571 µg/L); all samples were above the state standard.
- Detected in all 33 samples from well 199-K-132 (8 to 24 µg/L); 30 samples were above the state standard.
- Detected in all 30 samples from well 199-K-137 (13 to 145 µg/L); all samples were above the state standard.
- Detected in all 23 samples from well 199-K-139 (5.3 to 117 µg/L); 14 samples collected before December 2014 were above the state standard.
- Detected in all 24 samples from well 199-K-140 (2 to 25 µg/L); 15 samples were above the state standard.
- Detected in all 22 samples from well 199-K-200 (1.5 to 29 µg/L); 13 samples collected before January 2015 were above the state standard, Cr(VI) is not retained as a COPC at this well due to the downward concentration trend.
- Detected in all 23 samples from well 199-K-201 (30 to 131 µg/L); all 23 samples were above the state standard.

- As shown in Table D-6, dissolved lead was detected in 27 of 140 filtered groundwater samples (10% frequency) where concentrations ranged between 0.17 µg/L and 2.8 µg/L. As shown in Table D-7, dissolved lead was detected above the State surface water quality standard (WAC-173-201A) of 2.1 µg/L in two wells (199-K-32A and 699-73-61). Dissolved lead was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections.

Dissolved lead was reported above the State surface water quality standard (WAC 173-201A) at the following locations:

- Detected in 1 of 20 samples from well 199-K-32A (2.8 µg/L); 1 sample was above the State surface water standard.
- Detected in 5 of 6 samples from well 699-73-61 (0.19 to 2.3 µg/L); 1 sample was above the State surface water standard.

- As shown in Table D-6, dissolved mercury was detected in 3 of 63 filtered groundwater samples (4.8% frequency) where concentrations ranged between 0.031 µg/L and 0.17 µg/L. As shown in Table D-7, dissolved mercury was detected above the AWQC of 0.012 µg/L in two wells (199-K-108A and 199-K-137). Additionally, all MDLs for nondetected results were greater than the AWQC. Dissolved mercury was reported above the AWQC, but it is not retained as a COPC due to the sporadic nature of the detections. Dissolved mercury was reported above the AWQC at the following locations:
  - Detected in 1 of 12 samples from well 199-K-108A (0.031 µg/L); 1 sample was above the AWQC.
  - Detected in 2 of 9 samples from well 199-K-137 (0.071 to 0.17 µg/L); 2 samples were above the AWQC.
- As shown in Table D-6, dissolved nickel was detected in 134 of 352 filtered groundwater samples (38% frequency) where concentrations ranged between 0.28 µg/L and 250 µg/L. As shown in Table D-7, dissolved nickel was measured in four wells above the AWQC of 52 µg/L. Dissolved nickel was reported above the AWQC, but it is not retained as a COPC due to the sporadic nature of the detections. Dissolved nickel was reported above the AWQC at the following locations:
  - Detected in 20 of 31 samples from 199-K-108A (0.82 to 130 µg/L); 2 samples collected during 2016 were above the AWQC.
  - Detected in all 13 samples from 199-K-110A (6.1 to 97 µg/L); 3 samples collected before July 2012 were above the AWQC.
  - Detected in 17 of 22 samples from 199-K-34 (11 to 250 µg/L); 11 samples were above the AWQC. The presence of dissolved nickel above the AWQC is likely an indication of well corrosion.
  - Detected in all 16 samples from 199-K-36 (4.8 to 98 µg/L); 9 samples collected before May 2013 were above the AWQC.
- As shown in Table D-6, dissolved silver was detected in 15 of 374 filtered groundwater samples (4.0% frequency) where concentrations ranged between 0.05 µg/L and 9.4 µg/L. As shown in Table D-7, dissolved silver was detected above the State surface water quality standard (WAC 173-201A) of 2.6 µg/L in four wells. Note that the 146 of the 359 MDLs for nondetected results were greater than the State surface water standard. Dissolved silver was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections and most MDLs were not adequate for detecting levels below the state standard. Dissolved silver was reported

above the State surface water quality standard (WAC 173-201A) and the 90th percentile background value at the following locations:

- Detected in 2 of 28 samples from well 199-K-32A (4.6 to 9.4 µg/L); 1 sample was above the 90th percentile background value.
- Detected in 1 of 22 samples from well 199-K-34 (7 µg/L); 1 sample was above the 90th percentile background value.
- Detected in 2 of 18 samples from well 199-K-107A (0.05 to 6.5 µg/L); 1 sample was above the state standard.

- Detected in 2 of 19 samples from well 199-K-139 (1.5 to 9 µg/L); 2 samples were above the state standard. As shown in Table D-6, dissolved zinc was detected in 132 of 352 filtered groundwater samples (37.5% frequency) where concentrations ranged between 3.75 µg/L and 878 µg/L. As shown in Table D-7, dissolved zinc was detected above the State surface water quality standard (WAC 173-201A) of 91 µg/L in five wells. Dissolved zinc was reported above the state standard, but it is not retained as a COPC due to the likelihood that dissolved zinc is associated with the well screen or corrosion and not the result of a release. Dissolved zinc was reported above the State surface water quality standard (WAC 173-201A) at the following locations:
  - Detected in 20 of 31 samples from well 199-K-108A (4.6 to 217 µg/L); 1 sample was above the state standard and is likely an anomalous detection because the field duplicate result was consistent with previous sampling results.
  - Detected in 14 of 24 samples from well 199-K-137 (5 to 538 µg/L); 1 sample was above the state standard.
  - Detected in all 8 samples from well 199-K-19 (168 to 413 µg/L); all samples were above the state standard. This well includes a galvanized steel screen which is likely the cause of the elevated dissolved zinc concentrations.
  - Detected in all 10 samples from well 199-K-22 (250 to 878 µg/L); all samples were above the state standard. The presence of dissolved zinc above the state standard is likely an indication of well corrosion.
  - Detected in all 6 samples from well 699-73-61 (224 to 281 µg/L); all samples were above the state standard. This well includes a galvanized steel screen which is likely the cause of the elevated dissolved zinc concentrations.

D2.3 Comparison Results for Wells Screened in the Upper Unconfined Aquifer

A total of 30 wells are screened in the upper unconfined aquifer. Groundwater results from all wells were compiled, statistically analyzed, and summarized in Tables D-8 through D-11 Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Table D-8 and Table D-9, respectively. Results are also compared to federal AWQC and the State surface water quality standards (WAC 173-201A) and presented in Table D-10 and Table D-11. Each set of tables present the summary statistics for each analyte detected, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, pesticides, radionuclides, SVOCs, VOCs, and TPH-diesel range organics and TPH-gasoline range organics.

D2.3.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: All 30 wells were analyzed for carbon-14, strontium-90, technetium-99, and tritium. Sixteen wells were analyzed for gamma-emitting isotopes. A total of 22 wells were analyzed for gross alpha and gross beta. Five wells (199-K-114A, 199-K-125A, 199-K-141, 199-K-20, and 199-K-21) were analyzed for nickel-63. Four wells (199-K-142, 199-K-161, 199-K-21, and 199-K-37) were analyzed for americium-241 isotopic plutonium, selenium-79, and isotopic uranium. As shown in Table D-8, carbon-14, cesium-137, gross alpha, gross beta, strontium-90, technetium-99, and tritium were detected at least once in groundwater. Concentrations of cesium-137, gross alpha, and technetium-99 were less than their respective DWS; therefore, they are not retained as COPCs. Carbon-14, strontium-90 and tritium concentrations were greater than their respective DWS and are discussed below:

- As shown in Table D-8, carbon-14 was detected in 264 of 408 (65% frequency), with concentrations ranging between 4.4 and 26,600 pCi/L. As shown in Table D-9, carbon-14 was detected in all 19 samples from well 199-K-204; all samples were above the DWS.
- As shown in Table D-8, strontium-90 was detected in 149 of 399 groundwater samples (37% frequency), with concentrations ranging between 0.98 and 152 pCi/L. As shown in Table D-9, nine wells reported strontium-90 above the DWS and wells include 199-K-20, 199-K-21, 199-K-113A, 199-K-114A, 199-K-141, 199-K-147, 199-K-161, 199-K-221, and 199-K-222. Strontium-90 is retained as a COPC due to the following results exceeding the DWS.
  - Detected in 12 of 15 samples from 199-K-20 (2.8 to 15 pCi/L); 9 samples were above the DWS.
  - Detected in all 7 samples from well 199-K-21 (17 to 30 pCi/L); all 7 samples were above DWS.
  - Detected in all 13 samples from well 199-K-113A (2.5 to 8.9 pCi/L); 1 sample collected in June 2012 was above the DWS. Strontium-90 is not retained as a COPC in this well because of the downward concentration trend.
  - Detected in all 6 samples from well 199-K-114A (3.2 to 9.4 pCi/L); 3 samples collected before October 2012 were above the DWS. Strontium-90 is not retained as a COPC in this well because of the downward concentration trend.
  - Detected in 26 of 27 samples from 199-K-141 (2.2 to 84 pCi/L); 26 samples were above the DWS.
  - Detected in 1 of 11 samples from 199-K-147 (2.2 to 84 pCi/L); one sample collected in October 2012 was above the DWS. Strontium-90 is not retained as a COPC in this well because of the downward concentration trend.
  - Detected in 12 of 14 samples from 199-K-161 (5.8 to 13 pCi/L); 9 samples were above the DWS.
  - Detected in 3 of 5 samples from well 199-K-221 (2.7 to 8.7 pCi/L); one sample collected July 2016 was above the DWS; note concentration increase (44 pCi/L) in August 2017.

  - Detected in all 6 samples from well 199-K-222 (3.9 to 152 pCi/L); four samples above the DWS. Note concentration increase (13,900 pCi/L) in August 2017.

- As shown in Table D-8, gross beta was detected in 185 of 194 groundwater samples (95% frequency), with concentrations ranging between 1.59 pCi/L and 344 pCi/L. The presence of gross beta is generally consistent with that of strontium-90 and tritium. Note that the sum-of-fractions approach is used to determine whether the contribution of each beta- and photon-emitting radionuclide is greater than the cumulative annual dose equivalent of 4 mrem to the total body or any internal organ. This evaluation is presented in Section 6.3.5.

- As shown in Table D-8, tritium was detected in 331 of 431 groundwater samples (77% frequency), with concentrations ranging between 115 and 58,000 pCi/L. As shown in Table D-9, well 199-K-144 and 199-K-221 had concentrations greater than the DWS of 20,000 pCi/L. Tritium is retained as a COPC for monitoring based on the DWS exceedances listed below:

  - Detected in all 14 samples from well 199-K-144 (13,000 to 58,000 pCi/L); 5 samples above DWS, all samples collected since October 2012 were below DWS. Tritium is not retained as a COPC at this well because of the downward concentration trend.

  - Detected in all 5 samples from well 199-K-221 (569 to 30,100 pCi/L); 2 samples collected between November 2015 and July 2016 were above the DWS. Note tritium increase in August 2017 (24,300 pCi/L).

VOCs: VOCs were analyzed in 17 wells. As shown in Table D-8, 1,2,4-trichlorofobenzene, 1,2-dichlorobenzene, 2-butanone, 2-propanol, acetone, bromodichloromethane, bromomethane, chloroform, methylene chloride, o-xylene, toluene, trichloroethene, toluene, and xylenes (total) were detected in groundwater. 1,2,4-Trichlorobenzene, 1,2-dichlorobenzene, 2-butanone, 2-propanol, acetone, bromodichloromethane, bromomethane, o-xylene, toluene, and xylenes (total) are not retained as COPCs because all results (detected concentrations and MDLs) were less than the groundwater RBCs. Chloroform, methylene chloride, and trichloroethene were detected above the 2013 MTCA (WAC 173-340-720) RBCs and are discussed below:

- As shown in Table D-8, chloroform was detected in 103 of 173 groundwater samples (60% frequency), with concentrations ranging between 0.14 µg/L and 1.8 µg/L. As shown in Table D-9, one well (199-K-186) had chloroform concentrations above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 1.4 µg/L based on a target risk level of 1×10^{-6} in at least one sample, as discussed below:

  - Detected in 5 of 7 samples collected from well 199-K-186 (0.63 µg/L to 1.8 µg/L); two samples were greater than the RBC of 1.4 µg/L.

Chloroform concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 01.4 µg/L at three wells, However, the well-specific risk assessment determined that the cumulative risk level was less than the MTCA (WAC 173-340-708) risk threshold of $1\times1^{0-5}$ in all wells and the hazard index was less than 1 at all wells. As a result, chloroform is not retained as a COPC.

- As shown in Table D-8, methylene chloride was detected in 9 of 173 groundwater samples (5.2% frequency), with concentrations ranging between 0.31 µg/L and 5.3 µg/L. As shown in Table D-9, one well (199-K-194) had methylene chloride concentrations above the DWS of 5 µg/L in at least one sample. Methylene chloride is not retained as a COPC because it is a common laboratory

contaminant, which is introduced in the laboratory after the sample is collection in the field. Methylene chloride is discussed below:

  - Detected in 3 of 22 samples from well 99-K-194 (0.31 to5.3 µg/L). One of 22 methylene chloride results was above the DWS. Its low frequency of detection suggests its presence is contributed from the laboratory.

- As shown in Table D-8, trichloroethene was detected in 120 of 173 groundwater samples (69% frequency), with concentrations ranging between 0.47 µg/L and 6 µg/L. As shown in Table D-9, 11 wells (199-K-11, 199-K-31, 199-K-35/199-K-195/199-K-205, 199-K-138, 199-K-173, 199-K-183, 199-K-186, 199-K-187, 199-K-188, 199-K-204, 699-72-73) had trichloroethene concentrations above the 2013 MTCA (WAC 173-340-720) RBC of 0.54 µg/L in at least one sample, as discussed below:

  - Detected in all five samples from well 199-K-11 (1.6 to 6 µg/L); all samples were greater than the RBC.

  - Detected in all 8 samples from well 199-K-31 (2.2 µg/L to 4 µg/L); all samples were greater than the RBC.

  - Detected in all 13 samples from well 199-K-35/199-K-195/199-K-205 (3 µg/L to 5.4 µg/L); all samples were greater than the RBC.

  - Detected in all 17 samples from well 199-K-138 (2.7 µg/L to 5.6 µg/L); all samples were greater than the RBC.

  - Detected in all 27 samples from well 199-K-173 (2.8 µg/L to 5.3 µg/L); all detected results were greater than the RBC.

  - Detected in all 25 samples from well 199-K-183 (2.9 µg/L to 5.1 µg/L); all samples were greater than the RBC.

  - Detected in 3 of 7 samples from well 199-K-186 (0.47 µg/L to 0.64 µg/L); two detected results were greater than the RBC.

  - Detected in 5 of 8 samples from well 199-K-187 (1.5 µg/L to 1.6 µg/L); five results were greater than the RBC.

  - Detected in 5 of 6 samples from well 199-K-188 (1.5 µg/L to 2 µg/L); all five detected results were greater than the RBC.

  - Detected in all 10 samples from well 199-K-204 (1.5 µg/L to 8.3 µg/L); all 10 results were greater than the RBC.

  - Detected in 2 of 3 samples from well 699-72-73 (0.89 µg/L to 0.98 µg/L); two results were greater than the RBC.

Trichloroethene concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 0.54 µg/L at seven wells, However, the well-specific risk assessment determined that the cumulative risk level was less than the MTCA (WAC 173-340-708) risk threshold of 1×10^{-5} in all wells and HQ was greater than 1 at seven wells. As a result, trichloroethene is retained as a COPC at wells 199-K-11, 199-K-31, 199-K-35/199-K-195/199-K-205, 199-K-138, 199-K-173, 199-K-183, and 199-K-204.

Pesticides: Pesticides were analyzed in one well (199-K-37). Pesticides were not detected in any samples collected from well 199-K-37.

SVOCs: SVOCs were analyzed in two wells (199-K-37 and 199-K-173). As shown in Table D-8, bis(2-ethylhexy) phthalate and diethylphthalate were detected in groundwater. Bis(2-ethylhexy) phthalate and diethylphthalate are not retained as COPCs because all results (detected concentrations and MDLs) were less than the groundwater action level or the DWS.

TPH-diesel: TPH-diesel was analyzed in three wells (199-K-37, 199-K-173, and 199-K-186). TPH-diesel was not detected in any samples from these wells and is not retained as a COPC.

TPH-gasoline: TPH-gasoline was analyzed in three wells (199-K-37, 199-K-173, and 199-K-186). As shown in Table D-8, TPH-gasoline was detected in two of 10 groundwater samples (20% frequency). All TPH-gasoline results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 1,000 µg/L. Based on these results, TPH-gasoline is not retained as a COPC.

TPH-motor oil: TPH-motor oil was analyzed in three wells (199-K-37, 199-K-173, and 199-K-186). TPH-motor oil was not detected in any samples from these wells and is not retained as a COPC.

Anions: As shown in Table D-8, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride and nitrite results (detected concentrations and MDLs) were less than their respective Hanford Site background level and groundwater action levels and are not retained as COPCs. As shown in Table D-9, one well (199-K-11) had nitrate above the DWS of 45,000 µg/L. Nitrate is retained as a COPC for monitoring based on the DWS exceedances listed below:

- Detected in all 14 samples from well 199-K-11 (12,600 to 87,700 µg/L); four samples collected before December 2013 were above the DWS. Nitrate is not retained as a COPC at this well due to the downward concentration trend.

Cyanide: Cyanide was analyzed in two wells (199-K-37 and 199-K-204). As shown in Table D-8, cyanide was detected in one of seven samples (14% frequency) at a concentration of 6.5 µg/L. One of four samples collected from 199-K-204 was above the MTCA RBC of 4.8 µg/L. This result was assigned a “C” laboratory qualifier indicating it was detected in both the method blank and the associated sample. Cyanide is not retained as a COPC.

Metals: All wells were analyzed for total chromium and hexavalent chromium. All wells were analyzed for Method 6010 ICP metals. Eighteen wells were analyzed by Method 6010 ICP trace metals. A total of 24 wells were analyzed for ICP/MS trace metals by either Method 200.8 or 6020, and one well was analyzed for mercury by Method 7470. With the exception of total chromium, cobalt, hexavalent chromium, and thallium, all metals results (detected concentrations and MDLs) were less than their respective Hanford Site background values and/or action levels.

As shown in Table D-8, total chromium was detected in 479 of 508 unfiltered groundwater samples (94% frequency), with concentrations ranging between 0.69 and 3,250 µg/L. As shown in Table D-9, 3 wells (199-K-173, 199-K-178, and [199-K-35/199-K-195/199-K-205] had total chromium above the DWS of 100 µg/L and are discussed below:

- Detected in all 41 samples from well 199-K-173 (14 to 1,010 µg/L); 20 samples collected through October 2012 were above the DWS, remaining sample results show downward concentration trend. Total chromium is not retained as a COPC at this well because of the downward concentration trend.

- Detected in all 13 samples from well 199-K-178 (15.6 to 122 µg/L); one sample collected November 2009 was above the DWS, all other concentrations were below the DWS. Total chromium is not retained as a COPC at this well due to the downward concentration trend.

- Detected in all 26 samples from well [199-K-35/199-K-195/199-K-205] (19.5 to 3,250 µg/L); 19 samples were above the DWS.

As shown in Table D-8, cobalt was detected in 75 of 301 groundwater samples (25% frequency), with concentrations ranging between 0.07 µg/L and 13.7 µg/L. As shown in Table D-9, well 199-K-194 had one detected occurrence (13.7 µg/L) May 2015 above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 4.8 µg/L. Cobalt was detected above the MTCA groundwater cleanup level but is not retained as a COPC due to the sporadic nature of the detection.

As shown in Table D-9, hexavalent chromium was detected in 460 of 562 unfiltered groundwater samples (82% frequency), with concentrations ranging between 1.5 and 3,310 µg/L.

- Detected in all 18 samples from well 199-K-37 (16 to 56.7 µg/L); 1 sample collected in October 2009 was above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level, all other samples were less than the cleanup level. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

- Detected in all 15 samples from well 199-K-144 (15 to 117 µg/L); 1 sample collected in June 2010 was above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level, all other samples were less than the cleanup level. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

- Detected in 13 of 14 samples from well 199-K-148 (3.1 to 62 µg/L); 1 samples collected in June and July 2010 (62 and 53 µg/L, respectively) were above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level, all other samples were less than the cleanup level. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

- Detected in all 54 samples from well 199-K-173 (8.8 to 974 µg/L); 38 samples were greater than the 2013 MTCA (WAC 173-340-720) groundwater cleanup level, all other samples were less than the cleanup level.

- Detected in all 16 samples from well 199-K-178 (2.8 to 53 µg/L); 1 sample collected in November 2009 was above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level, all other samples were less than the cleanup level. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

- Detected in 20 of 24 samples from well 199-K-187 (2.8 to 53 µg/L); 1 sample collected in May 2011 was above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level, all other samples were less than the cleanup level. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

As shown in Table D-8, lead was detected in 39 of 140 unfiltered groundwater samples (28% frequency), with concentrations ranging between 0.067 and 16 µg/L. As shown in Table D-9, one well (199-K-188) had one of six samples (16 µg/L) greater than the DWS. Lead is not retained as a COPC due to the single sporadic occurrence above the DWS.

As shown in Table D-8, thallium was detected in 14 of 292 unfiltered groundwater samples (4.8% frequency), with concentrations ranging between 0.02 and 2.4 µg/L. As shown in Table D-9, thallium was detected above the 90th percentile Hanford Site value of 1.67 µg/L in wells (199-K-31, 199-K-117A, and 199-K-173). Thallium was detected in 1 of 28 samples from well 199-K-117A (2.4 µg/L); 1 of 11 samples from well 199-K-173 (1.7 µg/L); 1 of 6 samples from 199-K-23 (2.2 µg/L), and 1 of 17 samples from well 199-K-31 (1.8 µg/L). The range of thallium background concentrations (minimum, maximum,

and 90th percentile) is 0.883, 1.73, and 1.67 µg/L in filtered groundwater samples. All filtered thallium samples were less than the 90th percentile value. Thallium is not retained as a COPC due to the sporadic detections in unfiltered samples and because all filtered samples were less than background.

D2.3.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once are as follows:

Anions: As shown in Table D-10, chloride was detected in groundwater samples. All of the chloride results (detected concentrations and MDLs) were less than the AWQC.

Metals: Total concentrations of hexavalent chromium and cyanide and dissolved concentrations of aluminum, cadmium, chromium, copper, selenium, silver, and zinc had detected concentrations above their respective Hanford Site background values and/or surface water action levels. All dissolved arsenic, iron, lead, and nickel results (detected concentrations and MDLs) were less than their respective Hanford Site background values and/or surface water action levels.

- As shown in Table D-10, dissolved aluminum was detected in 41 of 294 groundwater samples (14% frequency), with concentrations ranging between 10 and 680 µg/L. As shown in Table D-11, dissolved aluminum was measured in 4 wells at concentrations greater than the AWQC of 87 µg/L. Dissolved aluminum was reported above the AWQC but is not retained as a COPC due to the sporadic nature of the detections. Aluminum is a common element in clay minerals and its presence in unfiltered groundwater samples is likely a result of sediment particles in the samples. Dissolved aluminum was reported above the AWQC in the following samples:
  - Detected in 2 of 10 samples from 199-K-11 (44 to 146 µg/L); 1 sample was above the AWQC.
  - Detected in 4 of 28 samples from 199-K-117A (19 to 680 µg/L); 1 sample was above the AWQC.
  - Detected in 4 of 17 samples from 199-K-31 (25 to 366 µg/L); 1 sample was above the AWQC.
  - Detected in 2 of 5 samples from 199-K-37 (76 to 232 µg/L); 1 sample was above the AWQC.
- As shown in Table D-10, dissolved cadmium was detected in six of 303 filtered groundwater samples (2.0% frequency), with concentrations ranging between 0.1 and 0.81 µg/L. As shown in Table D-11, dissolved cadmium was detected in one of 13 samples from well 199-K-161 at a concentration (0.81 µg/L) above the AWQC of 0.72 µg/L. Dissolved cadmium is not retained as a COPC due to the sporadic nature of the detection.
- As shown in Table D-10, dissolved chromium was detected in 471 of 511 filtered groundwater samples (92% frequency) where concentrations ranged between 0.54 µg/L and 5,220 µg/L. As shown in Table D-11, dissolved chromium was measured in 5 wells at concentrations greater than the AWQC of 74 µg/L. Dissolved chromium was reported above the AWQC in the following filtered samples:
  - Detected in 13 of 16 samples from well 199-K-142 (0.54 to 5,220 µg/L); the sample result from June 1, 2012 was flagged as a suspect result all other results were less than the AWQC. Dissolved total chromium is not retained as a COPC at this well due to the suspect nature of the result.
  - Detected in all 41 samples from well 199-K-173 (11.8 to 997 µg/L); 23 samples collected through October 2016 were above the AWQC.

- Detected in all 14 samples from well 199-K-178 (17 to 120 µg/L); 1 sample collected November 2009 was above the AWQC, all other samples were less than the AWQC. Dissolved total chromium is not retained as a COPC at this well due to the sporadic nature of the detection.
- Detected in all 22 samples from well 199-K-186 (6.58 to 290 µg/L); one sample collected August 2016 was above the AWQC. Dissolved total chromium is not retained as a COPC at this well due to the sporadic nature of the detection.
- Detected in all 26 samples from well 199-K-35/199-K-195/199-K-205 (19.7 to 3,360 µg/L); all 21 samples were above the AWQC.

- As shown in Table D-10, dissolved copper was detected in 145 of 303 filtered groundwater samples (48% frequency) where concentrations ranged between 0.20 µg/L and 19.9 µg/L. As shown in Table D-11, dissolved copper was measured in three wells at concentrations greater than the State surface water quality standard of 9.9 µg/L. Dissolved copper was reported above the State surface water quality standard, but it is not retained as a COPC due to the sporadic nature of the detections. Dissolved copper was reported above the State surface water quality standard in the following filtered samples:
  - Detected in all 13 samples from well 199-K-161 (0.24 to 13 µg/L); two samples were above the state standard.
  - Detected in all 7 samples from well 199-K-141 (3.2 to 17 µg/L); one sample was above the state standard.
  - Detected in 2 of 15 samples from well 199-K-142(0.34 to 20 µg/L); one sample was above the state standard.
- As shown in Table D-13, total cyanide was detected in one of seven unfiltered groundwater samples (14% frequency) at a concentration of 6.5 µg/L. As shown in Table D-14, cyanide was detected in 1 of 4 samples from 199-K-204 above the State surface water standard (WAC 173-201A) of 5.2 µg/L. Cyanide is not retained as a COPC due to the sporadic nature of the detection.
- As shown in Table D-10, hexavalent chromium was detected in 460 of 562 unfiltered groundwater samples (82% frequency) where concentrations ranged between 1.5 µg/L and 3,310 µg/L. As shown in Table D-11, hexavalent chromium was measured in 21 wells at concentrations greater than the State surface water quality standard (WAC 173-201A) of 10 µg/L. Hexavalent chromium was identified as a COPC and reported above the Washington State surface water quality standard (WAC 173-201A) of 10 µg/L in the following filtered samples:
  - Detected in 8 of 10 samples from well 199-K-11 (3.2 to 17 µg/L); 2 samples collected through April 2012 were above the state standard. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
  - Detected in 10 of 14 samples from well 199-K-21 (1.7 to 18.4 µg/L); 7 samples were above the state standard.
  - Detected in all 39 samples from well 199-K-35/199-K-195/199-K-205 (13 to 3,310 µg/L); all 39 samples were above the state standard.
  - Detected in all 18 samples from well 199-K-37 (16 to 56.7 µg/L); all 18 samples were above the state standard.

- Detected in all 22 samples from well 199-K-138 (6 to 24 µg/L); 12 samples collected through November 2014 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in 23 of 24 samples from well 199-K-141 (19 to 47.6 µg/L); 23 samples were above the state standard.
- Detected in 2 of 9 samples from well 199-K-142 (3.3 to 13 µg/L); samples collected November 2016 and November 2017 were above the state standard.
- Detected in all 15 samples from well 199-K-144 (20 to 56.2 µg/L); all samples were above the state standard.
- Detected in 13 of 14 samples from well 199-K-146 (2.6 to 20.5 µg/L); 3 samples collected through May 2011 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 14 samples from well 199-K-147 (9 to 33.4 µg/L); 13 samples were above the state standard.
- Detected in 13 of 14 samples from well 199-K-148 (3.1 to 61.7 µg/L); 10 samples collected through October 2015 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in 11 of 14 samples from well 199-K-161 (3 to 14.1 µg/L); one sample collected November 2010 was above the state standard. Hexavalent chromium is not retained as a COPC at this well due to the downward concentration trend.
- Detected in all 54 samples from well 199-K-173 (8.8 to 974 µg/L); 53 samples were above the state standard.
- Detected in all 16 samples from well 199-K-178 (15 to 117 µg/L); all 16 samples were above the state standard.
- Detected in all 22 samples from well 199-K-186 (3.9 to 30.8 µg/L); 17 samples were above the state standard.
- Detected in 20 of 24 samples from well 199-K-187 (2.8 to 53 µg/L); 3 samples collected through July 2012 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 15 samples from well 199-K-188 (8.3 to 44.4 µg/L); 13 samples were above the state standard.
- Detected in 19 of 23 samples from well 199-K-191 (2.3 to 10.4 µg/L); one sample collected November 2013 was above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

- Detected in all 21 samples from well 199-K-194 (5.6 to 15 µg/L); 12 samples collected through May 2015 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 5 samples from well 199-K-221 (6.9 to 32 µg/L); 3 samples were above the state standard.
- Detected in all 6 samples from well 199-K-222 (5.4 to 20 µg/L); 5 samples were above the state standard.

- As shown in Table D-10, dissolved selenium was detected in 76 of 294 unfiltered groundwater samples (26% frequency) where concentrations ranged between 0.61 µg/L and 5.6 µg/L. As shown in Table D-11, dissolved selenium was measured in 5 of 21 samples from well 199-K-191, one sample was above the State surface water quality standard (WAC 173-201A) of 5 µg/L. The dissolved selenium sample above the State surface water standard was flagged with a "C" by the laboratory indicating selenium was detected in the sample and the associated preparation blank; as a result, dissolved selenium is not retained as a COPC.

- As shown in Table D-10, dissolved silver was detected in 10 of 513 filtered groundwater samples (2.0% frequency) where concentrations ranged between 0.039 µg/L and 40 µg/L. As shown in Table D-11, dissolved silver was detected above the State surface water quality standard (WAC 173-201A) of 2.6 µg/L in five wells. Dissolved silver was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections. Dissolved silver was reported above the State surface water quality standard (WAC 173-201A) at the following locations:
  - Detected in 1 of 25 samples from well 199-K-141 (24 µg/L); this result was flagged with a "C" by the laboratory indicating silver was detected in the sample and the associated preparation blank.
  - Detected in 1 of 14 samples from well 199-K-148 (4.38 µg/L); this result was flagged with a "C" by the laboratory indicating silver was detected in the sample and the associated preparation blank.
  - Detected in 1 of 40 samples from well 199-K-173 (5.9 µg/L).
  - Detected in 1 of 14 samples from well 199-K-178 (40 µg/L).
  - Detected in 1 of 16 samples from well 199-K-188 (6.26 µg/L)

- As shown in Table D-10, dissolved zinc was detected in 145 of 423 filtered groundwater samples (34% frequency) where concentrations ranged between 1.82 µg/L and 547 µg/L. As shown in Table D-11, dissolved zinc was detected in 1 of 14 samples above the State surface water quality standard (WAC 173-201A) of 91 µg/L in well 199-K-146. Dissolved zinc was reported above the state standard in one sample, but it is not retained as a COPC due to the sporadic nature of the detections.

D2.4 Comparison Results for Wells Screened through the Entire Unconfined Aquifer

A total of 23 wells are screened through the entire unconfined aquifer. Groundwater data from all wells screened at the bottom of the unconfined aquifer and data from each individual well were compiled, statistically analyzed, and summarized in Tables D-12 through D-15. Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Tables D-12 and D-13. Similarly, results are compared to federal AWQC and the State surface water quality standards (WAC 173-201A) and presented in Tables D-14 and D-15. Each set of tables present the summary statistics for each analyte detected in wells screened through the entire unconfined aquifer, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, pesticides, radionuclides, SVOCs, VOCs, and TPH-diesel range organics and TPH-gasoline range organics.

D2.4.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: A total of 22 wells were analyzed for strontium-90 and tritium, 20 wells were analyzed for carbon-14, 19 wells were analyzed for gross alpha and gross beta, 18 wells were analyzed for technetium-99, 17 wells were analyzed for gamma-emitting isotopes, three wells (199-K-151, 199-K-182, and 199-K-203) were analyzed for isotopic plutonium and isotopic uranium, and one well (199-K-203) was analyzed for americium-241 and selenium-79. As shown in Table D-12, carbon-14, gross beta, strontium-90, and tritium were detected at least once in wells screened through the entire unconfined aquifer. Concentrations of gross alpha and technetium-99 were less than their respective DWS; therefore, they are not retained as COPCs. Carbon-14, gross beta, strontium-90, and tritium concentrations were greater than their respective DWS and are discussed below:

- As shown in Table D-12, carbon-14 was detected in 150 of 208 (72% frequency), with concentrations ranging between 5.7 and 6,140 pCi/L. As shown in Table D-13, three wells reported carbon-14 above the DWS and include 199-K-185, 199-K-189, and 199-K-202.
  - Detected in all 30 samples from well 199-K-185 (175 to 6,140 pCi/L); 5 samples were above the DWS and concentrations show an increasing trend.
  - Detected in all 22 samples from well 199-K-189 (66 to 3,260 pCi/L); 8 samples were above the DWS.
  - Detected in all 10 samples from well 199-K-202 (1,500 to 3,170 pCi/L); 3 samples were above the DWS.
- As shown in Table D-12, strontium-90 was detected in 25 of 215 groundwater samples (12% frequency), with concentrations ranging between 0.63 and 8.1 pCi/L. As shown in Table D-13, strontium-90 was detected in 1 of 10 samples from well 199-K-202 at a concentration of 8.1 pCi/L. Strontium-90 is not retained as a COPC at this well.

- As shown in Table D-12, gross beta was detected in 110 of 116 groundwater samples (95% frequency), with concentrations ranging between 2.8 pCi/L and 47 pCi/L. The presence of gross beta is generally consistent with that of strontium-90 and tritium. Note that the sum-of-fractions approach is used to determine whether the contribution of each beta- and photon-emitting radionuclide is greater than the cumulative annual dose equivalent of 4 mrem to the total body or any internal organ. This evaluation is presented in Section 6.3.5.4.

- As shown in Table D-12, tritium was detected in 256 of 267 groundwater samples (96% frequency), with concentrations ranging between 160 and 935,000 pCi/L. As shown in Table D-13, six wells reported concentrations greater than the DWS of 20,000 pCi/L and include 199-K-145, 199-K-157, 199-K-189, 199-K-202, 199-K-207, and 199-K-208. Although tritium concentrations were above the DWS during 2010 and 2011, tritium concentrations had declined below the DWS in 2013 through 2015. Tritium is retained as a COPC for monitoring based on the DWS exceedances listed below:

  - Detected in all 15 samples from well 199-K-145 (6,270 to 62,000 pCi/L); 10 samples were above the DWS through November 2014, concentrations were below the DWS after that date. Tritium is not retained as a COPC at this well because of the downward concentration trend.

  - Detected in all 31 samples from well 199-K-157 (1,520 to 290,000 pCi/L); 7 samples were above the DWS through December 2010, concentrations were below the DWS after that date. Tritium is not retained as a COPC at this well because of the downward concentration trend.

  - Detected in 21 of 22 samples from well 199-K-189 (510 to 47,900 pCi/L); 9 samples were above the DWS.

  - Detected in all 10 samples from well 199-K-202 (18,500 pCi/L to 47,900 pCi/L); 9 samples were above the DWS.

  - Detected in all 7 samples from well 199-K-207 (345,000 to 935,000 pCi/L); all samples were above the DWS.

  - Detected in all 7 samples from well 199-K-208 (10,100 to 83,500 pCi/L); two samples through May 2015 were above the DWS, concentrations were below the DWS after that date. Tritium is not retained as a COPC at this well because of the downward concentration trend.

VOCs: VOCs were analyzed in 12 wells. As shown in Table D-12, 2-butanone, 2-propanol, acetone, bromodichloromethane, bromomethane, chloroform, carbon tetrachloride, methylene chloride, toluene, and trichloroethene were detected in groundwater. 2-butanone, 2-propanol, acetone, bromodichloromethane, bromomethane, methylene chloride and toluene are not retained as COPCs because all results (detected concentrations and MDLs) were less than the groundwater action level. Chloroform, carbon tetrachloride, and trichloroethene were detected above the 2013 MTCA (WAC 173-340-720) RBCs and are discussed below.

- As shown in Table D-12, chloroform was detected in 64 of 95 groundwater samples (67% frequency), with concentrations ranging between 0.2 µg/L and 8.3 µg/L. As shown in Table D-13, two wells (199-K-151 and 199-K-152) had chloroform concentrations above the 2013 MTCA (WAC 173-340-720) RBC of 1.4 µg/L based on a target risk level of 1×10^{-6} in at least one sample, as discussed below:

  - Detected in all 17 samples collected from well 99-K-151 (1.3 µg/L to 8.3 µg/L); 14 samples were above the RBC.

- Detected in 5 of 6 samples collected from well 199-K-152 (2.1 µg/L to 2.3 µg/L); 1 sample was above the RBC.

Chloroform concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 1.4 µg/L at five wells (199-K-151 and 199-K-152), However, the well-specific risk assessment determined that the cumulative risk level was less than or equal to MTCA (WAC 173-340-708) risk threshold of 1×10^{-5} or the hazard index was less than 1 in all wells. As a result, chloroform is not retained as a COPC.

- As shown in Table D-12, carbon tetrachloride was detected in 1 of 95 groundwater samples (1.05% frequency), with a single detection of 1.1 µg/L. As shown in Table D-13, well 199-K-202 had carbon tetrachloride above the 2013 MTCA (WAC 173-340-720) RBC of 0.63 µg/L based on a target risk level of 1×10^{-6} in one of two samples. Carbon tetrachloride was reported above the RBC, but it is not retained as a COPC due to the sporadic nature of the detection.

- As shown in Table D-12, trichloroethene was detected in 64 of 96 groundwater samples (67% frequency), with concentrations ranging between 0.18 and 9.48 µg/L. As shown in Table D-13, five wells (199-K-165, 199-K-166, 199-K-185, 199-K-223, and 199-K-224) had trichloroethene concentrations above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 0.54 µg/L based on a target risk level of 1×10^{-6} in at least one sample, as discussed below.

  - Detected in all 12 samples from well 199-K-165 (3 to 4.7 µg/L); all samples were above the RBC.

  - Detected in 14 of 15 samples from well 199-K-166 (3.3 to 4.7 µg/L); 14 samples were above the RBC.

  - Detected in all 30 samples from well 199-K-185 (2.9 to 9.48 µg/L); all samples were above the RBC.

  - Detected in all 3 samples from well 199-K-223 (4.31 to 4.91µg/L); all samples were above the RBC.

  - Detected in all 3 samples from well 199-K-224 (3.1 to 5.5µg/L); all samples were above the RBC.

Trichloroethene concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 0.54 µg/L at nine wells, However, the well-specific risk assessment determined that the cumulative risk level was less than the MTCA (WAC 173-340-708) risk threshold of 1×10^{-5} in all wells and HQ was greater than 1 at five wells. As a result, trichloroethene is retained as a COPC at wells 199-K-165, 199-K-166, 199-K-185, 199-K-223, and 199-K-224.

Pesticides: Pesticides were analyzed in three wells (199-K-151, 199-K-152, and 199-K-182). Aldrin was detected in 2 of 9 samples (22% frequency), where concentrations range between 0.12 and 0.65 µg/L. Aldrin was detected in one of three samples (0.12 µg/L) collected from well 199-K-151 between June 2010 and January 2011 and was detected in one of three samples (0.65 µg/L) from well 199-K-152 between June 2010 and January 2011. The aldrin result for well 199-K-152 was flagged with a “B” laboratory qualifier indicating that aldrin was detected in the associated method blank and the sample. Biological controls including pesticides and herbicides are applied on the Hanford Site to prevent the spread of contamination by biological vectors and comply with environmental, safety, health, and quality principles. Aldrin is not retained as a COPC because its presence is likely from application of biological controls and not associated with a groundwater plume.

SVOCs: SVOCs were analyzed in three wells (199-K-151, 199-K-152, and 199-K-182). As shown in Table D-12, bis(2-ethylhexy) phthalate was detected in one of six samples (17% frequency) at a concentration of 11 µg/L. Bis(2-ethylhexy) phthalate is not retained as a COPC because of the sporadic nature of the detection. Additionally, bis(2-ethylhexyl) phthalate is considered a common laboratory contaminant, it is introduced in the laboratory and is not site-related.

TPH-diesel: TPH-diesel was analyzed in four wells (199-K-151, 199-K-152, 199-K-166, and 199-K-182). As shown in Table D-12, TPH-diesel was detected in one of 27 groundwater samples (3.7% frequency). All TPH-diesel results (detected concentrations and MDLs) were less than the MTCA (WAC 173-340-720) Method A value of 500 µg/L. Based on these results, TPH-diesel is not retained as a COPC.

TPH-gasoline: TPH-gasoline was analyzed in four wells (199-K-151, 199-K-152, 199-K-166, and 199-K-182). As shown in Table D-12, TPH-gasoline was detected in two of 24 groundwater samples (8.3% frequency). All TPH-gasoline results (detected concentrations and MDLs) were less than the MTCA (WAC 173-340-720) Method A value of 1,000 µg/L. Based on these results, TPH-gasoline is not retained as a COPC.

TPH-motor oil: TPH-motor oil was analyzed in four wells (199-K-151, 199-K-152, 199-K-166, and 199-K-182). TPH-motor oil was not detected in any samples from these wells and is not retained as a COPC.

Anions: Anions were analyzed in 23 wells. As shown in Table D-12, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride and nitrite results (detected concentrations and MDLs) were less than their respective Hanford Site background level and groundwater action levels and are not retained as COPCs.

As shown in Table D-12, nitrate was detected in all 291 groundwater samples (100% frequency), where concentrations range between 4,030 and 75,300. As shown in Table D-13, two wells (199-K-185 and 199-K-207) had nitrate above the DWS of 45,000 µg/L. Nitrate is retained as a COPC for monitoring based on the DWS exceedances.

- Detected in all 26 samples from well 199-K-185 (19,000 to 75,300 µg/L), 4 samples collected in 2015 and 2016 were above the DWS.
- Detected in all 7 samples from well 199-K-207 (39,800 to 48,700 µg/L); 2 samples collected in 2016 and 2017 were above the DWS.

Metals: A total of 23 wells were analyzed for total chromium, hexavalent chromium, and EPA Method 6010 ICP metals. A total of 17 wells were analyzed for ICP/MS trace metals by either Method 200.8 or 6020, and one well was analyzed for mercury by Method 7470. With the exception of beryllium, total chromium, cobalt, and hexavalent chromium, all metals results (detected concentrations and MDLs) were less than their respective Hanford Site background values and/or action levels.

- As shown in Table D-12, beryllium was detected in 3 of 99 groundwater samples (3.0% frequency), with concentrations ranging between 0.45 and 4.8 µg/L. As shown in Table D-13, well 199-K-157 had one of five samples with beryllium above the DWS of 4 µg/L. Beryllium is not retained as a COPC due to the sporadic nature of the detection.

- As shown in Table D-12, total chromium was detected in 286 of 294 unfiltered groundwater samples (97% frequency), with concentrations ranging between 1.9 and 261 µg/L. As shown in Table D-13, 3 wells (199-K-165, 199-K-202, and 199-K-224) had total chromium above the DWS of 100 µg/L.
  - Detected in all 26 samples from well 199-K-165 (9.1 to 261 µg/L); four samples collected through November 2011 were above the DWS; concentrations show a downward trend after that date. Total chromium is not retained as a COPC at this well because of the downward concentration trend.
  - Detected in all 3 samples from well 199-K-202 (19.4 to 160 µg/L); two samples collected in 2015 and 2016 were above the DWS, subsequent samples collected in 2017 were less than the DWS. Total chromium is not retained as a COPC at this well because of the downward concentration trend.
  - Detected in all 5 samples from well 199-K-224 (97.2 to 130 µg/L); four samples were above the DWS.
- As shown in Table D-12, cobalt was detected in 17 of 99 groundwater samples (25% frequency), with concentrations ranging between 0.082 and 5 µg/L. As shown in Table D-13, one of five samples from well 199-K-157 was above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 4.8 µg/L. Cobalt is not retained as a COPC due to the sporadic nature of the detection.

As shown in Table D-12, hexavalent chromium was detected in 337 of 349 unfiltered groundwater samples (97% frequency), with concentrations ranging between 1.5 and 353 µg/L. As shown in Table D-13, 11 wells had hexavalent chromium concentrations greater than the 2013 MTCA groundwater cleanup level of 48 µg/L. Hexavalent chromium was detected above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level in the following samples:

- Detected in all 14 samples from well 199-K-145 (3.1 to 74.2 µg/L); one sample collected through February 2010 was above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 18 samples from well 199-K-152 (28 to 73.3 µg/L); 11 samples collected through April 2013 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 15 samples from well 199-K-154 (25 to 95.7 µg/L); 11 samples collected through November 2014 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in 14 of 15 samples from well 199-K-157 (1.7 to 55.5 µg/L); 3 samples collected through June 2010 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 15 samples from well 199-K-163 (2.1 to 80.5 µg/L); 3 samples collected through November 2010 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.

- Detected in all 32 samples from well 199-K-165 (7.8 to 353 µg/L); 11 samples collected through October 2012 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in 25 of 26 samples from well 199-K-166 (3.1 to 66.1 µg/L); 1 sample collected August 2010 was above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 15 samples from well 199-K-171 (11 to 68.9 µg/L); 4 samples collected through May 2011 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 15 samples from well 199-K-182 (26 to 81.3 µg/L); 8 samples collected through July 2013 were above the cleanup level, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 7 samples from well 199-K-207 (74 to 120 µg/L); all 7 samples were above the cleanup level.
- Detected in all 10 samples from well 199-K-224 (97 to 130 µg/L); all 10 samples were above the cleanup level.

D2.4.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once are as follows:

Anions: As shown in Table D-14, chloride was detected in groundwater samples. All of the chloride results (detected concentrations and MDLs) were less than the AWQC.

Pesticides: As shown in Table D-14, aldrin was detected in 2 of 9 groundwater samples. Aldrin was detected in one of three samples (0.12 µg/L) collected from well 199-K-151 between June 2010 and January 2011 and was detected in one of three samples (0.65 µg/L) from well 199-K-152 between June 2010 and January 2011. The aldrin result for well 199-K-152 was flagged with a “B” laboratory qualifier indicating that aldrin was detected in the associated method blank and the sample. Biological controls including pesticides and herbicides are applied on the Hanford Site to prevent the spread of contamination by biological vectors and comply with environmental, safety, health, and quality principles. Aldrin is not retained as a COPC because its presence is likely from application of biological controls and not associated with a groundwater plume.

Metals: Total concentrations of hexavalent chromium and dissolved concentrations of chromium, copper, lead, mercury, silver, and zinc had detected concentrations above their respective Hanford Site background values and/or surface water action levels. All dissolved aluminum, arsenic, cadmium, iron, nickel, and selenium results detected concentrations and MDLs) were less than their respective Hanford Site background values and/or surface water action levels.

- As shown in Table D-14, dissolved total chromium was detected in 286 of 294 filtered groundwater samples (97% frequency) where concentrations ranged between 1.8 µg/L and 255 µg/L. As shown in Table D-15, dissolved total chromium was measured in 6 wells at concentrations greater than the

AWQC of 74 µg/L. Dissolved total chromium was reported above the AWQC in the following filtered samples:

- Detected in all 14 samples from well 199-K-154 (24.3 to 88 µg/L); 3 samples collected through November 2010 were above the AWQC, concentrations show downward trend after that date. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 14 samples from well 199-K-163 (3.79 to 78.4 µg/L); 1 sample collected January 2010 was above the AWQC, concentrations show downward trend after that date. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 26 samples from well 199-K-165 (8.9 to 255 µg/L); 9 sample collected through October 2012 were above the AWQC, concentrations show downward trend after that date. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 14 samples from well 199-K-182 (32.4 to 83 µg/L); 3 samples collected through January 2011 were above the AWQC, concentrations show downward trend after that date. Dissolved total chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in both samples from well 199-K-207 (85.2 to 95.3 µg/L); both samples were above the AWQC.
- Detected in all 5 samples from well 199-K-224 (97.1 to 170 µg/L); all 5 samples were above the AWQC.

- As shown in Table D-14, dissolved copper was detected in 61 of 99 filtered groundwater samples (61% frequency) where concentrations ranged between 0.21 µg/L and 18.8 µg/L. As shown in Table D-15, dissolved copper was detected above the AWQC of 9.9 µg/L in the only sample (18.8 µg/L) from well 199-K-166. Dissolved copper was reported above the AWQC, but it is not retained as a COPC due to the sporadic nature of the detections.
- As shown in Table D-14, hexavalent chromium was detected in 337 of 349 unfiltered groundwater samples (82% frequency) where concentrations ranged between 1.5 µg/L and 353 µg/L. As shown in Table D-15, hexavalent chromium was measured in 20 wells at concentrations greater than the State surface water quality standard (WAC 173-201A) of 10 µg/L. Hexavalent chromium was identified as a COPC and reported above the Washington State surface water quality standard (WAC 173-201A) of 10 µg/L in the following filtered samples:
  - Detected in 12 of 14 samples from well 199-K-116A (2.5 to 10.5 µg/L); 1 sample collected January 2011 was above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
  - Detected in all 14 samples from well 199-K-145 (3.1 to 71.2 µg/L); 10 samples collected through May 2015 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.

- Detected in 14 of 17 samples from well 199-K-151 (2.4 to 26.4µg/L); 3 samples collected through January 2011 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 18 samples from well 199-K-152 (28 to 73.3 µg/L); all 18 samples were above the state standard.
- Detected in all 15 samples from well 199-K-153 (13.9 to 30.9 µg/L); all 15 samples were above the state standard.
- Detected in all 15 samples from well 199-K-154 (25 to 95.7 µg/L); all 15 samples were above the state standard.
- Detected in 14 of 15 samples from well 199-K-157 (1.7 to 55.5 µg/L); 7 sample collected through October 2012 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected in all 15 samples from well 199-K-163 (2.1 to 80.5 µg/L); 10 samples collected through November 2014 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC in this well because of the downward concentration trend.
- Detected all 32 samples from well 199-K-165 (7.8 to 353 µg/L); 28 samples were above the state standard.
- Detected in 26 of 28 samples from well 199-K-166 (3.1 to 66.1 µg/L); 10 samples were above the state standard.
- Detected in all 15 samples from well 199-K-171 (11 to 68.9 µg/L); all 15 samples were above the state standard.
- Detected in all 15 samples from well 199-K-182 (26 to 81.3 µg/L); all 15 samples were above the state standard.
- Detected in all 21 samples from well 199-K-189 (1.5 to 34.8 µg/L); 8 samples were above the state standard.
- Detected in all 10 samples from well 199-K-202 (3.3 to 11.9 µg/L); 1 sample collected January 2015 was above the state standard, concentrations show downward trend after that date. Note concentration increase above the state standard since November 2017.
- Detected in all 8 samples from well 199-K-203 (10 to 28 µg/L); 7 samples were above the state standard.
- Detected in all 7 samples from well 199-K-207 (74 to 120 µg/L); all 7 samples were above the state standard.
- Detected in all 8 samples from well 199-K-208 (7.4 to 41.4 µg/L); 3 samples collected through August 2015 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

  - Detected in all 9 samples from well 199-K-210 (22 to 26.4 µg/L); all 9 samples were above the state standard.
  - Detected in all 10 samples from well 199-K-223 (6.6 to 16 µg/L); 2 samples were above the state standard, concentrations show increasing trend in 2017.
  - Detected in all 10 samples from well 199-K-224 (97 to 130 µg/L); 10 samples were above the state standard.
- As shown in Table D-14, dissolved lead was detected in 14 of 86 filtered groundwater samples (16% frequency) where concentrations ranged between 0.082 µg/L and 2.6 µg/L. As shown in Table D-15, dissolved lead was detected in 1 of 17 samples above the State surface water quality standard (WAC 173-201A) of 2.1 µg/L from well 199-K-151. Dissolved lead was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections.
- As shown in Table D-14, dissolved mercury was detected in 1 of 22 filtered groundwater samples (4.5% frequency) at a concentration of 0.116 µg/L. As shown in Table D-15, dissolved mercury was detected in 1 of 6 samples above the State surface water quality standard (WAC 173-201A) of 0.012 µg/L from well 199-K-165. Note that all MDLs for nondetected results were greater than the State surface water quality standard. Dissolved mercury was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detection.
- As shown in Table D-14, dissolved silver was detected in 3 of 293 filtered groundwater samples (1.0% frequency) where concentrations ranged between 1.0 µg/L and 10 µg/L. As shown in Table D-15, dissolved silver was detected in 1 of 15 samples from 199-K-171 above the State surface water quality standard (WAC 173-201A) of 2.6 µg/L. Dissolved silver was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections.
- As shown in Table D-14, dissolved zinc was detected in 137 of 272 filtered groundwater samples (50% frequency) where concentrations ranged between 3.99 µg/L and 477 µg/L. As shown in Table D-15, dissolved zinc was detected above the State surface water quality standard (WAC 173-201A) of 91 µg/L in 4 wells. Dissolved zinc was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections. Dissolved zinc was reported above the State surface water quality standard (WAC 173-201A) at the following locations:
  - Detected in 1 of 14 samples from well 199-K-151 (360 µg/L).
  - Detected in 10 of 14 samples from well 199-K-152 (4.22 to 477 µg/L); 1 sample was above the state standard.
  - Detected in 19 of 24 samples from well 199-K-166 (4.74 to 149 µg/L); 1 sample was above the state standard.
  - Detected in 12 of 15 samples from well 199-K-182 (4 to 338 µg/L); 1 sample was above the state standard.

D2.5 Comparison Results for Wells Screened in the Lower Unconfined Aquifer

A total of three wells are screened in the lower unconfined aquifer. Groundwater results from all wells were compiled and statistically analyzed, and summarized in Tables D-16 and D-19. Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Table D-16 and Table D-17, respectively. Results are also compared to federal AWQC and the State

surface water quality standards (WAC 173-201A) and presented in Table D-18 and Table D-19. Each set of tables presents the summary statistics for each analyte detected, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Groundwater samples were analyzed for the following classes of analytes: anions, metals, radionuclides, VOCs, TPH-diesel range organics, and TPH-gasoline range organics.

D2.5.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: All 3 wells were analyzed for carbon-14, gamma-emitting isotopes, strontium-90, technetium-99, and tritium. Well 199-K-168 was analyzed for gross alpha and gross beta and well 199-K-184 was analyzed for americium-241, selenium-79, and isotopic uranium. As shown in Table D-16, carbon-14, gross alpha, gross beta, strontium-90, technetium-99, and tritium were detected at least once in groundwater. Concentrations of carbon-14, gross alpha, strontium-90, technetium-99, and tritium were less than their respective DWS; therefore, they are not retained as COPCs. Gross beta is discussed below:

- As shown in Table D-16, gross beta was detected in all eight groundwater samples (100% frequency), with concentrations ranging between 13.9 pCi/L and 36 pCi/L. The presence of gross beta is generally consistent with that of strontium-90 and tritium. Note that the sum-of-fractions approach is used to determine whether the contribution of each beta- and photon-emitting radionuclide is greater than the cumulative annual dose equivalent of 4 mrem to the total body or any internal organ. This evaluation is presented in Section 6.3.5.

VOCs: VOCs were analyzed in 3 wells. As shown in Table D-16, 2-butanone, 2-propanol, acetone, carbon disulfide, chloroform, methylene chloride, and trichloroethene were detected in groundwater. 2-butanone, 2-propanol, acetone, carbon disulfide, chloroform, and methylene chloride are not retained as COPCs because all results (MDLs) were less than the groundwater action level. Trichloroethene was detected above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level and are discussed below:

- As shown in Table D-16, trichloroethene was detected in 51 groundwater samples (100% frequency), with concentrations ranging between 0.7 and 6.49 µg/L. As shown in Table D-17, all three wells (199-K-168, 199-K-184, and 199-K-190) had trichloroethene concentrations above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 0.54 µg/L based on a target risk level of 1×10^{-6} in at least one sample, as discussed below.
  - Detected in all 16 samples from well 199-K-168 (3.3 to 6.01 µg/L); all samples were above the RBC.
  - Detected in all 26 samples from well 199-K-184 (0.7 to 5.1 µg/L); all samples were above the RBC.
  - Detected in all 9 samples from well 199-K-190 (3.7 to 6.49 µg/L); all samples were above the RBC.

Trichloroethene concentrations were above the 2013 MTCA (WAC 173-340-720) groundwater RBC of 0.54 µg/L at nine wells, However, the well-specific risk assessment determined that the cumulative risk

level was less than the MTCA (WAC 173-340-708) risk threshold of 1×10-5 in all wells and HQ was greater than 1 at all three wells. As a result, trichloroethene is retained as a COPC at wells 199-K-168, 199-K-184, and 199-K-190.

TPH-diesel: TPH-diesel was analyzed in two wells (199-K-168 and 199-K-184). As shown in Table D-16, TPH-diesel was detected in 2 of 18 groundwater samples (11% frequency). All TPH-diesel results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 500 µg/L. Based on these results, TPH-diesel is not retained as a COPC.

TPH-gasoline: TPH-gasoline was analyzed in two wells (199-K-168 and 199-K-184). As shown in Table D-16, TPH-gasoline was detected in 4 of 18 groundwater samples (22% frequency). All TPH-gasoline results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 1,000 µg/L. Based on these results, TPH-gasoline is not retained as a COPC.

TPH-motor oil: TPH-motor oil was analyzed in two wells (199-K-168 and 199-K-184). TPH-motor oil was not detected in any samples from these wells and is not retained as a COPC.

Anions: As shown in Table D-16, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride and nitrate results (detected concentrations and MDLs) were less than their respective Hanford Site background level and groundwater action levels and are not retained as COPCs. As shown in Table D-17, one well (199-K-184) had nitrite in 1 of 24 samples above the DWS of 3,300 µg/L. Nitrite was detected above the DWS but is not retained as a COPC due to the sporadic nature of the detection.

Metals: All wells were analyzed for total chromium and hexavalent chromium, and all wells were analyzed for Method 6010 ICP metals, Method 6010 ICP trace metals, and ICP/MS trace metals by either Method 200.8 or 6020. As shown in Table D-16, all metals results (detected concentrations and MDLs) except hexavalent chromium were less than their respective Hanford Site background values or action levels.

As shown in Table D-16, hexavalent chromium was detected in all 79 unfiltered groundwater samples (100% frequency), with concentrations ranging between 4.6 and 95 µg/L. As shown in Table D-17, hexavalent chromium was detected in all 31 samples from Well 199-K-168, with concentrations ranging between 7.8 to 95 µg/L. Hexavalent chromium was above the 2013 MTCA groundwater cleanup level of 48 µg/L in 5 samples from well 199-K-168 collected before February 2011, concentrations show a downward trend after that date and isn't considered a COPC at this location.

D2.5.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once are as follows:

Anions: As shown in Table D-18, chloride was detected in all groundwater samples. All of the chloride results (detected concentrations and MDLs) were less than the AWQC.

Metals: Total concentrations of hexavalent chromium and dissolved concentrations of silver and zinc were above their respective Hanford Site background values or surface water action levels. All dissolved concentrations of aluminum, arsenic, cadmium, chromium, copper, iron, lead, nickel, and selenium results (detected concentrations and MDLs) were less than their respective Hanford Site background values and/or surface water action levels.

- As shown in Table D-18, hexavalent chromium was detected in all 79 unfiltered groundwater samples (100% frequency) where concentrations ranged between 4.6 µg/L and 95 µg/L. As shown in Table D-19, hexavalent chromium was measured in 3 wells at concentrations greater than the State

surface water quality standard (WAC 173-201A) of 10 µg/L. Hexavalent chromium was identified as a COPC and reported above the Washington State surface water quality standard (WAC 173-201A) of 10 µg/L in the following filtered samples:

- Detected in all 31 samples from well 199-K-168 (7.8 to 95 µg/L); 24 samples collected through November 2015 were above the state standard, concentrations show a downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 25 samples from well 199-K-184 (4.6 to 37.3 µg/L); 14 samples collected through February 2015 were above the state standard, concentrations show a downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.
- Detected in all 23 samples from well 199-K-190 (7.6 to 17.5 µg/L); 16 samples collected through May 2015 were above the state standard, concentrations show downward trend after that date. Hexavalent chromium is not retained as a COPC at this well because of the downward concentration trend.

- As shown in Table D-18, dissolved silver was detected in 4 of 75 filtered groundwater samples (5.3% frequency) where concentrations ranged between 0.104 µg/L and 18 µg/L. As shown in Table D-19, dissolved silver was detected in 2 of 26 samples from well 199-K-168 at concentrations above the State surface water quality standard (WAC 173-201A) of 2.6 µg/L. Dissolved silver was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections.
- As shown in Table D-18, dissolved zinc was detected in 30 of 67 filtered groundwater samples (45% frequency) where concentrations ranged between 3.97 µg/L and 500 µg/L. As shown in Table D-19, dissolved zinc was detected in 1 of 26 samples from well 199-K-168 above the State surface water quality standard (WAC 173-201A) of 91 µg/L. Dissolved zinc was reported above the state standard in one sample, but it is not retained as a COPC due to the sporadic nature of the detections.

D2.6 Comparison Results for Well 199-K-193 Screened in the Upper and Lower Unconfined Aquifer

Well 199-K-193 is screened in the upper and lower portions of the unconfined aquifer. Groundwater results from this well were compiled and statistically analyzed, and summarized in Tables D-20 and D-21. Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Table D-20. Results are also compared to federal AWQC and the State surface water quality standards (WAC 173-201A) and presented in Table D-21. Each set of tables present the summary statistics for each analyte detected, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Groundwater samples were analyzed for the following classes of analytes: anions, metals, radionuclides, and VOCs.

D2.6.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: Well 199-K-193 was analyzed for carbon-14, strontium-90, technetium-99, and tritium. As shown in Table D-20, strontium-90 and tritium were detected at least once in groundwater and were less than their respective DWS; therefore, they are not retained as COPCs.

VOCs: VOCs were analyzed in well 199-K-193. As shown in Table D-20, 2-butanone, acetone, carbon disulfide, chloroform, ethylbenzene, toluene, and xylenes (total) were detected in groundwater. All VOCs are not retained as COPCs because all results (detected concentrations and MDLs) were less than the groundwater action level.

Anions: As shown in Table D-20, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride, nitrate, and nitrite results (detected concentrations and MDLs) were less than their respective Hanford Site background level and groundwater action levels and are not retained as COPCs.

Metals: Well 199-K-193 was analyzed for all metals. As shown in Table D-20, all metals results (detected concentrations and MDLs) except thallium were less than their respective Hanford Site background values and/or action levels.

As shown in Table D-20, thallium was detected in 1 of 21 unfiltered groundwater samples (4.8% frequency), with a concentrations of 2.3 µg/L. As shown in Table D-20, thallium was detected above the 90th percentile Hanford Site value of 1.67 µg/L in well 199-K-193 at a concentration of 2.3 µg/L. The range of thallium background concentrations (minimum, maximum, and 90th percentile) is 0.883, 1.73, and 1.67 µg/L in filtered groundwater samples. All filtered thallium samples from well 199-K-193 were less than the 90th percentile value. Thallium is not retained as a COPC due to the sporadic detections in unfiltered samples and because all filtered samples were less than background.

D2.6.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once are as follows:

Anions: As shown in Table D-21, chloride was detected in all groundwater samples. All of the chloride results (detected concentrations and MDLs) were less than the AWQC.

Metals: Total concentrations of hexavalent chromium and dissolved concentrations of zinc were above their respective Hanford Site background values and/or surface water action levels. All total concentrations of aluminum, iron, and selenium, and dissolved concentrations of arsenic, chromium, copper, lead, and nickel results (detected concentrations and MDLs) were less than their respective Hanford Site background values or surface water action levels.

- As shown in Table D-21, hexavalent chromium was detected in all 23 unfiltered groundwater samples (100% frequency) where concentrations ranged between 6.1 µg/L and 33.3 µg/L. Hexavalent chromium was above the State surface water quality standard (WAC 173-201A) of 10 µg/L in 21 samples collected through November 2016. Hexavalent chromium is retained identified as a COPC.

- As shown in Table D-21, dissolved zinc was detected in 14 of 15 filtered groundwater samples (93% frequency) where concentrations ranged between 17.2 µg/L and 900 µg/L. Two of 15 samples were above the State surface water quality standard (WAC 173-201A) of 91 µg/L. Dissolved zinc was reported above the state standard in one sample, but it is not retained as a COPC due to the sporadic nature of the detections.

D2.7 Comparison Results for Wells Screened in the RUM

Two wells are screened in the RUM. Groundwater data from both wells screened within the RUM and data from each individual wells were compiled, statistically analyzed, and summarized in Tables D-22 through D-25. Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Table D-22 and Table D-23. Similarly, results are compared to federal AWQC and the State surface water quality standards (WAC 173-201A) and presented in Table D-24 and Table D-25. Each set of tables present the summary statistics for each analyte detected in the RUM, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Groundwater samples were analyzed for the following classes of analytes: anions, metals, radionuclides, VOCs, TPH-diesel, and TPH-gasoline.

D2.7.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: Both RUM wells were analyzed for gross alpha, gross beta, strontium-90 technetium-99, and tritium; well 199-K-192 was also analyzed for gamma-emitting isotopes. As shown in Table D-22, gross alpha, gross beta, strontium-90, and technetium-99 were detected at least once in groundwater. Concentrations of gross alpha, strontium-90, and technetium-99 were less than their respective DWS; therefore, they are not retained as COPCs. Gross beta is discussed below.

- As shown in Table D-22, gross beta was detected in all six groundwater samples (100% frequency), where concentrations range between 4.8 and 8.4 pCi/L. The presence of gross beta is generally consistent with that of strontium-90 and tritium. Note that the sum-of-fractions approach is used to determine whether the contribution of each beta- and photon-emitting radionuclide is greater than the cumulative annual dose equivalent of 4 mrem to the total body or any internal organ. This evaluation is presented in Section 6.3.5.

VOCs: VOCs were analyzed in well 199-K-192. As shown in Table D-22, acetone was detected in groundwater and all results (detected concentrations and MDLs) were less than the groundwater action level, acetone is not retained as a COPC.

TPH-diesel: TPH-diesel was analyzed in well 199-K-32B. TPH-diesel was not detected in any samples from this well and is not retained as a COPC.

TPH-gasoline: TPH-gasoline was analyzed in well 199-K-32B. As shown in Table D-22, TPH-gasoline was detected in 1 of 2 groundwater samples (50% frequency). All TPH-gasoline results (detected concentrations and MDLs) were less than the 2013 MTCA (WAC 173-340-720) Method A value of 1,000 μg/L. Based on these results, TPH-gasoline is not retained as a COPC.

TPH-motor oil: TPH-motor oil was analyzed in well 199-K-32B. TPH-motor oil was not detected in any samples from this well and is not retained as a COPC.

Anions: Anions were analyzed in both RUM wells. As shown in Table D-22, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride, nitrate, and nitrite results (detected concentrations and MDLs) were less than their respective Hanford Site background levels or groundwater action levels. Anions are not retained as COPCs.

Metals: Metals, including total chromium and hexavalent chromium, were analyzed in both RUM wells. All metals results (detected concentrations and MDLs) were less than their respective Hanford Site background values or groundwater action levels. No metals were retained as COPCs for wells screened within the RUM.

D2.7.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once in RUM wells are as follows:

Anions: As shown in Table D-24, chloride was detected in all groundwater samples. All chloride results (detected concentrations and MDLs) were less than the AWQC.

Metals: Dissolved concentrations of cadmium, lead, and zinc were above their respective Hanford Site background values and/or surface water action levels. All total concentrations of hexavalent chromium, and dissolved concentrations of aluminum, arsenic, chromium, copper, iron, nickel, selenium, and zinc results (detected concentrations and MDLs) were less than their respective Hanford Site background values and/or surface water action levels.

- As shown in Table D-24, dissolved cadmium was detected in one of 26 filtered groundwater samples (3.9% frequency) at a concentration of 2.8 µg/L. As shown in Table D-25, dissolved cadmium was detected in one of 21 samples from well 199-K-192 at a concentration (2.8 µg/L) above the AWQC of 0.72 µg/L. Dissolved cadmium is not retained as a COPC due to the sporadic nature of the detection.

- As shown in Table D-24, dissolved lead was detected in 5 of 26 filtered groundwater samples (19% frequency) where concentrations ranged between 0.0524 µg/L and 2.9 µg/L. As shown in Table D-25, dissolved lead was detected in 1 of 21 samples above the State surface water quality standard (WAC 173-201A) of 2.1 µg/L in wells 199-K-192. Dissolved lead was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections.

D2.8 Comparison Results for Aquifer Tubes

A total of 49 aquifer tubes installed adjacent to the 100-KR-4 Groundwater OU were sampled between 2010 and 2017. Groundwater data from all aquifer tubes combined and data from each individual aquifer tube were compiled, statistically analyzed; and summarized in Tables D-26 through Table D-29. Results are compared to DWSs and 2013 MTCA (WAC 173-340-720) groundwater cleanup levels and presented in Tables D-26 and D-27. Similarly, results are compared to federal AWQC and the State surface water quality standards (WAC 173-201A) and presented in Tables D-28 and D-29. Each set of tables presents the summary statistics for each analyte detected in the aquifer tube, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, the number of detections greater than the background value, the groundwater or surface water action level for each analyte, and the number of detections greater than the action level.

Aquifer tube samples were analyzed for the following classes of analytes: anions, metals, and radionuclides.

D2.8.1 Results of Comparisons to Drinking Water Standards and 2013 MTCA Risk-Based Concentrations

The analytes that were detected at least once are as follows:

Radionuclides: Gross alpha and gross beta were analyzed at eight aquifer tubes, strontium-90 was analyzed at 41 aquifer tubes, tritium was analyzed at 37 aquifer tubes, and technetium-99 was analyzed at seven aquifer tubes. As shown in Table D-26, carbon-14, gross alpha, gross beta, strontium-90,

technetium-99, and tritium were detected at least once in groundwater. Concentrations of carbon-14, gross alpha, technetium-99, and tritium were less than their DWS; therefore, they are not retained as COPCs. Strontium-90 was greater than its DWS in one as discussed below:

- As shown in Table D-26, strontium-90 was detected in 31 of 173 aquifer tube samples (18% frequency), where concentrations range between 0.85 and 8.8 pCi/L. As shown in Table D-27, aquifer tube 22-M had strontium-90 above the DWS in one of five samples; all samples collected after October 2013 were less than the DWS.

VOCs: VOCs were analyzed in 17 aquifer tubes. As shown in Table D-26, 1-butanol, 2-butanone, 2-propanol, acetone, carbon tetrachloride, chloroform, methylene chloride, toluene, trichloroethene, and xylenes (total) were detected in groundwater. 1-butanol, 2-butanone, 2-propanol, acetone, chloroform, methylene chloride, toluene, and xylenes (total) are not retained as COPCs because all results (MDLs) were less than the groundwater action level. Trichloroethene and carbon tetrachloride were detected above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level and are discussed below:

- As shown in Table D-26, carbon tetrachloride was detected in 3 of 113 groundwater samples (2.7% frequency), with concentrations ranging between 1.6 and 2.2 µg/L. As shown in Table D-27, three aquifer tubes (C7641, C7642, and C7643) had carbon tetrachloride concentrations above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 0.64 µg/L based on a target risk level of 1×10^{-6} in at least one sample. All carbon tetrachloride concentrations are less than the MCL of 5 µg/L; as a result, carbon tetrachloride is not retained as a COPC.

- As shown in Table D-26, trichloroethene was detected in 37 of 113 groundwater samples (33% frequency), with concentrations ranging between 0.3 and 2.7 µg/L. As shown in Table D-27, eight aquifer tubes (17-D, 17-M, C6236, C6237, C6238, C7641, C7642, and C7643) had trichloroethene concentrations above the 2013 MTCA (WAC 173-340-720) groundwater cleanup level of 0.54 µg/L based on a target risk level of 1×10^{-6} in at least one sample. All trichloroethene concentrations are less than the adjusted MCL of 4 µg/L; as a result, trichloroethene is not retained as a COPC.

- **Polynuclear aromatic hydrocarbons:** Polynuclear aromatic hydrocarbons analyzed by EPA Method 8310 were analyzed in three aquifer tubes. As shown in Table D-26, naphthalene was detected in groundwater and all results (detected concentrations and MDLs) were less than the groundwater action level; naphthalene is not retained as a COPC.

Anions: Anions were analyzed at 43 aquifer tubes. As shown in Table D-26, fluoride, nitrate, and nitrite were each detected in groundwater. All fluoride, nitrate, and nitrite results (detected concentrations and MDLs) were less than their respective Hanford Site background levels or groundwater action levels and are not retained as COPCs.

Metals: Hexavalent chromium was analyzed at all aquifer tubes and ICP metals were analyzed in up to 17 aquifer tubes. With the exception of hexavalent chromium, all metals results (detected concentrations and MDLs) were less than their respective Hanford Site background values or groundwater action levels. No metals were retained as COPCs; arsenic is discussed below:

- As shown in Table D-26, hexavalent chromium was detected in 153 of 370 groundwater samples (41% frequency) with concentrations ranging between 1.5 and 50 µg/L. As shown in Table D-27, hexavalent chromium concentrations in aquifer tube AT-K-3-M was detected in all eight samples, one result (50 µg/L) was above the cleanup level of 48 µg/l. Hexavalent chromium is not retained as a COPC.

D2.8.2 Results of Comparisons to Surface Water Quality Standards and Criteria

The analytes that were detected at least once are as follows:

Anions: As shown in Table D-28, chloride was detected in all 43 aquifer tube samples, where concentrations ranged between 1,420 and 17,300 µg/L. All chloride results were less than the AWQC and it is not retained as a COPC.

Metals: As shown in Table D-28, unfiltered hexavalent chromium concentrations were greater than the State surface water quality standard of 10 µg/L. Dissolved silver All remaining filtered metals results (detected concentrations and MDLs) were less than their respective Hanford Site background values or surface water action levels. Hexavalent chromium was detected in 153 of 370 samples (41% frequency), where concentrations ranged between 1.5 and 50 µg/L. Hexavalent chromium was reported above the State surface water quality standard of 10 µg/L at 11 locations. Hexavalent chromium was reported below the State surface water quality standard at 10 locations: AT-K-3-D, AT-K-3-M, AT-K-3-S, C6245, C6246, C6247, C6252, C6253, C6256, and C6261. Hexavalent chromium is not retained as a COPC at aquifer tube location AT-K-1D because of the sporadic detection above the State surface water quality standard. Hexavalent chromium is retained as a COPC as discussed below:

- As shown in Table D-29, hexavalent chromium was detected above the State surface water quality standard of 10 µg/L in the following unfiltered samples:
  - Three of five results from 22-D (5 to 43 µg/L); hexavalent chromium is retained as a COPC.
  - One of nine results from AT-K-1-D (1.5 to 29 µg/L); hexavalent chromium is not retained as a COPC.
  - All four results from AT-K-3-D (29 to 31 µg/L); hexavalent chromium is retained as a COPC.
  - All five results from AT-K-3-M (30 to 50 µg/L); hexavalent chromium is retained as a COPC.
  - All five results from AT-K-3-S (8.4 to 25.4 µg/L) hexavalent chromium is not retained as a COPC because of the downward concentration trend.
  - One of five results from C6246 (1.5 to 12 µg/L); hexavalent chromium is not retained as a COPC.
  - Two of five results from C6247 (9 to 11.1 µg/L); hexavalent chromium is not retained as a COPC because of the downward concentration trend.
  - One of five results from C6252 (3.5 to 12.5 µg/L); hexavalent chromium is not retained as a COPC.
  - One of four results from C6253 (7.6 to 12.2 µg/L); hexavalent chromium is not retained as a COPC.
  - All four results from C6256 (12.1 to 17.2 µg/L); hexavalent chromium is retained as a COPC.

As shown in Table D-28, dissolved silver was detected in 4 of 75 filtered groundwater samples (5.3% frequency) where concentrations ranged between 0.104 µg/L and 18 µg/L. As shown in Table D-29, dissolved silver was detected in 1 of 22 samples from well 199-K-34 at concentrations above the State surface water quality standard (WAC 173-201A) of 2.6 µg/L and the Hanford Site 90th percentile background concentration of 5.3 µg/L. Dissolved silver was reported above the state standard, but it is not retained as a COPC due to the sporadic nature of the detections.

D2.9 Summary of Analytes Greater than Action Levels

Table D-30 summarizes the outcome of the evaluation of individual groundwater concentrations. Analytes that are retained as COPCs include carbon-14, nitrate, strontium-90, trichloroethene, tritium, total chromium, total dissolved chromium, and hexavalent chromium.

The information in this chapter will be used in Chapter 5 to evaluate the fate and transport of groundwater contaminants associated with the 100-KR-4 OU. As described earlier in this section, the results of this evaluation will also be used to support the COPC identification process that is provided in the groundwater baseline risk assessment, which is presented in Chapter 6. The groundwater baseline risk assessment provides a comprehensive evaluation of cumulative cancer risks and noncancer hazards based on evaluation of each exposure area and on a well-specific basis for a subset of monitoring wells.

D3 Field Name Definitions

Many of the data in this appendix were derived from the Hanford Environmental Information System (HEIS) database, which is designated as the central repository for Hanford Site environmental data. Users may access HEIS via the Hanford Site Environmental Dashboard application.

This section includes an alphabetical list of selected field names (column headers) used in the accompanying data tables. A full listing of field names and their meanings is included in HNF-38155, *HEIS Sample, Result, and Sampling Site Data Dictionary*.

EASTING – Geographic east-west coordinates of the sample site in meters (North American Datum of 1983).

LAB_QUALIFIER – A code that qualifies the associated result. These codes are reported by the analytical laboratory. The meaning of many codes depends on the METHOD_CATEGORY. Table D-31 describes laboratory qualifier codes.

Table D-31. Laboratory Qualifiers

Code	Translations
*	INORGANICS - Duplicate analysis not within control limits.
+	INORGANICS - Correlation coefficient for MSAs is < 0.995.
>	WETCHEM - Result greater than quantifiable range or greater than upper limit of the analysis range.
A	ORGANICS - Valid for TICs only: The TIC is a suspected aldolcondensation product.
B	INORGANICS and WETCHEM - The analyte was detected at a value less than the contract RDL, but greater than or equal to the IDL/MDL (as appropriate). ORGANICS - The analyte was detected in both the associated. QC blank and in the sample. RADIONUCLIDES - The associated QC sample blank has a result >= 2X the MDA and, after corrections, result is >= MDA for this sample.
C	INORGANICS/WETCHEM: The analyte was detected in both the sample and the associated QC blank, and the sample concentration was <= 5X the blank concentration. ORGANICS (PESTICIDE only) – The identification of a pesticide confirmed by gas chromatograph/mass spectrometer (GC/MS).
D	All - Analyte was reported at a secondary dilution factor, typically DF>1 (i.e., the primary preparation required dilution to either bring the analyte within the calibration range or to minimize interference). Required for organics/wetchem if the sample was diluted.
E	INORGANICS - Reported value is estimated because of interference. See comment on cover page, hardcopy case narrative, or specific inorganic hardcopy data sheet. ORGANICS - Concentration exceeds the calibration range of the GC/MS.

Table D-31. Laboratory Qualifiers

Code	Translations
J	ORGANICS - Estimated value; (1) constituent detected at a level less than the RDL or PQL and greater than or equal to the MDL, (2) estimated concentration for TICs. Note - For HEIS data generated prior to December 1, 2002, laboratories may have applied a "J" qualifier to nonorganic results. When applied, application was based primarily on criteria comparable to statement (1) above. Prior to January, 1998, validation qualifiers (including "J") were recorded in the LAB_QUALIFIER field without identification as validation qualifiers.
L	MDL <= value < CRQL [RETIRED].
M	INORGANICS - Duplicate precision criteria not met.
N	ALL (except GC/MS based analysis) - Spike and/or spike duplicate sample recovery is outside control limits. ORGANICS (GC/MS only) - Presumptive evidence of compound based on mass spectral library search.
P	ORGANICS (PCB only) - Aroclor target analyte with greater than 25% difference between column analyses.
Q	ORGANICS (Dioxins and PCB Congeners only) – Estimated maximum concentration. Used if one of the qualitative identification criteria is not met (e.g., Cl isotopic ratios outside theoretical range.)
S	INORGANICS - Reported value determined by the MSA.
T	Organics (GC/MS only) - Spike and/or spike duplicate sample recovery is outside control limits.
U	ALL - Analyzed for but not detected above limiting criteria. Limiting criteria may be any of the following: value reported < 0; value reported < counting error ; value reported < total analytical error; value_rptd <=contract MDL/IDL/MDA/PQL. Note – When another qualifier accompanies a "U" qualifier the result is always considered nondetected. The qualifier combinations "UJ" and "UL" indicate that the result was nondetected, but the detection limit (i.e., value reported in the VALUE_RPTD or MIN_DETECTABLE_ACTIVITY [rad analysis only] fields) was estimated.
W	INORGANICS - Post-digestion spike recovery for GFAA out of control limit. Sample absorbency <50% of spike absorbency.
X	ALL – The result-specific translation of this qualifier code is provided in the hardcopy data report and/or case narrative. Additional result-specific translation information may also be found in the RESULT_COMMENT field for this record.
Y	Same as X if more than one flag is required. In the process of being retired.
Z	Same as X and Y if more than two flags are required. In the process of being retired.

GC/MS	=	gas chromatography/mass spectrometry	RDL	=	required detection limit
GFAA	=	graphite-furnace atomic absorption	TIC	=	tentatively identified compound
HEIS	=	Hanford Environmental Information System	MDL	=	method detection limit
IDL	=	instrument detection limit	MSA	=	method of standard addition
PCB	=	polychlorinated biphenyl	QC	=	quality control
PQL	=	practical quantitation limit	RDL	=	required detection limit

NORTHING – Geographic north-south coordinates of the sample site in meters (North American Datum of 1983).

RESULT_COMMENT – Comments about the result record may be entered. Entries into this column are not reported by the laboratories but are added by data reviewers.

REVIEW_QUALIFIER – A code indicating that the quality of the record has been questioned by the reviewer. Table D-32 defines the codes.

Table D-32 Review Qualifiers

Code	Translations
A	Administrative technical issue. An issue was identified with the chain of custody or other administrative documents during the verification process that may potentially affect the data quality/defensibility of the associated analytical results.
F	This code is temporarily assigned while the result is undergoing further review.
G	Record has been reviewed and determined to be correct, or the record has been corrected with laboratory confirmation or other supporting information.
H	Laboratory holding time exceeded before the sample was analyzed.
P	Potential problem. Collection/analysis circumstances makes value questionable.
Q	Associated quality control sample is out of limits.
R	Do not use. Further review indicates the result is not valid.
Y	Result suspect. Review - insufficient evidence to show result valid or invalid.
Z	Miscellaneous circumstances exist. Additional information may be found in the RESULT_COMMENT field for this record and/or in the SAMP_COMMENT field of the parent sample record.

SAMP_DATE_TIME – Date the sample was collected.

SAMP_NUM – A unique identifier for a physical sample.

SAMP_SITE_NAME – Well name, borehole number, or in the case of test pits, waste site name associated with the sample.

STD_ANAL_UNITS_RPTD – Analytical units for results.

STD_CON_LONG_NAME – Standardized name of the constituent or property reported.

STD_COUTING_ERROR – Error value measured by counting disintegrations of radioactive analytes, reported in the same units as the STD_VALUE_REPORTED. This error serves as a lower bound for the uncertainty of the measurement.

STD_MDA – Minimum detectable activity, typically dependent on the measured instrument background and sample yield, reported in the same units as the STD_VALUE_REPORTED. Generally, it depends on the actual aliquot, count time, yield, efficiency, decay correction, and some measurement of the background. The background might be from associated instrument blanks, reagent blanks, baseline information for the sample, or some combination of these.

STD_SAMP_INTV_BOT – Depth below land surface of bottom of sampling device, standardized to units of meters.

STD_SAMP_INTV_TOP – Depth below land surface of top of sampling device, standardized to units of meters.

STD_TOTAL_ANAL_ERROR – A combination of counting error plus a laboratory-specific estimate dependent on the chosen analysis methods, representing sample-specific error (at 2 sigma) that could possibly be introduced into the analysis while at the laboratory, reported in the same units as the STD_VALUE_REPORTED. For radiological analyses, this is the total propagated uncertainty.

STD_VALUE_RPTD – The analytical result (e.g., concentration), converted if necessary to standard analytical units.

VALIDATION_QUALIFIER – Codes that are assigned by an individual who validates the result; this validation is performed only at the request of the project management for which the sample was collected. If no VALIDATION_QUALIFIER is recorded, then the validator either did not validate the record or agreed with the value reported and LAB_QUALIFIER code(s). Table D-33 defines the codes.

Table D-33. Validation Qualifiers

Code	Translations
J	Estimated value: The associated result value may not reflect quantitation/detection levels (if assigned with an associated "U" qualifier) or actual concentrations with the precision/accuracy typically associated with results by this methodology. Result precision/accuracy may have been impacted due to minor quality control deficiency/s or sample matrix interferences identified during data validation.
R	Rejected value: The value may not reflect true concentrations. The ability to establish detection/ nondetection may be questionable. Validation activities identified major quality control deficiency/s or sample matrix interferences. The data should be considered unusable for most purposes. Any use of this data should be undertaken with great care. The data should not be used for certain regulatory decision-making purposes.
U	Functional nondetect: The constituent was analyzed for and reported as detected by the laboratory. The constituent has been assigned a nondetect qualifier due to associated low-level analytical batch contamination or other circumstances noted by the validator that indicates that use of the data as detected is inappropriate. Validation may result in a revised reported value. Revised results typically involve substituting the quantitation/reporting limit if greater than the initial laboratory reported value. This qualifier may be assigned along with either, but never both, of the other validation qualifiers. In that case, both definitions apply to the associated result. The data should be considered usable as a nondetect for most decision-making purposes.

WELL_ID – Unique well identification number.

WELL_NAME – Name of the well or borehole from which the sample was collected. Names beginning with 199-K are located in 100-K. Names beginning with 699- are located outside the former operational area. Temporary boreholes and some aquifer tubes have names identical to the WELL_ID. Other well name formats (e.g., 05-M, AT-B-4-S) are aquifer tubes.

D4 Water Levels

This section includes water-level data from manual or automated measurements in wells, and automated river stage data measured at 100-K.

D4.1 Manual Data

The data file “100KR4_Manual_WL.xlsx” includes manual water-level measurements in 100-K, associated 100-N, and 600 Area wells near 100-K for dates from 1957 to April 2017. The following text explains field codes that are specific to water-level data. Other field codes are explained in Section D.1.

WELL_NAME and WELL_ID – Same as described in Section D2.

HYD_DATE_TIME_PST – Date and time of measurement, Pacific Standard Time (if no time associated with measurement, the time is recorded as 0:00).

HYD_HEAD_METERS_NAVD88 – Water-level elevation in meters above North American Vertical Datum of 1988.

DEPTH_TO_WATER_MP – Measured depth below measuring point.

DEPTH_TO_WATER_MP_UNITS – Units in which original measurement made.

MP_DESCRIPTION – Description of measuring point (e.g., top of casing, top of pump plate).

RP_ELEV_METERS_NAVD88 – Elevation of reference point (surveyed) in meters above North American Vertical Datum of 1988.

MP_MINUS_RP – Difference in elevation between measuring point and reference point.

MP_MINUS_RP_UNITS – Units of depth.

DEPTH_TO_WATER_RP – Depth below reference point.

DEPTH_TO_WATER_RP_UNITS – Depth units.

REVIEW_QUALIFIER – Indicator code that the quality of the data point is questioned, assigned by the data owners. Table D-3 explains the qualifier codes.

REVIEW_COMMENT – Reference to request for data review record associated with review qualifier.

D4.2 Automated Water-Level Network

Selected 100-K wells are equipped with pressure transducers and data loggers to collect hourly water-level measurements. Table D-34 lists the wells with transducers and their periods of operation. There are a total of eight data files (i.e., “100K_AWLN_1of8.xlsx”) which includes the data. Columns include the following:

Well Name – Is the official designation of a well that is based primarily on the well’s location.

Date/Time: Date and time (Pacific Standard Time).

Elevation: Water-level elevation in the well, meters above NAVD88, North American Vertical Datum of 1988.

MP Elevation: The elevation of the measuring point, listed in meters using NAVD88, North American Vertical Datum of 1988. This is typically the top of the outer casing of the well.

DTW: Depth to water, the measured or calculated distance from the measuring point to the water level in a given well, reported in feet.

Table D-34. Automated Water-Level Data Available for 100-K Wells

Well Name	Data Start	Data End	Included in Data File Name
199-K-18	1/1/2004	12/31/2017	100K_AWLN_6of8.xlsx
199-K-19	7/2/2008	12/31/2017	100K_AWLN_6of8.xlsx
199-K-20	1/1/2004	12/31/2017	100K_AWLN_7of8.xlsx
199-K-21	1/1/2004	12/31/2017	100K_AWLN_7of8.xlsx
199-K-22	1/1/2004	12/21/2017	100K_AWLN_7of8.xlsx
199-K-30	1/1/2004	3/22/2010	100K_AWLN_8of8.xlsx

Table D-34. Automated Water-Level Data Available for 100-K Wells

Well Name	Data Start	Data End	Included in Data File Name
199-K-31	7/18/2014	12/31/2017	100K_AWLN_8of8.xlsx
199-K-32A	1/1/2004	12/23/2017	100K_AWLN_8of8.xlsx
199-K-32B	1/1/2004	12/31/2017	100K_AWLN_8of8.xlsx
199-K-36	12/30/2014	7/9/2015	100K_AWLN_8of8.xlsx
199-K-37	1/1/2004	12/31/2017	100K_AWLN_8of8.xlsx
199-K-107A	3/20/2008	12/31/2017	100K_AWLN_1of8.xlsx
199-K-108A	12/1/2008	12/31/2017	100K_AWLN_1of8.xlsx
199-K-111A	9/13/2007	12/31/2017	100K_AWLN_1of8.xlsx
199-K-112A	7/28/2004	12/31/2017	100K_AWLN_1of8.xlsx
199-K-113A	1/1/2004	6/10/2010	100K_AWLN_1of8.xlsx
199-K-114A	1/1/2004	6/10/2010	100K_AWLN_2of8.xlsx
199-K-115A	1/1/2004	6/10/2010	100K_AWLN_2of8.xlsx
199-K-116A	1/1/2004	6/10/2010	100K_AWLN_2of8.xlsx
199-K-117A	1/1/2004	12/31/2017	100K_AWLN_2of8.xlsx
199-K-118A	7/8/2010	12/31/2017	100K_AWLN_2of8.xlsx
199-K-119A	1/1/2004	12/30/2017	100K_AWLN_3of8.xlsx
199-K-120A	1/1/2004	8/10/2009	100K_AWLN_3of8.xlsx
199-K-121A	1/1/2004	6/10/2010	100K_AWLN_3of8.xlsx
199-K-122A	1/1/2004	6/10/2010	100K_AWLN_3of8.xlsx
199-K-123A	1/1/2004	6/10/2010	100K_AWLN_3of8.xlsx
199-K-124A	1/1/2004	3/30/2015	100K_AWLN_4of8.xlsx
199-K-125A	1/1/2004	6/10/2010	100K_AWLN_4of8.xlsx
199-K-126	1/1/2004	12/31/2017	100K_AWLN_4of8.xlsx
199-K-127	1/1/2004	8/10/2009	100K_AWLN_4of8.xlsx
199-K-128	1/1/2004	6/10/2010	100K_AWLN_4of8.xlsx
199-K-129	2/2/2004	6/10/2010	100K_AWLN_5of8.xlsx
199-K-130	1/1/2004	3/25/2008	100K_AWLN_5of8.xlsx
199-K-131	10/28/2004	3/19/2008	100K_AWLN_5of8.xlsx
199-K-137	4/22/2008	8/12/2008	100K_AWLN_5of8.xlsx
199-K-141	8/13/2007	3/25/2009	100K_AWLN_5of8.xlsx

Table D-34. Automated Water-Level Data Available for 100-K Wells

Well Name	Data Start	Data End	Included in Data File Name
199-K-142	3/26/2009	12/31/2017	100K_AWLN_5of8.xlsx
199-K-147	1/7/2008	2/26/2008	100K_AWLN_5of8.xlsx
199-K-149	12/5/2014	6/28/2017	100K_AWLN_5of8.xlsx
199-K-151	6/25/2008	6/27/2017	100K_AWLN_5of8.xlsx
199-K-153	6/25/2008	7/6/2009	100K_AWLN_5of8.xlsx
199-K-157	7/2/2008	12/31/2017	100K_AWLN_6of8.xlsx
199-K-163	6/25/2008	3/26/2009	100K_AWLN_6of8.xlsx
199-K-183	7/25/2014	12/31/2017	100K_AWLN_6of8.xlsx
199-K-184	11/21/2014	12/14/2017	100K_AWLN_6of8.xlsx
199-K-185	7/25/2014	12/31/2017	100K_AWLN_6of8.xlsx
199-K-186	7/25/2014	12/31/2017	100K_AWLN_6of8.xlsx
199-K-187	11/21/2014	12/31/2017	100K_AWLN_6of8.xlsx
199-K-190	3/19/2005	12/31/2017	100K_AWLN_7of8.xlsx
199-K-191	6/29/2017	12/31/2017	100K_AWLN_7of8.xlsx
199-K-193	12/5/2014	7/31/2017	100K_AWLN_7of8.xlsx
199-K-194	11/24/2014	12/31/2017	100K_AWLN_7of8.xlsx
199-K-197	12/5/2014	12/31/2017	100K_AWLN_7of8.xlsx
199-K-202	11/21/2014	12/31/2017	100K_AWLN_7of8.xlsx
199-K-207	4/8/2015	12/31/2017	100K_AWLN_7of8.xlsx
199-K-223	3/31/2017	12/31/2017	100K_AWLN_7of8.xlsx
699-78-62	12/8/2008	12/31/2017	100K_AWLN_8of8.xlsx
699-81-62	12/5/2014	3/30/2017	100K_AWLN_8of8.xlsx

D2.3 River Stage A river stage gauge operated at 100-K until 2012. A more continuous record was generated by applying a model to simulate river stage at 100-K based on discharge of Priest Rapids Dam, as described in ECF-HANFORD-13-0028, *Columbia River Stage Correlation for the Hanford Area*. The file “River_Stage.xlsx” includes a macro enable tool which downloads data directly from the Priest Rapids Dam through the USGS website. The file includes daily average elevations (meter above NAVD88) from Oct. 2007 through Aug. 2017.

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Table D-1. 100-KR-4 Groundwater OU Monitoring Wells by Exposure Area

Wells Screened at the Top of the Unconfined Aquifer [a]				
199-K-18	199-K-19	199-K-22	199-K-23	199-K-29
199-K-30	199-K-32A	199-K-34	199-K-36	199-K-106A
199-K-107A	199-K-108A	199-K-109A [b]	199-K-110A	199-K-111A
199-K-132 [c]	199-K-137 [c]	199-K-139 [c]	199-K-140 [c]	199-K-200
199-K-201	699-73-61	--	--	--
Wells Screened in the Upper Unconfined Aquifer [d]				
199-K-11	199-K-20	199-K-21	199-K-31	199-K-35, 199-K-195, 199-K-205 [c]
199-K-37	199-K-113A [e]	199-K-114A [e]	199-K-117A	199-K-125A [e]
199-K-138 [c]	199-K-141 [f]	199-K-142	199-K-144 [f]	199-K-146 [f]
199-K-147 [f]	199-K-148 [f]	199-K-161 [f]	199-K-173 [c]	199-K-178 [c]
199-K-183	199-K-186	199-K-187	199-K-188	199-K-191
199-K-194	199-K-204	199-K-221	199-K-222	699-72-73
Wells Screened through the Entire Unconfined Aquifer [g]				
199-K-116A [e]	199-K-120A [e]	199-K-145[e]	199-K-151	199-K-152 [f]
199-K-153 [f]	199-K-154 [f]	199-K-157	199-K-163 [f]	199-K-165 [c]
199-K-166 [c]	199-K-171 [f]	199-K-182 [c]	199-K-185	199-K-189
199-K-202	199-K-203	199-K-207	199-K-208 [f]	199-K-209
199-K-210 [f]	199-K-223	199-K-224 [c]	--	--
Wells Screened in the Lower Unconfined Aquifer [h]				
199-K-168 [c]	199-K-184	199-K-190	--	--
Well Screened in the Upper and Lower Unconfined Aquifer [i]				
199-K-193	--	--	--	--
Wells Screened in the RUM [j]				
199-K-32B	199-K-192	--	--	--

Table D-1. 100-KR-4 Groundwater OU Monitoring Wells by Exposure Area

Aquifer Tubes				
14-D	17-D	17-M	18-S	19-D
21-M	21-S	22-D	22-M	23-M
26-D	26-M	AT-K-1-D	AT-K-1-M	AT-K-1-S
AT-K-2-D	AT-K-3-D	AT-K-3-M	AT-K-3-S	AT-K-4-M
AT-K-4-S	AT-K-5-D	AT-K-5-M	AT-K-5-S	C6236
C6237	C6238	C6240	C6241	C6242
C6243	C6244	C6245	C6246	C6247
C6248	C6249	C6250	C6251	C6252
C6253	C6254	C6255	C6256	C6260
C6261	C6263	C6264	C6265	C7641
C7642	C7643	--	--	--

a. Decommissioned well (no data available during the identified time frame).

b. Wells screened through less than 25% of available aquifer based on 2016 water table and interpolated RUM surface.

c. Wells screened through less than 85% of available aquifer based on 2016 water table and interpolated RUM surface.

d. Top of well screen is deeper than inferred 2016 water table and screens <60% of available aquifer based on 2016 water table and interpolated RUM surface.

e. Well 199-K-193 has two screens separated by 9.1 m (30 ft) of blank casing. It is a fully penetrating well that can be used to monitor both the upper and lower unconfined aquifer.

f. Wells screened in the Ringold upper mud.

g. The well screen fully penetrates the entire unconfined aquifer.

h. KR4 pump and treat extraction well.

i. KW pump and treat extraction well.

j. KX pump and treat extraction well.

OU = operable unit

RUM = Ringold upper mud

Table D-2. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-KR-4 Groundwater OU

CAS Number	Analyte Name	Units	Surface Water					Action Level Value	
			CWA National Recommended Water Quality Criteria		WAC 173-201A	40 CFR 131		—	
			Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
120-82-1	1,2,4-Trichlorobenzene	µg/L	—	—	—	—	—	—	—
95-50-1	1,2-Dichlorobenzene	µg/L	—	—	—	—	—	—	—
541-73-1	1,3-Dichlorobenzene	µg/L	—	—	—	—	—	—	—
78-92-2	2-Butanol	µg/L	—	—	—	—	—	—	—
78-93-3	2-Butanone	µg/L	—	—	—	—	—	—	—
67-63-0	2-Propanol	µg/L	—	—	—	—	—	—	—
67-64-1	Acetone	µg/L	—	—	—	—	—	—	—
309-00-2	Aldrin	µg/L	3	—	3	—	2.5	0.0019	0.0019
7429-90-5	Aluminum	µg/L	750	87	—	—	—	—	87
7440-36-0	Antimony	µg/L	—	—	—	—	—	—	—
7440-38-2	Arsenic	µg/L	340	150	360	190	360	190	150
7440-39-3	Barium	µg/L	—	—	—	—	—	—	—
7440-41-7	Beryllium	µg/L	—	—	—	—	—	—	—
117-81-7	Bis(2-ethylhexyl) phthalate	µg/L	—	—	—	—	—	—	—
7440-69-9	Bismuth	µg/L	—	—	—	—	—	—	—
7440-42-8	Boron	µg/L	—	—	—	—	—	—	—
75-27-4	Bromodichloromethane	µg/L	—	—	—	—	—	—	—
74-83-9	Bromomethane	µg/L	—	—	—	—	—	—	—
7440-43-9	Cadmium	µg/L	1.8	0.72	3.1	0.91	3.1	0.91	0.72
7440-70-2	Calcium	µg/L	—	—	—	—	—	—	—
75-15-0	Carbon disulfide	µg/L	—	—	—	—	—	—	—
56-23-5	Carbon tetrachloride	µg/L	—	—	—	—	—	—	—
14762-75-5	Carbon-14	pCi/L	—	—	—	—	—	—	—
10045-97-3	Cesium-137	pCi/L	—	—	—	—	—	—	—
16887-00-6	Chloride	µg/L	860,000	230,000	--	--	860,000	230,000	230,000
108-90-7	Chlorobenzene	µg/L	—	—	—	—	—	—	—
67-66-3	Chloroform	µg/L	—	—	—	—	—	—	—
74-87-3	Chloromethane	µg/L	—	—	—	—	—	—	—
7440-47-3	Chromium	µg/L	570	74	480	156	480	156	74
7440-48-4	Cobalt	µg/L	—	—	—	—	—	—	—
10198-40-0	Cobalt-60	pCi/L	—	—	—	—	—	—	—
7440-50-8	Copper	µg/L	—	—	15	9.9	15	9.9	9.9

Table D-2. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-KR-4 Groundwater OU

CAS Number	Analyte Name	Units	Surface Water					Action Level Value	
			CWA National Recommended Water Quality Criteria		WAC 173-201A	40 CFR 131		—	
			Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
57-12-5	Cyanide	µg/L	22	5.2	22	5.2	22	5.2	5.2
84-66-2	Diethylphthalate	µg/L	—	—	—	—	—	—	—
100-41-4	Ethylbenzene	µg/L	—	—	—	—	—	—	—
16984-48-8	Fluoride	µg/L	—	—	—	—	—	—	—
12587-46-1	Gross alpha	pCi/L	—	—	—	—	—	—	—
12587-47-2	Gross beta	pCi/L	—	—	—	—	—	—	—
110-54-3	Hexane	µg/L	—	—	—	—	—	—	—
18540-29-9	Hexavalent Chromium	µg/L	16	11	15	10	15	10	10
7439-89-6	Iron	µg/L	—	1,000	—	—	—	—	1,000
7439-92-1	Lead	µg/L	65	2.5	54	2.1	54	2.1	2.1
7439-93-2	Lithium	µg/L	—	—	—	—	—	—	—
7439-95-4	Magnesium	µg/L	—	—	—	—	—	—	—
7439-96-5	Manganese	µg/L	—	—	—	—	—	—	—
7439-97-6	Mercury	µg/L	1.4	0.77	2.1	0.012	2.1	0.012	0.012
75-09-2	Methylene chloride	µg/L	—	—	—	—	—	—	—
7439-98-7	Molybdenum	µg/L	—	—	—	—	—	—	—
7440-02-0	Nickel	µg/L	470	52	1,234	137	1,234	137	52
13981-37-8	Nickel-63	pCi/L	—	—	—	—	—	—	—
14797-55-8	Nitrate	µg/L	—	—	—	—	—	—	—
14797-65-0	Nitrite	µg/L	—	—	—	—	—	—	—
95-47-6	o-Xylene	µg/L	—	—	—	—	—	—	—
7440-09-7	Potassium	µg/L	—	—	—	—	—	—	—
7782-49-2	Selenium	µg/L	—	—	—	—	—	—	—
15758-45-9	Selenium-79	pCi/L	—	—	—	—	—	—	—
7440-21-3	Silicon	µg/L	—	—	—	—	—	—	—
7440-22-4	Silver	µg/L	3.2	--	2.6	--	2.6	--	2.6
7440-23-5	Sodium	µg/L	—	—	—	—	—	—	—
7440-24-6	Strontium	µg/L	—	—	—	—	—	—	—
10098-97-2	Strontium-90	pCi/L	—	—	—	—	—	—	—
100-42-5	Styrene	µg/L	—	—	—	—	—	—	—
14808-79-8	Sulfate	µg/L	—	—	—	—	—	—	—
14133-76-7	Technetium-99	pCi/L	—	—	—	—	—	—	—

Table D-2. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-KR-4 Groundwater OU

CAS Number	Analyte Name	Units	Surface Water					Action Level Value	
			CWA National Recommended Water Quality Criteria		WAC 173-201A	40 CFR 131		—	
			Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
109-99-9	Tetrahydrofuran	µg/L	—	—	—	—	—	—	—
7440-28-0	Thallium	µg/L	—	—	—	—	—	—	—
7440-29-1	Thorium	µg/L	—	—	—	—	—	—	—
7440-31-5	Tin	µg/L	—	—	—	—	—	—	—
7440-32-6	Titanium	µg/L	—	—	—	—	—	—	—
108-88-3	Toluene	µg/L	—	—	—	—	—	—	—
TPHDIESEL	Total petroleum hydrocarbons - diesel range	µg/L	—	—	—	—	—	—	—
TPHGASOLINE	Total petroleum hydrocarbons - gasoline range	µg/L	—	—	—	—	—	—	—
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	µg/L	—	—	—	—	—	—	—
79-01-6	Trichloroethene	µg/L	—	—	—	—	—	—	—
10028-17-8	Tritium	pCi/L	—	—	—	—	—	—	—
7440-61-1	Uranium	µg/L	—	—	—	—	—	—	—
U-233/234	Uranium-233/234	pCi/L	—	—	—	—	—	—	—
15117-96-1	Uranium-235	pCi/L	—	—	—	—	—	—	—
U-238	Uranium-238	pCi/L	—	—	—	—	—	—	—
7440-62-2	Vanadium	µg/L	—	—	—	—	—	—	—
1330-20-7	Xylenes (total)	µg/L	—	—	—	—	—	—	—
7440-66-6	Zinc	µg/L	120	120	100	91	100	91	91

Note: 40 CFR 131, EPA, 2009, and WAC 173-201A only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

Ecology Publication 94-06, *Model Toxics Control Act Regulation and Statute*.

EPA, 2009, *National Recommended Water Quality Criteria*.

Federal Water Pollution Control Act.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CCC = criteria continuous concentration

CMC = criteria maximum concentration

Cr(VI) = hexavalent chromium

CWA = *Clean Water Act of 1977*

OU = operable unit

Table D-3. Summary of Federal and State DWSs Used as Human Health Action Levels for the 100-KR-4 Groundwater OU

			Groundwater					Human Health Action Level Value	
			40 CFR 141 [a,b]		WAC 246-290-310 [c]	WAC 173-340-720 [d,e]			
CAS Number	Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Action Level	Action Level Basis
120-82-1	1,2,4-Trichlorobenzene	µg/L	70	70	—	—	1.5	1.5	WAC 173-340-720(4)(b)(iii)(A) and (B)
95-50-1	1,2-Dichlorobenzene	µg/L	600	600	—	—	720	600	40 CFR 141 - federal MCL
541-73-1	1,3-Dichlorobenzene	µg/L	—	—	—	—	—	—	—
78-92-2	2-Butanol	µg/L	—	—	—	—	16,000	16,000	WAC 173-340-720(4)(b)(iii)(A) and (B)
78-93-3	2-Butanone	µg/L	—	—	—	—	4,800	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)
67-63-0	2-Propanol	µg/L	—	—	—	—	16,000	16,000	WAC 173-340-720(4)(b)(iii)(A) and (B)
67-64-1	Acetone	µg/L	—	—	—	—	7,200	7,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
309-00-2	Aldrin	µg/L	—	—	—	—	0.0026	0.0026	WAC 173-340-720(4)(b)(iii)(A) and (B)
7429-90-5	Aluminum	µg/L	—	—	—	—	16,000	16,000	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-36-0	Antimony	µg/L	6.0	6.0	6.0	—	6.4	6.0	40 CFR 141 - federal MCL
7440-38-2	Arsenic	µg/L	10	0	10	—	0.058	10 [g]	40 CFR 141 - federal MCL
7440-39-3	Barium	µg/L	2,000	2,000	2,000	—	3,200	2,000	40 CFR 141 - federal MCL
7440-41-7	Beryllium	µg/L	4.0	4.0	4.0	—	32	4.0	40 CFR 141 - federal MCL
117-81-7	Bis(2-ethylhexyl) phthalate	µg/L	6.0	0	—	—	6.3	6.0	40 CFR 141 - federal MCL
7440-42-8	Boron	µg/L	—	—	—	—	3,200	3,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-27-4	Bromodichloromethane	µg/L	80	0	—	—	0.71	0.71	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-83-9	Bromomethane	µg/L	—	—	—	—	11	11	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-43-9	Cadmium	µg/L	5.0	5.0	5.0	—	8.0	5.0	40 CFR 141 - federal MCL
75-15-0	Carbon disulfide	µg/L	—	—	—	—	800	800	WAC 173-340-720(4)(b)(iii)(A) and (B)
56-23-5	Carbon tetrachloride	µg/L	5.0	0	—	—	0.63	0.63	WAC 173-340-720(4)(b)(iii)(A) and (B)
14762-75-5	Carbon-14	pCi/L	2,000	—	—	—	—	2,000	40 CFR 141 - federal MCL
10045-97-3	Cesium-137	pCi/L	200	—	—	—	—	200	40 CFR 141 - federal MCL
108-90-7	Chlorobenzene	µg/L	100	100	—	—	160	100	40 CFR 141 - federal MCL
67-66-3	Chloroform	µg/L	80	70	—	—	1.4	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)
74-87-3	Chloromethane	µg/L	—	—	—	—	—	—	—
7440-47-3	Chromium	µg/L	100	100	100	—	24,000	100	40 CFR 141 - federal MCL
7440-48-4	Cobalt	µg/L	—	—	—	—	4.8	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)
10198-40-0	Cobalt-60	pCi/L	100	—	—	—	—	100	40 CFR 141 - federal MCL
7440-50-8	Copper	µg/L	1,300 [f]	1,300	1,300 [f]	—	640	640	WAC 173-340-720(4)(b)(iii)(A) and (B)
57-12-5	Cyanide	µg/L	200	200	200	—	4.8	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)
84-66-2	Diethylphthalate	µg/L	—	—	—	—	12,800	12,800	WAC 173-340-720(4)(b)(iii)(A) and (B)
100-41-4	Ethylbenzene	µg/L	700	700	—	—	4.0	4.0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-3. Summary of Federal and State DWSs Used as Human Health Action Levels for the 100-KR-4 Groundwater OU

			Groundwater					Human Health Action Level Value	
			40 CFR 141 [a,b]		WAC 246-290-310 [c]	WAC 173-340-720 [d,e]			
CAS Number	Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Action Level	Action Level Basis
16984-48-8	Fluoride	µg/L	4,000	4,000	4,000	—	960	960	WAC 173-340-720(4)(b)(iii)(A) and (B)
12587-46-1	Gross alpha	pCi/L	15	—	—	—	—	15	40 CFR 141 - federal MCL
12587-47-2	Gross beta	pCi/L	4 mrem/yr	—	—	—	—	4 mrem/yr	40 CFR 141 - federal MCL
110-54-3	Hexane	µg/L	—	—	—	—	—	—	—
18540-29-9	Hexavalent Chromium	µg/L	—	—	—	—	48	48	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-89-6	Iron	µg/L	—	—	—	—	11,200	11,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-92-1	Lead	µg/L	15 [f]	0	15 [f]	15	—	15	40 CFR 141 - federal MCL
7439-93-2	Lithium	µg/L	—	—	—	—	32	32	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-96-5	Manganese	µg/L	—	—	—	—	384	384	WAC 173-340-720(4)(b)(iii)(A) and (B)
7439-97-6	Mercury	µg/L	2.0	2.0	2.0	—	4.8	2.0	40 CFR 141 - federal MCL
75-09-2	Methylene chloride	µg/L	5.0	0	—	—	22	5.0	40 CFR 141 - federal MCL
7439-98-7	Molybdenum	µg/L	—	—	—	—	80	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-02-0	Nickel	µg/L	—	—	100	—	320	100	WAC 246-290-310
13981-37-8	Nickel-63	pCi/L	50	—	—	—	—	50	40 CFR 141 - federal MCL
14797-55-8	Nitrate	µg/L	45,000	45,000	45,000	—	113,600	45,000	40 CFR 141 - federal MCL
14797-65-0	Nitrite	µg/L	3,300	3,300	3,300	—	4,800	3,300	40 CFR 141 - federal MCL
95-47-6	o-Xylene	µg/L	—	—	—	—	1,600	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
7782-49-2	Selenium	µg/L	50	50	50	—	80	50	40 CFR 141 - federal MCL
15758-45-9	Selenium-79	pCi/L	—	—	—	—	—	—	—
7440-21-3	Silicon	µg/L	—	—	—	—	—	—	—
7440-22-4	Silver	µg/L	—	—	—	—	80	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-24-6	Strontium	µg/L	—	—	—	—	9,600	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
10098-97-2	Strontium-90	pCi/L	8.0	—	—	—	—	8.0	40 CFR 141 - federal MCL
100-42-5	Styrene	µg/L	100	100	—	—	1,600	100	40 CFR 141 - federal MCL
14133-76-7	Technetium-99	pCi/L	900	—	—	—	—	900	40 CFR 141 - federal MCL
109-99-9	Tetrahydrofuran	µg/L	—	—	—	—	7,200	7,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-28-0	Thallium	µg/L	2.0	0.50	2.0	—	0.16	0.50	40 CFR 141 - federal MCLG
7440-31-5	Tin	µg/L	—	—	—	—	9,600	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-32-6	Titanium	µg/L	—	—	—	—	—	—	—
108-88-3	Toluene	µg/L	1,000	1,000	—	—	640	640	WAC 173-340-720(4)(b)(iii)(A) and (B)
TPHDIESEL	Total petroleum hydrocarbons - diesel range	µg/L	—	—	—	500	—	500	WAC 173-340-900, Table 720-1

Table D-3. Summary of Federal and State DWSs Used as Human Health Action Levels for the 100-KR-4 Groundwater OU

			Groundwater					Human Health Action Level Value	
			40 CFR 141 [a,b]		WAC 246-290-310 [c]	WAC 173-340-720 [d,e]			
CAS Number	Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Action Level	Action Level Basis
TPHGASOLINE	Total petroleum hydrocarbons - gasoline range	µg/L	—	—	—	1,000	—	1,000	WAC 173-340-900, Table 720-1
TPH/OILH	Total petroleum hydrocarbons - motor oil (high boiling)	µg/L	—	—	—	500	—	500	WAC 173-340-900, Table 720-1
79-01-6	Trichloroethene	µg/L	5.0	0	—	—	0.54	0.54	WAC 173-340-720(4)(b)(iii)(A) and (B)
10028-17-8	Tritium	pCi/L	20,000	—	—	—	—	20,000	40 CFR 141 - federal MCL
7440-61-1	Uranium	µg/L	30	0	—	—	48	30	40 CFR 141 - federal MCL
U-233/234	Uranium-233/234	pCi/L	—	—	—	—	—	—	—
15117-96-1	Uranium-235	pCi/L	—	—	—	—	—	—	—
U-238	Uranium-238	pCi/L	—	—	—	—	—	—	—
7440-62-2	Vanadium	µg/L	—	—	—	—	80	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
1330-20-7	Xylenes (total)	µg/L	10,000	10,000	—	—	1,600	1,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-66-6	Zinc	µg/L	—	—	—	—	4,800	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)

a. 40 CFR 141.61, “National Primary Drinking Water Regulations,” “Maximum Contaminant Levels for Organic Contaminants."

b. 40 CFR 141.62, “National Primary Drinking Water Regulations,” “Maximum Contaminant Levels for Inorganic Contaminants."

c. WAC 246-290-310, “Group A Public Water Supplies,” “Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

d. Standard Method B groundwater cleanup levels calculated per requirements in WAC 173-340-720, “Model Toxics Control Act—Cleanup,” "Ground Water Cleanup Standards," as documented in ECF-100NPL-10-0462, *Calculation of Standard Method B Groundwater Cleanup Levels for Potable Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

e. WAC 173-340-720(3)(b), Table 720-1, "Method A Cleanup Levels for Groundwater."

f. Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of the tap water exceed the action level, water systems must take additional steps. For copper the action level is 1,300 µg/L, and for lead is 15 µg/L.

g. The federal MCL was selected as the groundwater action level for arsenic because the Method B groundwater cleanup level is less than the Hanford Site 90th percentile background value of 7.85 µg/L.

CAS = Chemical Abstracts Service

Cr(VI) = hexavalent chromium

DWS = drinking water standard

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-4. Groundwater Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Carbon-14	No	pCi/L	10/22/2009	3/17/2017	308	273	88.64	7.8	56	8.35	40,100	--	--	--	2,000	66	40 CFR 141 - federal MCL
Cobalt-60	No	pCi/L	10/22/2009	12/2/2016	177	1	0.56	1.74	26	12	12	0.023	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Gross alpha	No	pCi/L	10/22/2009	2/26/2017	264	116	43.94	1.2	5.3	1.4	18	--	--	--	15	1	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/22/2009	2/26/2017	264	259	98.11	3.04	7.8	2.91	426	0.0081	259	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Nickel-63	No	pCi/L	4/1/2010	12/2/2010	7	2	28.57	3.31	4.43	4.24	4.42	--	--	--	50	0	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	10/22/2009	3/17/2017	276	146	52.9	0.458	2.6	0.879	251	0.015	146	Scott W. Petersen, Jan. 27,1998 Memo	8.0	109	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/22/2009	2/26/2017	230	72	31.3	2.87	42.2	6.2	220	0.83	72	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/22/2009	3/17/2017	383	339	88.51	160	428	129	379,000	119	339	DOE/RL-96-61 Rev.0, Table ES-1	20,000	55	40 CFR 141 - federal MCL
Volatile Organic Compounds																	
1-Butanol	No	ug/L	11/22/2016	11/28/2016	2	2	100	--	--	21	27	--	--	--	16000	0	WAC
2-Butanone	No	ug/L	10/22/2009	2/28/2017	161	6	3.73	0.47	3	0.55	1	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	5/27/2015	2/26/2017	14	11	78.57	250	250	6.5	370	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	10/22/2009	2/28/2017	161	22	13.66	0.34	5	0.5	8.6	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	No	ug/L	10/22/2009	1/7/2011	25	2	8	0.082	1	0.13	0.16	--	--	--	0.71	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	1/7/2011	25	9	36	0.084	2	0.11	1.6	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon disulfide	No	ug/L	10/22/2009	2/28/2017	161	1	0.62	0.05	1.6	0.54	0.54	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chlorobenzene	No	ug/L	10/22/2009	2/28/2017	159	1	0.63	0.11	1	0.17	0.17	--	--	--	100	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	2/28/2017	161	97	60.25	0.1	1	0.11	2.3	--	--	--	1.4	8	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	10/22/2009	2/28/2017	161	8	4.97	0.11	1.6	0.31	14	--	--	--	5.0	2	40 CFR 141 - federal MCL

Table D-4. Groundwater Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Styrene	No	ug/L	10/22/2009	1/7/2011	25	2	8	0.036	1	0.12	0.21	--	--	--	100	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	10/22/2009	2/28/2017	161	2	1.24	0.062	1	0.11	0.12	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	2/28/2017	161	109	67.7	0.16	1	0.22	7.4	--	--	--	0.54	103	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	10/22/2009	2/28/2017	161	1	0.62	0.11	1	0.24	0.24	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Semivolatile Organic Compounds																	
Tetrahydrofuran	No	ug/L	10/22/2009	11/30/2016	127	1	0.79	0.5	2	1.2	1.2	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons - diesel range	No	ug/L	11/10/2009	12/2/2016	56	3	5.36	0.4	200	78	139	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - gasoline range	No	ug/L	11/10/2009	12/2/2016	48	6	12.5	10	200	8.61	36	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - motor oil (high boiling)	No	ug/L	11/6/2015	2/9/2016	5	3	60	48.1	48.1	64.6	203	--	--	--	500	0	WAC 173-340-900,Table 720-1
Metals																	
Aluminum	No	ug/L	10/22/2009	12/2/2016	141	84	59.57	10	20	8.87	1,950	7.1	84	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	12/2/2016	150	12	8	0.084	15	0.12	0.81	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	12/2/2016	149	123	82.55	0.4	10	0.672	5.63	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	2/26/2017	371	371	100	--	--	12.9	71.6	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	12/2/2016	150	4	2.67	0.05	1	0.226	0.71	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/5/2010	12/2/2016	99	82	82.83	6.4	41	7.2	79.3	36.0	7	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-4. Groundwater Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	No	ug/L	10/22/2009	12/2/2016	150	4	2.67	0.05	1	0.108	0.6	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/22/2009	2/26/2017	366	358	97.81	13	14	0.828	764	2.4	357	DOE/RL-96-61 Rev.0, Table ES-1	100	52	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	12/2/2016	150	66	44	0.05	2.7	0.066	5.58	0.92	9	DOE/RL-96-61 Rev.0, Table ES-1	4.8	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	12/2/2016	150	96	64	0.2	10	0.248	31.8	0.81	55	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/22/2009	3/17/2017	438	402	91.78	1.5	9.68	1.5	571	--	--	--	48.0	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	2/26/2017	340	253	74.41	12.8	50	16.9	1,980	570	19	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	12/2/2016	140	39	27.86	0.05	10	0.066	16.3	0.92	18	DOE/RL-96-61 Rev.0, Table ES-1	15.0	1	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/5/2010	1/7/2011	18	17	94.44	4	4	4.1	29	11.3	8	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	2/26/2017	348	146	41.95	0.2	6	0.4	93	38.5	9	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	10/22/2009	11/30/2016	62	4	6.45	0.06	0.2	0.068	0.194	0.0030	4	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	3/5/2010	12/2/2016	133	124	93.23	0.1	4	0.559	9	3.2	47	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	2/26/2017	348	153	43.97	0.2	66.5	0.72	300	1.6	140	DOE/RL-96-61 Rev.0, Table ES-1	100	8	WAC 246-290-310
Selenium	No	ug/L	10/22/2009	12/2/2016	140	56	40	0.6	10	0.642	4.92	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/22/2009	2/26/2017	371	11	2.96	0.039	7	0.04	12.5	5.3	4	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/22/2009	2/21/2017	313	313	100	--	--	171	456	323	55	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	10/22/2009	12/2/2016	140	5	3.57	0.014	5	0.497	2.2	1.7	1	DOE/RL-96-61 Rev.0, Table ES-1	0.50	4	40 CFR 141 - federal MCLG

Table D-4. Groundwater Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tin	No	ug/L	3/5/2010	12/2/2016	133	16	12.03	0.05	39	0.0619	5.7	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	10/22/2009	12/2/2016	117	117	100	--	--	0.124	10.5	9.9	1	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	2/26/2017	344	224	65.12	1	17	0.63	23	11.5	37	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	2/26/2017	348	152	43.68	1.6	20	3.31	1270	21.8	62	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Cyanide	No	ug/L	6/18/2010	3/17/2017	11	1	9.09	1.67	4	4.2	4.2	8.4	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	3/17/2017	409	353	86.31	46	130	46.7	400	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/22/2009	3/17/2017	409	409	100	--	--	797	100,900	26,871	260	DOE/RL-96-61 Rev.0, Table ES-1	45,000	77	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	3/17/2017	409	85	20.78	9.85	131	30.2	640	93.7	84	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-18																	
Aluminum	No	ug/L	10/22/2009	6/11/2010	3	2	66.67	10	10	12	36	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/22/2009	10/7/2014	5	5	100	--	--	1.9	2.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	1/30/2017	27	27	100	--	--	29	41	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	10/7/2014	5	1	20	0.10	0.28	0.23	0.23	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4	0	40 CFR 141 - federal MCL
Bromomethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	1.0	2.0	1.0	1.0	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2009	10/13/2016	10	8	80	18	50	11	35	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	2.0	2.1	--	--	--	1.4	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	10/13/2016	26	26	100	--	--	2.5	203	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	100	4	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	10/7/2014	5	1	20	0.10	2.7	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	1/30/2017	26	18	69.23	46	88	51	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/11/2010	10/13/2016	8	2	25	1.8	3.2	2.6	5.4	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/11/2010	10/13/2016	8	8	100	--	--	2.9	22	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	1/30/2017	28	28	100	--	--	1.5	201	--	--	--	48.0	8	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	1/30/2017	27	27	100	--	--	43	485	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	3/5/2010	6/11/2010	2	2	100	--	--	5.7	25	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	1/30/2017	27	23	85.19	4.0	6.0	4.0	27	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Molybdenum	No	ug/L	3/5/2010	6/11/2010	2	2	100	--	--	0.85	7.0	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	1/30/2017	27	7	25.93	1.6	13	2.1	5.9	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nickel-63	No	pCi/L	4/1/2010	4/1/2010	1	1	100	--	--	4.2	4.2	--	--	--	50	0	
Nitrate	No	ug/L	10/22/2009	1/30/2017	26	26	100	--	--	15,100	76,600	26,871	8	DOE/RL-96-61 Rev.0, Table ES-1	45,000	4	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	1/30/2017	26	5	19.23	9.9	131	126	189	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	1.1	1.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/22/2009	1/30/2017	27	27	100	--	--	239	368	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	No	ug/L	10/22/2009	1/30/2017	26	26	100	--	--	55,600	100,000	47,014	26	DOE/RL-96-61 Rev.0, Table ES-1	250,000	0	
Technetium-99	No	pCi/L	10/22/2009	10/13/2016	8	1	12.5	6.5	10.0	55	55	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tin	No	ug/L	3/5/2010	6/11/2010	2	1	50	0.10	0.10	0.18	0.18	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	10/13/2016	16	16	100	--	--	3,050	290,000	119	16	DOE/RL-96-61 Rev.0, Table ES-1	20,000	11	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	0.65	0.79	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	1/30/2017	27	21	77.78	10	17	5.9	13	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	1/30/2017	27	27	100	--	--	28	65	22	27	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-19																	
Arsenic	No	ug/L	12/3/2010	11/9/2016	13	8	61.54	1.2	10	0.67	1.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	12/3/2010	11/9/2016	13	13	100	--	--	24	32	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Boron	No	ug/L	10/27/2011	11/9/2016	8	7	87.5	6.4	6.4	7.5	12	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	12/3/2010	11/9/2016	13	1	7.69	0.099	1.0	0.13	0.13	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	12/3/2010	11/9/2016	7	4	57.14	17	56	8.8	26	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	12/3/2010	11/9/2016	13	13	100	--	--	4.5	15	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	12/3/2010	11/9/2016	13	4	30.77	0.10	2.0	0.12	0.29	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	12/3/2010	11/9/2016	13	3	23.08	0.20	10	0.36	3.4	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	12/3/2010	11/9/2016	11	8	72.73	46	100	54	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	12/3/2010	11/9/2016	7	1	14.29	1.7	4.9	9.7	9.7	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	12/3/2010	11/9/2016	7	7	100	--	--	19	37	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	7/22/2010	11/9/2016	13	12	92.31	8.0	8.0	1.8	11	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/3/2010	11/9/2016	6	6	100	--	--	92	590	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	12/3/2010	11/9/2016	13	12	92.31	10	10	0.86	1.9	0.92	11	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/3/2010	11/9/2016	8	8	100	--	--	4.0	16	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	12/3/2010	11/9/2016	13	12	92.31	0.10	0.10	1.1	2.1	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/3/2010	11/9/2016	8	3	37.5	0.20	4.2	0.72	14	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	12/3/2010	11/9/2016	11	11	100	--	--	19,500	29,500	26,871	3	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	12/3/2010	11/9/2016	11	1	9.09	20	131	148	148	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Selenium	No	ug/L	12/3/2010	11/9/2016	13	6	46.15	1.5	10	1.1	4.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/3/2010	11/9/2016	13	1	7.69	0.039	5.0	0.12	0.12	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/3/2010	11/9/2016	8	8	100	--	--	258	294	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	12/3/2010	11/9/2016	7	7	100	--	--	12	15	0.015	7	Scott W. Petersen, Jan. 27,1998 Memo	8.0	7	40 CFR 141 - federal MCL
Sulfate	No	ug/L	12/3/2010	11/9/2016	11	11	100	--	--	57,900	70,600	47,014	11	DOE/RL-96-61 Rev.0, Table ES-1	250,000	0	
Tin	No	ug/L	12/3/2010	11/9/2016	13	3	23.08	0.10	5.0	0.13	2.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	12/3/2010	11/9/2016	7	7	100	--	--	1,500	4,800	119	7	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/22/2013	11/9/2016	7	7	100	--	--	1.8	2.1	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/3/2010	11/9/2016	7	5	71.43	4.4	4.4	1.9	5.0	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	12/3/2010	11/9/2016	8	8	100	--	--	216	432	22	8	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-22																	
Aluminum	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	10	10	14	14	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	10/22/2009	11/9/2016	10	10	100	--	--	16	46	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Bromomethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.084	1.0	0.97	0.97	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/22/2009	11/17/2014	4	1	25	0.20	0.20	0.60	0.60	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/22/2009	11/9/2016	10	3	30	8.0	48	10	24	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	6/11/2010	3	2	66.67	1.0	1.0	0.76	0.79	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	No	ug/L	10/22/2009	11/1/2015	9	9	100	--	--	26	125	2.4	9	DOE/RL-96-61 Rev.0, Table ES-1	100	3	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	11/17/2014	4	2	50	0.10	2.7	0.10	0.12	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	11/17/2014	4	1	25	0.20	2.1	0.56	0.56	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	11/9/2016	14	9	64.29	46	72	77	150	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/22/2009	11/9/2016	8	1	12.5	1.5	5.0	2.6	2.6	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/22/2009	11/9/2016	8	8	100	--	--	11	30	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	11/9/2016	16	16	100	--	--	12	128	--	--	--	48.0	10	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	11/9/2016	10	8	80	20	25	42	160	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	3/10/2010	6/11/2010	2	2	100	--	--	5.2	21	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	11/9/2016	10	4	40	4.0	4.0	2.3	79	39	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/10/2010	6/11/2010	2	2	100	--	--	2.4	2.8	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	11/9/2016	10	2	20	1.6	10	3.2	4.7	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	11/9/2016	14	14	100	--	--	10,300	66,400	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	1	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	11/9/2016	14	2	14.29	9.9	131	142	156	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	1.9	2.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/22/2009	11/9/2016	10	10	100	--	--	191	337	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium-90	No	pCi/L	10/22/2009	11/9/2016	10	9	90	1.7	1.7	4.0	15	0.015	9	Scott W. Petersen, Jan. 27,1998 Memo	8.0	5	40 CFR 141 - federal MCL
Sulfate	No	ug/L	10/22/2009	11/9/2016	14	14	100	--	--	36,500	74,500	47,014	11	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	10/22/2009	11/9/2016	8	1	12.5	6.5	39	220	220	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/22/2009	11/9/2016	10	5	50	170	340	160	2,770	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	2.0	2.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	11/9/2016	10	2	20	4.4	12	2.3	18	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	11/9/2016	10	10	100	--	--	260	919	22	10	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-23																	
Aluminum	No	ug/L	10/10/2011	12/2/2016	6	4	66.67	10	20	13	185	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/10/2011	12/2/2016	6	6	100	--	--	1.0	3.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/10/2011	12/2/2016	9	9	100	--	--	13	51	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/10/2011	12/2/2016	6	1	16.67	0.10	0.20	0.71	0.71	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/10/2011	12/2/2016	3	3	100	--	--	15	79	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/10/2011	12/2/2016	10	10	100	--	--	36	101	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/10/2011	12/2/2016	9	9	100	--	--	3.1	110	2.4	9	DOE/RL-96-61 Rev.0, Table ES-1	100	1	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/10/2011	12/2/2016	6	6	100	--	--	0.14	0.80	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/10/2011	12/2/2016	6	6	100	--	--	0.89	3.0	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross alpha	No	pCi/L	10/10/2011	12/2/2016	9	7	77.78	3.9	4.9	3.6	8.7	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/10/2011	12/2/2016	9	8	88.89	7.8	7.8	9.2	23	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/10/2011	12/2/2016	10	7	70	1.5	1.5	2.2	115	--	--	--	48.0	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/10/2011	12/2/2016	9	8	88.89	30	30	371	1,620	570	5	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/10/2011	12/2/2016	6	2	33.33	0.10	0.50	0.067	0.54	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	10/10/2011	12/2/2016	9	9	100	--	--	4.8	93	39	3	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/10/2011	12/2/2016	6	6	100	--	--	0.56	2.1	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/10/2011	12/2/2016	9	7	77.78	1.5	13	0.89	37	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/10/2011	12/2/2016	7	7	100	--	--	797	70,800	26,871	5	DOE/RL-96-61 Rev.0, Table ES-1	45,000	4	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/10/2011	12/2/2016	7	2	28.57	125	131	321	443	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/10/2011	12/2/2016	6	2	33.33	1.6	2.0	1.6	2.0	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/10/2011	12/2/2016	9	1	11.11	0.050	1.0	0.047	0.047	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/10/2011	12/2/2016	9	9	100	--	--	212	456	323	7	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/10/2011	12/2/2016	9	2	22.22	0.73	2.0	0.88	1.7	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Sulfate	No	ug/L	10/10/2011	12/2/2016	7	7	100	--	--	26,000	38,100	47,014	0	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Thallium	No	ug/L	10/10/2011	12/2/2016	6	1	16.67	0.050	0.60	2.2	2.2	1.7	1	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/10/2011	12/2/2016	6	2	33.33	0.10	1.0	0.062	0.13	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Total petroleum hydrocarbons - diesel range	No	ug/L	10/10/2011	12/2/2016	6	2	33.33	48	70	91	139	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - motor oil (high boiling)	No	ug/L	2/9/2016	2/9/2016	1	1	100	--	--	203	203	--	--	--	500	0	WAC 173-340-900,Table 720-1
Tritium	No	pCi/L	10/10/2011	12/2/2016	5	1	20	270	395	129	129	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	1/16/2014	12/2/2016	2	2	100	--	--	1.8	6.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/10/2011	12/2/2016	9	9	100	--	--	1.4	11	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/10/2011	12/2/2016	9	2	22.22	3.3	7.0	3.6	3.8	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-29																	
Barium	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	24	24	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	**No**	pCi/L	12/2/2010	12/2/2010	1	1	100	--	--	3,120	3,120	--	--	--	2,000	1	40 CFR 141 - federal MCL
Fluoride	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	152	152	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	**No**	pCi/L	12/2/2010	12/2/2010	1	1	100	--	--	5.9	5.9	0.0081	1	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Iron	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	731	731	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	35	35	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	46,500	46,500	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	1	40 CFR 141 - federal MCL
Strontium	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	227	227	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	19,100	19,100	47,014	0	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Technetium-99	**No**	pCi/L	12/2/2010	12/2/2010	1	1	100	--	--	6.8	6.8	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	**No**	pCi/L	12/2/2010	12/2/2010	1	1	100	--	--	130,000	130,000	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	1	40 CFR 141 - federal MCL
Zinc	**No**	ug/L	12/2/2010	12/2/2010	1	1	100	--	--	6.0	6.0	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-30																	
Barium	**No**	ug/L	4/6/2010	12/2/2010	2	2	100	--	--	23	26	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	**No**	pCi/L	4/15/2010	12/2/2010	2	2	100	--	--	3,510	4,110	--	--	--	2,000	2	40 CFR 141 - federal MCL
Cobalt-60	**No**	pCi/L	4/15/2010	12/2/2010	2	1	50	9.5	9.5	12	12	0.023	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	Federal MCL
Fluoride	**No**	ug/L	1/14/2010	12/2/2010	4	4	100	--	--	79	211	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	**No**	pCi/L	1/14/2010	12/2/2010	4	1	25	2.2	2.3	3.5	3.5	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	**No**	pCi/L	1/14/2010	12/2/2010	4	3	75	3.4	3.4	6.4	94	0.0081	3	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	**No**	ug/L	4/15/2010	12/2/2010	2	1	50	2.0	2.0	7.5	7.5	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	**No**	ug/L	4/6/2010	12/2/2010	2	1	50	38	38	31	31	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel-63	**No**	pCi/L	4/15/2010	12/2/2010	2	1	50	3.9	3.9	4.4	4.4	--	--	--	50	0	
Nitrate	**No**	ug/L	1/14/2010	12/2/2010	4	4	100	--	--	25,100	60,600	26,871	3	DOE/RL-96-61 Rev.0, Table ES-1	45,000	1	40 CFR 141 - federal MCL
Nitrite	**No**	ug/L	1/14/2010	12/2/2010	4	1	25	118	118	588	588	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	**No**	ug/L	4/6/2010	12/2/2010	2	2	100	--	--	245	270	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	**No**	ug/L	1/14/2010	12/2/2010	4	4	100	--	--	18,600	28,400	47,014	0	DOE/RL-96-61 Rev.0, Table ES-1	250,000	0	
Tritium	**No**	pCi/L	1/14/2010	12/2/2010	4	4	100	--	--	16,000	280,000	119	4	DOE/RL-96-61 Rev.0, Table ES-1	20,000	3	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-32A																	
Aluminum	**No**	ug/L	10/22/2009	11/11/2016	20	16	80	10	10	13	1,950	7.1	16	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	**No**	ug/L	10/22/2009	11/11/2016	20	13	65	0.80	1.7	0.86	3.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	**No**	ug/L	10/22/2009	11/11/2016	28	28	100	--	--	22	48	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	**No**	ug/L	3/10/2010	11/11/2016	14	13	92.86	15	15	11	27	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	**No**	ug/L	10/22/2009	6/11/2010	3	2	66.67	1.0	1.0	0.13	0.16	--	--	--	0.71	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	**No**	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.084	1.0	0.97	0.97	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	**No**	pCi/L	10/22/2009	11/11/2016	28	28	100	--	--	115	359	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	**No**	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	2.1	2.3	--	--	--	1.4	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	**No**	ug/L	10/22/2009	11/11/2016	28	27	96.43	13	13	12	24	2.4	27	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	**No**	ug/L	10/22/2009	11/11/2016	20	9	45	0.10	0.22	0.10	0.90	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	**No**	ug/L	10/22/2009	11/11/2016	20	10	50	0.20	0.52	0.29	2.9	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	**No**	ug/L	10/22/2009	2/21/2017	28	9	32.14	46	130	54	103	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	**No**	pCi/L	12/22/2009	2/21/2017	30	12	40	1.2	3.6	1.4	4.9	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	**No**	pCi/L	12/22/2009	2/21/2017	30	30	100	--	--	6.2	26	0.0081	30	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	**No**	ug/L	10/22/2009	11/11/2016	23	23	100	--	--	8.2	17	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	**No**	ug/L	10/22/2009	11/11/2016	26	25	96.15	20	20	19	1,980	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	**No**	ug/L	10/22/2009	11/11/2016	20	1	5	0.10	0.50	1.5	1.5	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Lithium	**No**	ug/L	3/10/2010	6/11/2010	2	2	100	--	--	4.1	16	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	**No**	ug/L	10/22/2009	11/11/2016	26	8	30.77	1.0	6.0	1.1	38	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	**No**	ug/L	3/10/2010	11/11/2016	19	18	94.74	1.0	1.0	0.71	9.0	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	**No**	ug/L	10/22/2009	11/11/2016	26	15	57.69	4.0	13	2.2	8.8	1.6	15	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	**No**	ug/L	10/22/2009	2/21/2017	28	28	100	--	--	12,400	53,100	26,871	13	DOE/RL-96-61 Rev.0, Table ES-1	45,000	1	40 CFR 141 - federal MCL
Nitrite	**No**	ug/L	10/22/2009	2/21/2017	28	7	25	62	131	142	526	94	7	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	**No**	ug/L	10/22/2009	11/11/2016	20	2	10	0.60	2.0	0.70	1.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	**No**	ug/L	10/22/2009	11/11/2016	28	1	3.57	0.040	7.0	13	13	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	**No**	ug/L	10/22/2009	11/11/2016	26	26	100	--	--	220	322	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	**No**	pCi/L	10/22/2009	11/11/2016	25	16	64	1.1	2.0	1.6	7.4	0.015	16	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	**No**	pCi/L	10/22/2009	11/11/2016	27	9	33.33	5.8	40	13	22	0.83	9	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	**No**	pCi/L	10/22/2009	2/21/2017	32	32	100	--	--	1,800	13,200	119	32	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	**No**	ug/L	10/22/2009	11/11/2016	14	14	100	--	--	2.2	3.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	**No**	ug/L	10/22/2009	11/11/2016	26	10	38.46	1.0	17	0.73	4.0	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	**No**	ug/L	10/22/2009	11/11/2016	26	7	26.92	3.3	7.0	3.5	27	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-34																	
2-Propanol	**No**	ug/L	2/26/2017	2/26/2017	1	1	100	--	--	130	130	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	**No**	ug/L	10/22/2009	2/26/2017	10	2	20	0.34	5.0	2.9	8.6	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	**No**	ug/L	10/22/2009	11/18/2016	8	4	50	10	17	16	118	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	**No**	ug/L	10/22/2009	11/18/2016	7	1	14.29	0.60	1.0	0.55	0.55	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	**No**	ug/L	10/22/2009	11/18/2016	7	6	85.71	1.7	1.7	0.95	2.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	**No**	ug/L	10/22/2009	2/26/2017	22	22	100	--	--	23	39	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	**No**	ug/L	3/5/2010	11/18/2016	7	6	85.71	19	19	15	46	36	2	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	**No**	pCi/L	10/22/2009	3/17/2017	24	24	100	--	--	654	8,210	--	--	--	2,000	6	40 CFR 141 - federal MCL
Chloroform	**No**	ug/L	10/22/2009	2/26/2017	10	5	50	0.30	1.0	0.14	0.51	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	**No**	ug/L	10/22/2009	2/26/2017	23	23	100	--	--	8.6	49	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	**No**	ug/L	10/22/2009	11/18/2016	7	6	85.71	0.10	0.10	0.26	5.6	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	**No**	ug/L	10/22/2009	11/18/2016	7	5	71.43	0.20	0.89	0.47	1.3	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	**No**	ug/L	10/22/2009	3/17/2017	40	39	97.5	60	60	149	290	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	**No**	pCi/L	12/22/2009	2/26/2017	31	17	54.84	2.1	4.7	2.1	8.9	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	**No**	pCi/L	12/22/2009	2/26/2017	31	31	100	--	--	38	180	0.0081	31	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	**No**	ug/L	10/22/2009	3/17/2017	30	30	100	--	--	2.0	47	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	**No**	ug/L	10/22/2009	2/26/2017	22	19	86.36	18	30	18	318	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	**No**	ug/L	3/5/2010	6/30/2010	2	2	100	--	--	5.5	20	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	**No**	ug/L	10/22/2009	2/26/2017	22	10	45.45	3.3	6.0	2.6	50	39	2	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	**No**	ug/L	3/5/2010	11/18/2016	7	6	85.71	4.0	4.0	1.6	2.7	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	**No**	ug/L	10/22/2009	2/26/2017	22	17	77.27	4.0	4.0	12	300	1.6	17	DOE/RL-96-61 Rev.0, Table ES-1	100	3	WAC 246-290-310
Nitrate	**No**	ug/L	10/22/2009	3/17/2017	40	40	100	--	--	27,900	66,800	26,871	40	DOE/RL-96-61 Rev.0, Table ES-1	45,000	14	40 CFR 141 - federal MCL
Nitrite	**No**	ug/L	10/22/2009	3/17/2017	40	7	17.5	9.9	131	179	289	94	7	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	**No**	ug/L	10/22/2009	11/18/2016	7	4	57.14	0.70	1.5	0.97	2.2	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	**No**	ug/L	10/22/2009	2/26/2017	22	1	4.55	0.10	7.0	0.042	0.042	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	**No**	ug/L	10/22/2009	11/18/2016	18	18	100	--	--	234	409	323	7	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	**No**	pCi/L	10/22/2009	3/17/2017	24	24	100	--	--	16	56	0.015	24	Scott W. Petersen, Jan. 27,1998 Memo	8.0	24	40 CFR 141 - federal MCL
Sulfate	**No**	ug/L	10/22/2009	3/17/2017	40	40	100	--	--	17,300	85,000	47,014	17	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	**No**	pCi/L	10/22/2009	11/18/2016	10	3	30	5.9	10	9.9	64	0.83	3	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - motor oil (high boiling)	**No**	ug/L	11/6/2015	11/6/2015	1	1	100	--	--	71	71	--	--	--	500	0	WAC 173-340-900,Table 720-1
Trichloroethene	**No**	ug/L	10/22/2009	2/26/2017	10	6	60	0.50	1.0	0.39	4.0	--	--	--	0.54	5	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tritium	**No**	pCi/L	10/22/2009	2/26/2017	34	34	100	--	--	669	4,800	119	34	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	**No**	ug/L	10/22/2009	11/18/2016	12	12	100	--	--	3.7	7.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	**No**	ug/L	10/22/2009	2/26/2017	22	9	40.91	4.1	17	2.8	14	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	**No**	ug/L	10/22/2009	2/26/2017	22	1	4.55	2.0	7.0	6.5	6.5	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-36																	
Aluminum	**No**	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	13	43	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	**No**	ug/L	10/22/2009	11/21/2014	4	4	100	--	--	1.9	5.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	**No**	ug/L	10/22/2009	11/30/2016	15	15	100	--	--	40	72	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	**No**	ug/L	10/22/2009	11/21/2014	4	1	25	0.10	0.10	0.60	0.60	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	**No**	ug/L	3/8/2010	6/11/2010	2	1	50	19	19	51	51	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	**No**	ug/L	10/22/2009	6/11/2010	3	2	66.67	1.0	1.0	0.12	1.0	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	**No**	pCi/L	3/8/2010	11/30/2016	14	14	100	--	--	56	158	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	**No**	ug/L	10/22/2009	6/11/2010	3	2	66.67	1.0	1.0	0.67	0.70	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	**No**	ug/L	10/22/2009	8/31/2016	14	14	100	--	--	26	454	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	10	40 CFR 141 - federal MCL
Cobalt	**No**	ug/L	10/22/2009	11/21/2014	4	3	75	2.7	2.7	0.62	1.4	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	**No**	ug/L	10/22/2009	11/21/2014	4	3	75	2.1	2.1	1.6	2.5	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	**No**	ug/L	6/11/2010	11/30/2016	12	12	100	--	--	235	400	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	**No**	ug/L	10/22/2009	11/30/2016	16	16	100	--	--	9.3	403	--	--	--	48.0	9	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	**No**	ug/L	3/8/2010	11/30/2016	14	14	100	--	--	32	838	570	3	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	**No**	ug/L	3/8/2010	6/11/2010	2	2	100	--	--	6.0	20	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	**No**	ug/L	3/8/2010	11/30/2016	14	7	50	0.70	4.0	1.6	11	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	**No**	ug/L	3/8/2010	11/30/2016	14	2	14.29	0.060	0.10	0.068	0.072	0.0030	2	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Molybdenum	**No**	ug/L	3/8/2010	6/11/2010	2	2	100	--	--	4.3	4.6	3.2	2	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	**No**	ug/L	3/8/2010	11/30/2016	14	14	100	--	--	5.3	115	1.6	14	DOE/RL-96-61 Rev.0, Table ES-1	100	3	WAC 246-290-310
Nitrate	**No**	ug/L	6/11/2010	11/30/2016	12	12	100	--	--	19,000	33,300	26,871	4	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	**No**	ug/L	6/11/2010	11/30/2016	12	3	25	9.9	131	230	326	94	3	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	**No**	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	0.89	1.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	**No**	ug/L	3/8/2010	11/30/2016	14	14	100	--	--	230	416	323	6	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	**No**	ug/L	6/11/2010	11/30/2016	12	12	100	--	--	52,000	137,000	47,014	12	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	**No**	pCi/L	12/3/2010	11/30/2016	12	7	58.33	6.4	9.8	6.2	36	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Trichloroethene	**No**	ug/L	10/22/2009	6/11/2010	3	2	66.67	1.0	1.0	0.54	0.60	--	--	--	0.54	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	**No**	pCi/L	3/8/2010	11/30/2016	14	10	71.43	160	310	320	701	119	10	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	**No**	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	4.8	5.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Vanadium	**No**	ug/L	3/8/2010	11/30/2016	14	11	78.57	10	17	7.3	19	12	6	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-106A																	
2-Propanol	No	ug/L	11/18/2016	2/26/2017	2	2	100	--	--	64	370	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	10/22/2009	2/26/2017	19	3	15.79	0.34	5.0	0.50	3.7	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/22/2009	11/18/2016	16	10	62.5	10	15	8.9	93	7.1	10	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/22/2009	11/18/2016	16	16	100	--	--	2.6	4.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	2/26/2017	21	21	100	--	--	32	52	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/8/2010	11/18/2016	10	10	100	--	--	22	40	36	3	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	6/13/2010	3	2	66.67	1.0	1.0	0.11	1.6	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2009	3/17/2017	29	29	100	--	--	3,970	40,100	--	--	--	2,000	29	40 CFR 141 - federal MCL
Chlorobenzene	No	ug/L	10/22/2009	2/26/2017	19	1	5.26	0.15	1.0	0.17	0.17	--	--	--	100	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	2/26/2017	19	14	73.68	0.30	1.0	0.13	1.5	--	--	--	1.4	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	2/26/2017	21	20	95.24	13	13	3.9	15	2.4	20	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	11/18/2016	16	8	50	0.050	0.22	0.066	0.21	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	11/18/2016	16	14	87.5	0.20	0.97	0.25	1.4	0.81	7	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	3/17/2017	40	40	100	--	--	139	300	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	12/17/2009	2/26/2017	29	20	68.97	2.5	5.3	3.0	9.3	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	12/17/2009	2/26/2017	29	29	100	--	--	5.6	16	0.0081	29	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	10/22/2009	3/17/2017	30	20	66.67	1.5	9.7	1.7	4.4	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	2/26/2017	13	11	84.62	18	30	27	168	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	3/8/2010	6/13/2010	2	2	100	--	--	29	29	11	2	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	2/26/2017	15	5	33.33	1.0	4.0	1.6	5.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/8/2010	11/18/2016	15	15	100	--	--	2.5	8.0	3.2	5	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	2/26/2017	15	11	73.33	4.0	4.0	1.7	6.5	1.6	11	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	3/17/2017	40	40	100	--	--	34,100	100,931	26,871	40	DOE/RL-96-61 Rev.0, Table ES-1	45,000	30	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	3/17/2017	40	8	20	9.9	131	256	640	94	8	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	11/18/2016	16	5	31.25	1.0	2.0	0.64	1.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/22/2009	11/18/2016	11	11	100	--	--	265	418	323	6	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	2/26/2017	22	1	4.55	0.54	2.1	6.3	6.3	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Styrene	No	ug/L	10/22/2009	6/13/2010	3	1	33.33	0.036	1.0	0.21	0.21	--	--	--	100	0	40 CFR 141 - federal MCL
Sulfate	No	ug/L	10/22/2009	3/17/2017	40	40	100	--	--	10,000	46,300	47,014	0	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Thallium	No	ug/L	10/22/2009	11/18/2016	16	1	6.25	0.050	0.60	0.50	0.50	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	0	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/8/2010	11/18/2016	15	2	13.33	0.050	1.0	0.096	1.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	10/22/2009	2/26/2017	19	1	5.26	0.062	1.0	0.12	0.12	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Total petroleum hydrocarbons - gasoline range	No	ug/L	10/10/2011	11/18/2016	6	1	16.67	17	50	18	18	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	10/22/2009	2/26/2017	19	19	100	--	--	0.78	7.4	--	--	--	0.54	19	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	3/17/2017	41	41	100	--	--	402	91,900	119	41	DOE/RL-96-61 Rev.0, Table ES-1	20,000	13	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	11/18/2016	10	10	100	--	--	6.1	11	9.9	1	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	2/26/2017	14	12	85.71	12	12	8.3	19	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	10/22/2009	2/26/2017	19	1	5.26	0.11	1.0	0.24	0.24	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	2/26/2017	15	2	13.33	2.0	8.3	5.1	6.6	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-107A																	
2-Butanone	No	ug/L	4/8/2010	2/26/2017	16	2	12.5	0.47	3.0	0.55	0.77	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	2/26/2017	2/26/2017	1	1	100	--	--	140	140	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	4/8/2010	2/26/2017	16	4	25	0.34	5.0	0.57	7.3	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	11/21/2014	11/18/2016	5	2	40	13	17	46	110	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	11/21/2014	11/18/2016	5	2	40	1.7	1.7	0.27	0.58	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	11/21/2014	11/18/2016	5	5	100	--	--	1.7	3.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/8/2010	2/26/2017	17	17	100	--	--	37	62	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	11/21/2014	11/18/2016	5	1	20	0.27	0.35	0.31	0.31	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Boron	No	ug/L	11/21/2014	11/18/2016	5	4	80	11	11	13	17	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/6/2011	2/26/2017	13	13	100	--	--	347	816	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	4/8/2010	2/26/2017	16	9	56.25	1.0	1.0	0.23	0.58	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	4/8/2010	2/26/2017	17	17	100	--	--	8.2	32	2.4	17	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	11/21/2014	11/18/2016	5	2	40	0.22	0.22	0.15	0.22	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	11/21/2014	11/18/2016	5	1	20	0.45	1.1	1.2	1.2	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	1/14/2010	2/26/2017	29	29	100	--	--	93	229	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	1/14/2010	2/26/2017	28	8	28.57	1.7	5.3	1.8	4.3	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	1/14/2010	2/26/2017	28	28	100	--	--	8.7	89	0.0081	28	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	11/9/2009	3/17/2017	30	30	100	--	--	5.6	27	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/8/2010	2/26/2017	17	15	88.24	16	30	24	570	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/21/2014	11/18/2016	5	1	20	0.16	0.17	0.39	0.39	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	4/8/2010	2/26/2017	17	5	29.41	0.70	4.0	0.88	11	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	4/8/2010	2/26/2017	16	1	6.25	0.27	1.6	0.31	0.31	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	11/21/2014	11/18/2016	5	5	100	--	--	1.5	1.9	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/8/2010	2/26/2017	17	6	35.29	1.6	13	1.2	15	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	1/14/2010	2/26/2017	29	29	100	--	--	21,900	64,200	26,871	10	DOE/RL-96-61 Rev.0, Table ES-1	45,000	1	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	1/14/2010	2/26/2017	29	6	20.69	9.9	131	177	266	94	6	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/21/2014	11/18/2016	5	1	20	0.66	1.6	2.1	2.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	4/8/2010	2/26/2017	17	2	11.76	0.82	6.0	0.040	0.070	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	4/8/2010	11/18/2016	13	13	100	--	--	229	381	323	2	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/6/2011	3/17/2017	24	24	100	--	--	9.2	32	0.015	24	Scott W. Petersen, Jan. 27,1998 Memo	8.0	24	40 CFR 141 - federal MCL
Sulfate	No	ug/L	1/14/2010	2/26/2017	29	29	100	--	--	37,200	116,000	47,014	21	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	10/6/2011	11/18/2016	11	10	90.91	10	10	16	52	0.83	10	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tin	No	ug/L	11/21/2014	11/18/2016	5	1	20	1.1	1.3	5.2	5.2	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	4/8/2010	2/26/2017	16	1	6.25	0.070	1.0	0.11	0.11	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total petroleum hydrocarbons - gasoline range	No	ug/L	10/6/2011	11/5/2015	5	1	20	10	50	36	36	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	4/8/2010	2/26/2017	16	15	93.75	0.50	0.50	2.3	5.0	--	--	--	0.54	15	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/14/2010	3/17/2017	39	39	100	--	--	617	1,700	119	39	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/3/2010	11/18/2016	9	9	100	--	--	1.7	3.8	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/8/2010	2/26/2017	17	13	76.47	5.0	15	6.6	9.4	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/8/2010	2/26/2017	17	4	23.53	3.0	9.3	6.2	20	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-108A																	
Acetone	No	ug/L	10/22/2009	2/24/2017	9	1	11.11	0.34	5.0	0.59	0.59	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/22/2009	11/18/2016	27	13	48.15	10	20	13	74	7.1	13	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	11/18/2016	27	1	3.7	0.60	1.7	0.28	0.28	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	11/18/2016	27	26	96.3	1.7	1.7	1.7	3.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	2/24/2017	36	36	100	--	--	30	49	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/8/2010	11/18/2016	16	15	93.75	19	19	18	29	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	6/13/2010	3	2	66.67	1.0	1.0	0.12	1.1	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2009	2/24/2017	23	23	100	--	--	265	1,180	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	2/24/2017	9	4	44.44	0.30	1.0	0.18	0.66	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	2/24/2017	37	34	91.89	14	14	5.4	92	2.4	34	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	11/18/2016	27	15	55.56	0.10	0.22	0.10	0.86	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	11/18/2016	27	20	74.07	0.20	0.54	0.27	4.4	0.81	8	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	2/24/2017	31	31	100	--	--	180	340	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/22/2009	11/18/2016	15	8	53.33	2.5	5.2	2.8	11	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/22/2009	11/18/2016	15	15	100	--	--	6.5	22	0.0081	15	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	2/24/2017	39	26	66.67	2.0	9.7	2.1	7.9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	No	ug/L	10/22/2009	2/24/2017	29	27	93.1	19	28	22	289	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	11/18/2016	27	5	18.52	0.10	0.50	0.11	0.27	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/8/2010	6/13/2010	2	2	100	--	--	8.1	24	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	2/24/2017	31	17	54.84	2.0	6.0	1.1	23	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	10/22/2009	11/18/2016	13	1	7.69	0.060	0.10	0.077	0.077	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	3/8/2010	11/18/2016	26	26	100	--	--	2.8	4.8	3.2	24	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	2/24/2017	31	24	77.42	4.0	13	2.3	136	1.6	24	DOE/RL-96-61 Rev.0, Table ES-1	100	1	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	2/24/2017	31	31	100	--	--	29,700	73,500	26,871	31	DOE/RL-96-61 Rev.0, Table ES-1	45,000	10	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	2/24/2017	31	8	25.81	9.9	131	208	317	94	8	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	11/18/2016	27	7	25.93	1.5	2.0	1.2	4.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/22/2009	11/18/2016	28	28	100	--	--	246	376	323	4	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	2/24/2017	22	1	4.55	0.46	2.6	0.93	0.93	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Styrene	No	ug/L	10/22/2009	6/13/2010	3	1	33.33	0.036	1.0	0.12	0.12	--	--	--	100	0	40 CFR 141 - federal MCL
Sulfate	No	ug/L	10/22/2009	2/24/2017	31	31	100	--	--	18,000	91,000	47,014	9	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	10/22/2009	11/18/2016	13	1	7.69	5.5	37	24	24	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tetrahydrofuran	No	ug/L	10/22/2009	5/21/2014	6	1	16.67	1.1	2.0	1.2	1.2	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Thallium	No	ug/L	10/22/2009	11/18/2016	27	2	7.41	0.060	0.60	0.57	0.80	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	2	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/8/2010	11/18/2016	26	4	15.38	0.10	1.1	0.19	3.1	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	2/24/2017	9	9	100	--	--	1.3	4.2	--	--	--	0.54	9	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	2/24/2017	23	16	69.57	250	365	170	1,150	119	16	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	11/18/2016	17	17	100	--	--	4.2	9.3	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	2/24/2017	30	20	66.67	4.4	17	4.8	23	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	2/24/2017	31	28	90.32	3.3	5.0	4.1	17	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-110A																	
Aluminum	No	ug/L	12/8/2010	11/13/2016	7	5	71.43	10	10	21	86	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	12/8/2010	11/13/2016	8	2	25	0.60	3.7	0.16	0.20	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	12/8/2010	11/13/2016	8	7	87.5	1.8	1.8	1.2	2.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/15/2010	11/13/2016	14	14	100	--	--	25	34	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/23/2014	11/13/2016	5	4	80	6.4	6.4	7.4	15	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	4/15/2010	11/13/2016	14	14	100	--	--	26	169	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	3	40 CFR 141 - federal MCL
Cobalt	No	ug/L	12/8/2010	11/13/2016	8	8	100	--	--	0.84	5.5	0.92	7	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	12/8/2010	11/13/2016	8	8	100	--	--	1.5	5.7	0.81	8	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/15/2010	11/13/2016	14	10	71.43	46	72	69	132	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross alpha	No	pCi/L	4/15/2010	11/13/2016	14	1	7.14	1.7	3.6	3.4	3.4	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	4/15/2010	11/13/2016	14	12	85.71	3.0	3.4	5.0	10	0.0081	12	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	12/8/2010	11/13/2016	13	12	92.31	2.0	2.0	1.5	13	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/15/2010	11/13/2016	13	13	100	--	--	230	1,370	570	7	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	12/8/2010	11/13/2016	7	2	28.57	0.17	0.20	0.22	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	4/15/2010	11/13/2016	13	13	100	--	--	4.4	27	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	12/8/2010	11/13/2016	7	7	100	--	--	1.0	4.6	3.2	2	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/15/2010	11/13/2016	13	13	100	--	--	10	108	1.6	13	DOE/RL-96-61 Rev.0, Table ES-1	100	1	WAC 246-290-310
Nitrate	No	ug/L	4/15/2010	11/13/2016	14	14	100	--	--	9,870	24,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/15/2010	11/13/2016	14	2	14.29	9.9	131	250	411	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	12/8/2010	11/13/2016	7	3	42.86	0.60	1.6	1.0	1.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	4/15/2010	11/13/2016	13	13	100	--	--	216	310	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	No	ug/L	4/15/2010	11/13/2016	14	14	100	--	--	13,900	63,000	47,014	7	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Tin	No	ug/L	12/8/2010	11/13/2016	7	1	14.29	0.10	1.3	1.6	1.6	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total petroleum hydrocarbons - diesel range	No	ug/L	12/8/2010	11/13/2016	7	1	14.29	16	70	78	78	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - gasoline range	No	ug/L	12/8/2010	11/13/2016	7	1	14.29	10	50	35	35	--	--	--	1,000	0	WAC 173-340-900,Table 720-1

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tritium	No	pCi/L	4/15/2010	11/13/2016	14	3	21.43	200	334	299	350	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/23/2014	11/13/2016	5	5	100	--	--	1.4	2.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/15/2010	11/13/2016	13	8	61.54	4.1	12	4.8	7.7	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/15/2010	11/13/2016	13	1	7.69	1.6	9.3	9.1	9.1	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-111A																	
Acetone	No	ug/L	10/6/2011	11/11/2016	6	1	16.67	0.34	5.0	1.4	1.4	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	11/23/2014	11/11/2016	9	8	88.89	14	14	47	94	7.1	8	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	11/23/2014	11/11/2016	9	2	22.22	0.084	2.0	0.45	0.81	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	11/23/2014	11/11/2016	9	9	100	--	--	3.1	4.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	12/22/2009	2/21/2017	30	30	100	--	--	32	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/23/2014	11/11/2016	9	9	100	--	--	11	25	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	12/22/2009	11/11/2016	15	15	100	--	--	108	297	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/6/2011	11/11/2016	6	3	50	1.0	1.0	0.50	0.52	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	12/22/2009	11/11/2016	29	29	100	--	--	33	622	2.4	29	DOE/RL-96-61 Rev.0, Table ES-1	100	22	40 CFR 141 - federal MCL
Cobalt	No	ug/L	11/23/2014	11/11/2016	9	1	11.11	0.070	0.90	0.19	0.19	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	11/23/2014	11/11/2016	9	4	44.44	0.68	2.0	0.41	1.4	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	12/22/2009	2/21/2017	27	27	100	--	--	135	280	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross alpha	No	pCi/L	12/22/2009	2/21/2017	31	20	64.52	1.9	4.1	1.7	18	--	--	--	15.0	1	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	12/22/2009	2/21/2017	31	30	96.77	3.7	3.7	6.6	23	0.0081	30	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	12/22/2009	11/11/2016	26	26	100	--	--	30	571	--	--	--	48.0	23	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/22/2009	2/21/2017	30	27	90	28	40	28	180	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/23/2014	11/11/2016	9	2	22.22	0.16	1.0	0.19	0.22	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/22/2009	2/21/2017	30	9	30	0.30	6.0	1.6	6.6	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/23/2014	11/11/2016	9	9	100	--	--	3.6	4.4	3.2	9	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/22/2009	2/21/2017	30	10	33.33	1.5	13	1.0	13	1.6	8	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	12/22/2009	2/21/2017	27	27	100	--	--	27,000	44,700	26,871	27	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	12/22/2009	2/21/2017	27	8	29.63	62	131	167	288	94	8	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/23/2014	11/11/2016	9	5	55.56	0.66	2.0	1.9	4.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/22/2009	2/21/2017	30	1	3.33	0.039	7.0	0.050	0.050	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/22/2009	2/21/2017	30	30	100	--	--	260	327	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	12/22/2009	11/11/2016	15	3	20	0.49	2.0	1.3	2.1	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Sulfate	No	ug/L	12/22/2009	2/21/2017	27	27	100	--	--	35,500	46,600	47,014	0	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	12/22/2009	11/11/2016	16	4	25	5.9	11	16	45	0.83	4	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	11/23/2014	11/11/2016	9	1	11.11	0.014	0.90	1.0	1.0	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tin	No	ug/L	11/23/2014	11/11/2016	9	1	11.11	0.68	1.3	5.7	5.7	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	12/22/2009	2/21/2017	34	34	100	--	--	15,000	379,000	119	34	DOE/RL-96-61 Rev.0, Table ES-1	20,000	27	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/23/2014	11/11/2016	9	9	100	--	--	3.7	5.1	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/22/2009	2/21/2017	30	24	80	4.4	17	8.5	19	12	15	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	12/22/2009	2/21/2017	30	5	16.67	3.3	9.3	4.0	13	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-132																	
1-Butanol	No	ug/L	11/22/2016	11/22/2016	1	1	100	--	--	21	21	--	--	--	16000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Butanone	No	ug/L	6/15/2010	2/28/2017	22	1	4.55	0.47	2.0	0.82	0.82	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	8/31/2016	2/1/2017	3	3	100	--	--	11	80	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	6/15/2010	2/28/2017	22	3	13.64	0.34	5.0	0.95	4.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	8/27/2015	11/22/2016	4	2	50	17	20	18	21	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	8/27/2015	11/22/2016	4	1	25	1.7	2.0	0.34	0.34	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	8/27/2015	11/22/2016	4	3	75	4.0	4.0	1.7	2.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/1/2017	17	17	100	--	--	21	46	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	8/27/2015	11/22/2016	4	3	75	25	25	10	15	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	6/15/2010	3/13/2017	30	30	100	--	--	1,570	10,900	--	--	--	2,000	27	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/15/2010	2/28/2017	22	15	68.18	1.0	1.0	0.30	0.47	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	No	ug/L	6/15/2010	2/1/2017	18	18	100	--	--	11	26	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	8/27/2015	11/22/2016	4	4	100	--	--	0.52	15	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cyanide	No	ug/L	12/7/2016	2/28/2017	4	1	25	3.1	3.1	4.2	4.2	8.4	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/15/2010	2/28/2017	29	27	93.1	60	88	83	180	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/15/2010	11/22/2016	12	4	33.33	2.3	4.4	2.2	3.4	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/15/2010	11/22/2016	12	12	100	--	--	8.0	32	0.0081	12	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	2/3/2010	3/13/2017	33	33	100	--	--	8.0	24	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/1/2017	17	3	17.65	13	30	18	80	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	8/27/2015	11/22/2016	4	3	75	1.0	1.0	0.21	0.78	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	6/15/2010	2/1/2017	17	2	11.76	0.70	6.0	0.52	5.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/15/2010	2/28/2017	22	1	4.55	0.27	1.0	14	14	--	--	--	5.0	1	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	8/27/2015	11/22/2016	4	3	75	2.0	2.0	1.1	1.9	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/15/2010	2/1/2017	17	3	17.65	0.80	67	0.85	8.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/15/2010	2/28/2017	29	29	100	--	--	29,700	75,300	26,871	29	DOE/RL-96-61 Rev.0, Table ES-1	45,000	10	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/28/2017	29	5	17.24	9.9	131	184	286	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	8/27/2015	11/22/2016	4	1	25	1.6	2.0	1.3	1.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/15/2010	11/22/2016	12	12	100	--	--	240	419	323	2	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium-90	No	pCi/L	11/22/2010	2/1/2017	11	1	9.09	0.66	2.0	2.2	2.2	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Sulfate	No	ug/L	6/15/2010	2/28/2017	29	29	100	--	--	33,600	89,000	47,014	18	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	6/15/2010	11/22/2016	12	11	91.67	9.4	9.4	13	35	0.83	11	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	6/15/2010	2/28/2017	22	21	95.45	1.0	1.0	1.5	6.4	--	--	--	0.54	21	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	6/15/2010	2/1/2017	23	23	100	--	--	1,250	12,900	119	23	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	8/27/2015	11/22/2016	4	4	100	--	--	1.4	4.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/15/2010	2/1/2017	17	6	35.29	4.1	17	2.4	8.5	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/15/2010	2/1/2017	17	11	64.71	3.0	7.5	4.3	52	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-137																	
Arsenic	No	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	2.5	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/24/2017	24	24	100	--	--	39	56	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	6/15/2010	2/24/2017	20	20	100	--	--	492	1,390	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/2/2016	2/24/2017	3	2	66.67	0.30	0.30	0.31	0.53	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/15/2010	2/24/2017	22	22	100	--	--	15	133	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	100	1	40 CFR 141 - federal MCL
Copper	No	ug/L	10/31/2011	5/22/2014	2	2	100	--	--	2.2	5.1	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/15/2010	2/24/2017	21	20	95.24	60	60	110	280	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/15/2010	11/18/2016	12	7	58.33	2.2	3.5	1.9	4.6	--	--	--	15.0	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross beta	No	pCi/L	6/15/2010	11/18/2016	12	12	100	--	--	13	38	0.0081	12	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/15/2010	3/17/2017	30	30	100	--	--	13	145	--	--	--	48.0	4	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/24/2017	24	3	12.5	13	50	23	162	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/15/2010	2/24/2017	24	5	20.83	1.0	6.0	1.1	15	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	6/22/2011	11/18/2016	9	1	11.11	0.060	0.10	0.19	0.19	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Nickel	No	ug/L	6/15/2010	2/24/2017	24	2	8.33	1.5	13	1.4	9.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/15/2010	2/24/2017	21	21	100	--	--	22,100	30,800	26,871	8	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/24/2017	21	6	28.57	9.9	131	169	318	94	6	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/15/2010	2/24/2017	24	1	4.17	0.99	7.0	7.0	7.0	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/15/2010	11/18/2016	17	17	100	--	--	245	349	323	3	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	No	ug/L	6/15/2010	2/24/2017	21	21	100	--	--	40,500	110,000	47,014	14	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	6/15/2010	11/18/2016	14	14	100	--	--	15	53	0.83	14	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - gasoline range	No	ug/L	6/15/2010	11/18/2016	8	2	25	17	50	8.6	20	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - motor oil (high boiling)	No	ug/L	11/30/2015	11/30/2015	1	1	100	--	--	65	65	--	--	--	500	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	6/2/2016	2/24/2017	3	3	100	--	--	3.6	4.4	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/4/2011	2/24/2017	18	18	100	--	--	838	2,000	119	18	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Vanadium	No	ug/L	6/15/2010	2/24/2017	24	23	95.83	10	10	7.3	19	12	6	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/15/2010	2/24/2017	24	15	62.5	3.3	20	5.5	314	22	4	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-139																	
Acetone	No	ug/L	6/15/2010	2/13/2017	17	3	17.65	0.34	5.0	0.80	4.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	11/10/2009	2/13/2017	19	19	100	--	--	26	55	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/10/2009	2/13/2017	11	11	100	--	--	347	2,370	--	--	--	2,000	1	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/15/2010	2/13/2017	17	10	58.82	1.0	1.0	0.35	0.45	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	11/10/2009	2/13/2017	19	19	100	--	--	8.4	125	2.4	19	DOE/RL-96-61 Rev.0, Table ES-1	100	1	40 CFR 141 - federal MCL
Copper	No	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	2.6	2.6	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	11/10/2009	2/13/2017	17	16	94.12	60	60	124	282	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/15/2010	11/28/2016	8	3	37.5	2.0	4.8	2.5	3.5	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/15/2010	11/28/2016	8	8	100	--	--	14	68	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	11/10/2009	2/13/2017	23	23	100	--	--	5.3	117	--	--	--	48.0	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	11/10/2009	2/13/2017	19	3	15.79	18	38	22	31	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	11/10/2009	2/13/2017	19	4	21.05	1.0	6.0	0.44	3.9	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	11/10/2009	2/13/2017	19	4	21.05	1.3	67	2.2	7.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	11/10/2009	2/13/2017	17	17	100	--	--	23,900	35,000	26,871	12	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	11/10/2009	2/13/2017	17	1	5.88	9.9	131	180	180	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	11/10/2009	2/13/2017	19	1	5.26	0.93	7.0	10	10	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	11/10/2009	11/28/2016	15	15	100	--	--	211	313	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/10/2009	2/13/2017	12	12	100	--	--	4.7	22	0.015	12	Scott W. Petersen, Jan. 27,1998 Memo	8.0	6	40 CFR 141 - federal MCL
Sulfate	No	ug/L	11/10/2009	2/13/2017	17	17	100	--	--	36,800	97,000	47,014	12	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	11/10/2009	11/28/2016	8	7	87.5	10	10	13	57	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - gasoline range	No	ug/L	11/10/2009	11/28/2016	8	1	12.5	10	200	23	23	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	6/15/2010	2/13/2017	17	17	100	--	--	3.5	6.3	--	--	--	0.54	17	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/10/2009	2/13/2017	12	12	100	--	--	804	4,000	119	12	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	11/10/2009	2/13/2017	19	14	73.68	5.0	17	4.2	11	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	11/10/2009	2/13/2017	19	12	63.16	3.3	6.0	6.6	41	22	3	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-140																	
1-Butanol	No	ug/L	11/28/2016	11/28/2016	1	1	100	--	--	27	27	--	--	--	16000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Butanone	No	ug/L	5/4/2011	2/13/2017	14	1	7.14	0.47	3.0	0.86	0.86	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	5/27/2015	2/13/2017	4	4	100	--	--	6.5	110	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	5/4/2011	2/13/2017	14	2	14.29	0.34	5.0	0.58	5.2	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Aluminum	No	ug/L	5/4/2011	11/28/2016	11	3	27.27	10	20	21	45	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	5/4/2011	11/28/2016	11	1	9.09	0.60	2.0	0.12	0.12	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	5/4/2011	11/28/2016	11	9	81.82	1.7	4.0	1.0	4.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	5/4/2011	2/13/2017	15	15	100	--	--	37	59	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/21/2013	11/28/2016	7	6	85.71	25	25	7.2	15	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	5/4/2011	11/28/2016	11	1	9.09	0.099	0.20	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	5/4/2011	2/13/2017	14	14	100	--	--	24	766	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	5/4/2011	2/13/2017	14	9	64.29	1.0	1.0	0.25	0.51	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	5/4/2011	2/13/2017	15	15	100	--	--	8.2	764	2.4	15	DOE/RL-96-61 Rev.0, Table ES-1	100	1	40 CFR 141 - federal MCL
Copper	No	ug/L	5/4/2011	11/28/2016	11	9	81.82	0.20	0.20	0.39	32	0.81	7	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	5/4/2011	2/13/2017	13	13	100	--	--	67	310	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	5/4/2011	11/28/2016	6	2	33.33	1.6	4.2	1.8	4.0	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	5/4/2011	11/28/2016	6	6	100	--	--	6.5	37	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	2/3/2010	2/13/2017	24	24	100	--	--	2.0	25	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	5/4/2011	2/13/2017	10	8	80	13	30	17	159	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	5/4/2011	11/28/2016	11	5	45.45	0.10	1.0	0.33	1.2	0.92	2	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	5/4/2011	2/13/2017	12	5	41.67	0.20	4.0	0.40	4.2	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Methylene chloride	No	ug/L	5/4/2011	2/13/2017	14	3	21.43	0.27	1.6	1.5	3.7	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	5/4/2011	11/28/2016	11	6	54.55	0.10	2.0	0.70	2.1	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	5/4/2011	2/13/2017	12	6	50	0.20	10	0.78	1.7	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	5/4/2011	2/13/2017	13	13	100	--	--	23,000	27,000	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	5/4/2011	2/13/2017	13	2	15.38	62	131	132	252	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	5/4/2011	11/28/2016	11	6	54.55	1.5	2.0	0.75	2.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	5/4/2011	11/28/2016	8	8	100	--	--	221	364	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	5/4/2011	2/13/2017	14	1	7.14	0.56	1.8	1.9	1.9	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Sulfate	No	ug/L	5/4/2011	2/13/2017	13	13	100	--	--	36,700	115,000	47,014	12	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Trichloroethene	No	ug/L	5/4/2011	2/13/2017	14	13	92.86	1.0	1.0	3.0	5.9	--	--	--	0.54	13	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	6/27/2016	2/13/2017	4	4	100	--	--	1,290	1,760	119	4	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/21/2013	11/28/2016	7	7	100	--	--	1.2	2.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	5/4/2011	2/13/2017	11	8	72.73	15	15	8.0	12	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	5/4/2011	2/13/2017	12	7	58.33	4.6	7.5	7.5	134	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-200																	
Barium	No	ug/L	4/26/2011	11/30/2016	22	22	100	--	--	39	54	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	4/26/2011	11/30/2016	22	14	63.64	7.9	54	9.5	51	--	--	--	2,000	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chloroform	No	ug/L	4/26/2011	11/30/2016	8	2	25	0.30	1.0	0.77	1.2	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	4/26/2011	8/2/2016	21	21	100	--	--	2.5	32	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	4/26/2011	11/30/2016	19	12	63.16	46	72	54	120	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/8/2012	6/2/2014	3	1	33.33	2.6	4.8	3.3	3.3	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/8/2012	6/2/2014	3	3	100	--	--	410	426	0.0081	3	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/26/2011	11/30/2016	22	22	100	--	--	1.5	29	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/26/2011	11/30/2016	22	19	86.36	30	40	22	211	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	4/26/2011	11/30/2016	22	3	13.64	2.0	4.0	1.7	3.7	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	4/26/2011	11/30/2016	8	2	25	1.0	1.6	2.2	6.3	--	--	--	5.0	1	40 CFR 141 - federal MCL
Nickel	No	ug/L	4/26/2011	11/30/2016	22	2	9.09	1.3	13	2.1	4.1	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	4/26/2011	11/30/2016	19	19	100	--	--	19,500	37,600	26,871	12	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/26/2011	11/30/2016	19	3	15.79	125	131	169	214	94	3	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	4/26/2011	11/30/2016	22	2	9.09	0.93	6.0	2.3	7.9	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	4/26/2011	11/30/2016	22	22	100	--	--	263	345	323	4	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/26/2011	11/30/2016	22	22	100	--	--	137	251	0.015	22	Scott W. Petersen, Jan. 27,1998 Memo	8.0	22	40 CFR 141 - federal MCL
Sulfate	No	ug/L	4/26/2011	11/30/2016	19	19	100	--	--	65,000	78,700	47,014	19	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Tritium	No	pCi/L	4/26/2011	11/30/2016	22	22	100	--	--	1,200	5,500	119	22	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Uranium	No	ug/L	4/17/2012	2/19/2014	3	3	100	--	--	1.8	2.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/26/2011	11/30/2016	22	10	45.45	4.1	10	1.3	2.1	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/26/2011	11/30/2016	22	3	13.64	3.3	7.0	3.3	11	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-201																	
2-Butanone	No	ug/L	4/28/2011	11/13/2016	20	2	10	0.52	2.0	0.67	1.0	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	4/28/2011	11/13/2016	20	3	15	0.34	5.0	0.52	4.4	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	5/9/2014	8/21/2014	2	1	50	1.8	1.8	2.1	2.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/28/2011	11/13/2016	23	23	100	--	--	28	36	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon disulfide	No	ug/L	4/28/2011	11/13/2016	20	1	5	0.050	1.0	0.54	0.54	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	4/28/2011	11/13/2016	22	10	45.45	7.8	54	8.4	23	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	4/28/2011	11/13/2016	20	11	55	1.0	1.0	0.36	0.91	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	4/28/2011	8/3/2016	22	22	100	--	--	39	130	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	100	6	40 CFR 141 - federal MCL
Copper	No	ug/L	5/9/2014	8/21/2014	2	1	50	2.1	2.1	3.1	3.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/28/2011	11/13/2016	20	15	75	46	72	47	150	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/10/2011	11/13/2016	6	1	16.67	1.5	3.1	2.1	2.1	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/10/2011	11/13/2016	6	6	100	--	--	14	40	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/28/2011	11/13/2016	23	23	100	--	--	30	131	--	--	--	48.0	21	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	No	ug/L	4/28/2011	11/13/2016	23	10	43.48	13	30	24	161	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	4/28/2011	11/13/2016	23	2	8.7	0.70	4.0	2.4	4.3	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	4/28/2011	11/13/2016	20	1	5	0.27	1.0	0.34	0.34	--	--	--	5.0	0	40 CFR 141 - federal MCL
Nickel	No	ug/L	4/28/2011	11/13/2016	23	6	26.09	1.5	13	2.6	8.0	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	4/28/2011	11/13/2016	20	20	100	--	--	18,100	44,100	26,871	12	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/28/2011	11/13/2016	20	6	30	9.9	131	138	203	94	6	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	4/28/2011	11/13/2016	23	23	100	--	--	279	378	323	10	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/28/2011	11/13/2016	22	22	100	--	--	5.2	18	0.015	22	Scott W. Petersen, Jan. 27,1998 Memo	8.0	21	40 CFR 141 - federal MCL
Sulfate	No	ug/L	4/28/2011	11/13/2016	20	20	100	--	--	48,000	79,500	47,014	20	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	4/28/2011	11/13/2016	22	1	4.55	5.9	38	7.4	7.4	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	4/28/2011	11/13/2016	22	15	68.18	310	355	270	2,910	119	15	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	4/17/2012	2/20/2014	3	3	100	--	--	2.5	3.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/28/2011	11/13/2016	23	16	69.57	4.4	15	3.7	7.3	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/28/2011	11/13/2016	23	2	8.7	3.0	8.3	8.5	8.8	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
699-73-61																	
Aluminum	No	ug/L	10/28/2009	1/6/2014	6	1	16.67	10	20	235	235	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/28/2009	1/6/2014	6	4	66.67	0.40	0.80	1.3	2.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Barium	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	25	37	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/5/2010	1/6/2014	5	1	20	19	41	8.0	8.0	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/28/2009	1/6/2014	6	1	16.67	0.20	0.20	0.11	0.11	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/28/2009	1/7/2011	5	3	60	0.10	1.0	0.11	0.15	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	0.83	7.3	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/28/2009	1/6/2014	6	1	16.67	0.10	0.10	0.10	0.10	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/28/2009	1/6/2014	6	4	66.67	0.20	0.20	0.38	3.2	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/28/2009	11/10/2011	6	6	100	--	--	61	240	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	9/19/2010	1/7/2011	2	2	100	--	--	5.2	9.4	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Iron	No	ug/L	10/28/2009	1/6/2014	6	5	83.33	38	38	76	1,280	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	0.36	16	0.92	4	DOE/RL-96-61 Rev.0, Table ES-1	15.0	1	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/5/2010	1/7/2011	4	3	75	4.0	4.0	4.9	10	11	0	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	12	70	39	3	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/5/2010	1/6/2014	5	5	100	--	--	1.8	4.5	3.2	3	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/28/2009	1/6/2014	6	1	16.67	4.0	4.0	0.82	0.82	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/28/2009	11/10/2011	6	6	100	--	--	7,970	9,830	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-5. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	10/28/2009	11/10/2011	6	2	33.33	118	118	30	147	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/28/2009	1/6/2014	6	5	83.33	2.0	2.0	0.66	1.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	171	233	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Sulfate	No	ug/L	10/28/2009	11/10/2011	6	6	100	--	--	30,900	34,900	47,014	0	DOE/RL-96-61 Rev.0, Table ES-1	250000	0	
Technetium-99	No	pCi/L	9/19/2010	11/10/2011	3	2	66.67	7.5	7.5	7.7	13	0.83	2	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tin	No	ug/L	3/5/2010	1/6/2014	5	1	20	0.10	0.10	0.10	0.10	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/28/2009	4/21/2016	8	2	25	170	428	230	260	119	2	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	0.12	1.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/28/2009	1/6/2014	6	3	50	12	17	0.63	20	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	291	1,270	22	6	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-6. Groundwater Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	Yes	ug/L	10/22/2009	12/2/2016	141	26	18.44	5	20	6.94	209	7.1	25	DOE/RL-96-61 Rev.0, Table ES-1	87	3	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	12/2/2016	150	129	86	0.4	4	0.56	4.88	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	12/2/2016	151	4	2.65	0.099	1	0.117	3.7	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	0.72	1	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	2/26/2017	369	346	93.77	0.2	14	0.682	541	2.4	338	DOE/RL-96-61 Rev.0, Table ES-1	74	64	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	12/2/2016	151	66	43.71	0.1	10	0.158	19.9	0.81	28	DOE/RL-96-61 Rev.0, Table ES-1	9.9	2	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	3/17/2017	438	402	91.78	1.5	9.68	1.5	571	--	--	--	10	237	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	2/26/2017	344	87	25.29	12.8	40	12.8	785	570	1	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	12/2/2016	140	27	19.29	0.1	10	0.17	2.8	0.92	7	DOE/RL-96-61 Rev.0, Table ES-1	2.1	2	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	11/30/2016	63	3	4.76	0.045	0.2	0.0308	0.166	0.0030	3	DOE/RL-96-61 Rev.0, Table ES-1	0.012	3	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	2/26/2017	352	134	38.07	0.2	66.5	0.284	250	1.6	113	DOE/RL-96-61 Rev.0, Table ES-1	52	25	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	12/2/2016	140	59	42.14	0.6	2	0.624	4.17	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	2/26/2017	374	15	4.01	0.033	7	0.05	9.4	5.3	5	DOE/RL-96-61 Rev.0, Table ES-1	2.6	9	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	2/26/2017	352	132	37.5	1.6	20	3.75	878	21.8	57	DOE/RL-96-61 Rev.0, Table ES-1	91.0	26	WAC 173-201A - freshwater CCC
Anions/Cations																	
Chloride	No	ug/L	10/22/2009	3/17/2017	409	409	100	--	--	5,930	148,000	--	--	--	230,000	0	CWA - freshwater CCC
Cyanide	No	ug/L	6/18/2010	3/17/2017	11	1	9.09	1.67	4	4.2	4.2	8.4	0	DOE/RL-96-61 Rev.0, Table ES-1	5.2	0	WAC 173-201A - freshwater CCC

Table D-6. Groundwater Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services

CCC = criteria continuous concentration

CMC = criteria maximum concentration

CWA = *Clean Water Act of 1977*

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-18																	
Aluminum	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	5	10	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	10/7/2014	5	5	100	--	--	2.0	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	10/7/2014	5	0	0	0.1	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	10/13/2016	26	25	96.15	3.4	3.4	2.0	188	2.4	24	DOE/RL-96-61 Rev.0, Table ES-1	74	5	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	10/7/2014	5	0	0	0.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	1/30/2017	28	28	100	--	--	1.5	201	--	--	--	10	16	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	1/30/2017	27	4	14.81	12.8	40	15	64	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.1	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.05	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	1/30/2017	27	7	25.93	1.5	67	2.7	8.0	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	1.0	1.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	1/30/2017	27	0	0	0.1	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	1/30/2017	27	27	100	--	--	17	36	22	23	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-19																	
Aluminum	Yes	ug/L	12/3/2010	11/9/2016	13	6	46.15	10	20	6.9	91	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/3/2010	11/9/2016	13	10	76.92	1.2	1.7	0.56	2.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/3/2010	11/9/2016	13	0	0	0.099	1.0	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	12/3/2010	11/9/2016	13	13	100	--	--	3.4	11	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	12/3/2010	11/9/2016	13	3	23.08	0.1	10	0.23	1.3	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	7/22/2010	11/9/2016	13	12	92.31	8	8.0	1.8	11	--	--	--	10	1	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/3/2010	11/9/2016	6	6	100	--	--	15	81	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	12/3/2010	11/9/2016	13	12	92.31	10	10	0.54	1.1	0.92	3	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/27/2011	10/27/2011	1	0	0	0.2	0.20	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/3/2010	11/9/2016	8	3	37.5	0.2	4.2	0.28	2.4	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	12/3/2010	11/9/2016	13	5	38.46	1.5	2.0	1.2	3.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/3/2010	11/9/2016	13	0	0	0.039	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/3/2010	11/9/2016	8	8	100	--	--	168	413	22	8	DOE/RL-96-61 Rev.0, Table ES-1	91	8	WAC 173-201A - freshwater CCC
199-K-22																	
Aluminum	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	10	10	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/17/2014	4	1	25	0.8	1.8	0.81	0.81	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/17/2014	4	0	0	0.2	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	11/1/2015	9	9	100	--	--	22	122	2.4	9	DOE/RL-96-61 Rev.0, Table ES-1	74	3	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/17/2014	4	1	25	0.2	2.1	0.22	0.22	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	11/9/2016	16	16	100	--	--	12	128	--	--	--	10	16	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	11/9/2016	10	4	40	12.8	40	13	42	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	11/9/2016	10	1	10	1.6	10	4.1	4.1	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	1.4	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	11/9/2016	10	0	0	0.2	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	11/9/2016	10	10	100	--	--	250	878	22	10	DOE/RL-96-61 Rev.0, Table ES-1	91	10	WAC 173-201A - freshwater CCC
199-K-23																	
Aluminum	Yes	ug/L	10/10/2011	12/2/2016	6	0	0	10	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/10/2011	12/2/2016	6	6	100	--	--	0.81	3.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/10/2011	12/2/2016	6	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/10/2011	12/2/2016	9	7	77.78	1	3.0	3.0	97	2.4	7	DOE/RL-96-61 Rev.0, Table ES-1	74	2	CWA - freshwater CCC
Copper	Yes	ug/L	10/10/2011	12/2/2016	6	6	100	--	--	0.27	1.7	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/10/2011	12/2/2016	10	7	70	1.5	1.5	2.2	115	--	--	--	10	5	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/10/2011	12/2/2016	9	7	77.78	28.2	30	20	302	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/10/2011	12/2/2016	6	0	0	0.1	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/10/2011	12/2/2016	9	4	44.44	1.5	13	0.71	17	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/10/2011	12/2/2016	6	1	16.67	1.6	2.0	2.1	2.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/10/2011	12/2/2016	9	0	0	0.04	1.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	Yes	ug/L	10/10/2011	12/2/2016	9	2	22.22	3.3	7.0	3.8	6.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-29																	
Chromium	Yes	ug/L	12/2/2010	12/2/2010	1	0	0	14	14	--	--	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	12/2/2010	12/2/2010	1	0	0	2	2.0	--	--	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/2/2010	12/2/2010	1	0	0	38	38	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	12/2/2010	12/2/2010	1	0	0	4	4.0	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	12/2/2010	12/2/2010	1	0	0	7	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/2/2010	12/2/2010	1	0	0	4	4.0	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-30																	
Chromium	Yes	ug/L	4/6/2010	12/2/2010	2	0	0	13	14	--	--	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	4/15/2010	12/2/2010	2	1	50	2	2.0	7.5	7.5	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/6/2010	12/2/2010	2	1	50	38	38	19	19	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	4/6/2010	12/2/2010	2	0	0	4	4.0	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	4/6/2010	12/2/2010	2	0	0	5	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/6/2010	12/2/2010	2	0	0	4	6.0	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-32A																	
Aluminum	Yes	ug/L	10/22/2009	11/11/2016	20	2	10	10	20	11	31	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/11/2016	20	14	70	0.8	1.7	0.76	3.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/11/2016	20	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	10/22/2009	11/11/2016	28	26	92.86	13	14	9.5	29	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/11/2016	20	7	35	0.2	0.44	0.22	1.5	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	11/11/2016	23	23	100	--	--	8.2	17	--	--	--	10	15	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	11/11/2016	26	5	19.23	18	38	21	49	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	11/11/2016	20	1	5	0.1	0.50	2.8	2.8	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	1	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	11/11/2016	26	14	53.85	1.5	13	1.4	15	1.6	9	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	11/11/2016	20	4	20	0.6	2.0	0.62	1.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	11/11/2016	28	2	7.14	0.04	7.0	4.6	9.4	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	2	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	11/11/2016	26	2	7.69	3.3	7.0	7.6	40	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-34																	
Aluminum	Yes	ug/L	10/22/2009	11/18/2016	8	0	0	10	17	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/18/2016	7	6	85.71	1.7	1.7	0.90	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/18/2016	7	0	0	0.11	0.27	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	2/26/2017	23	18	78.26	5	14	5.9	45	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/18/2016	7	3	42.86	0.2	0.63	0.40	0.59	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	3/17/2017	30	30	100	--	--	2.0	47	--	--	--	10	5	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	2/26/2017	22	13	59.09	16	40	20	193	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	Yes	ug/L	10/22/2009	11/18/2016	7	0	0	0.18	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	3/5/2010	2	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	2/26/2017	22	17	77.27	4	4.0	11	250	1.6	17	DOE/RL-96-61 Rev.0, Table ES-1	52	11	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	11/18/2016	7	4	57.14	0.7	1.5	0.97	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	2/26/2017	22	1	4.55	0.033	7.0	7.0	7.0	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	2/26/2017	22	3	13.64	2	7.0	6.8	9.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-36																	
Aluminum	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	10	10	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/21/2014	5	5	100	--	--	1.8	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/21/2014	5	0	0	0.2	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	8/31/2016	15	15	100	--	--	19	427	2.4	15	DOE/RL-96-61 Rev.0, Table ES-1	74	10	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/21/2014	5	1	20	0.2	2.1	0.20	0.20	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	11/30/2016	16	16	100	--	--	9.3	403	--	--	--	10	15	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	11/30/2016	16	10	62.5	12.8	19	20	313	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	11/30/2016	16	0	0	0.045	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	11/30/2016	16	16	100	--	--	4.8	98	1.6	16	DOE/RL-96-61 Rev.0, Table ES-1	52	9	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	6/11/2010	3	3	100	--	--	1.5	2.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	10/22/2009	11/30/2016	16	0	0	0.2	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	11/30/2016	16	2	12.5	3	8.3	12	19	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-106A																	
Aluminum	Yes	ug/L	10/22/2009	11/18/2016	16	2	12.5	5	20	15	26	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/18/2016	16	16	100	--	--	2.5	4.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/18/2016	16	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	2/26/2017	21	19	90.48	2	13	2.0	4.8	2.4	17	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/18/2016	16	13	81.25	0.2	0.70	0.35	1.3	0.81	4	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	3/17/2017	30	20	66.67	1.5	9.7	1.7	4.4	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	2/26/2017	13	1	7.69	18	30	30	30	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	11/18/2016	16	1	6.25	0.1	0.50	0.33	0.33	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	11/18/2016	8	0	0	0.05	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	2/26/2017	15	9	60	1.5	4.0	1.00	4.0	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	11/18/2016	16	5	31.25	1.5	2.0	0.75	1.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	2/26/2017	21	0	0	0.04	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	2/26/2017	15	1	6.67	3.3	8.3	6.4	6.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-107A																	
Aluminum	Yes	ug/L	11/21/2014	11/18/2016	5	2	40	12.9	17	30	30	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	Yes	ug/L	11/21/2014	11/18/2016	5	5	100	--	--	1.9	3.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/21/2014	11/18/2016	5	0	0	0.099	0.10	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	4/8/2010	2/26/2017	18	18	100	--	--	7.6	19	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/21/2014	11/18/2016	5	1	20	0.45	1.1	1.2	1.2	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	11/9/2009	3/17/2017	30	30	100	--	--	5.6	27	--	--	--	10	11	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/8/2010	2/26/2017	18	5	27.78	12.8	30	20	90	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/21/2014	11/18/2016	5	1	20	0.16	0.17	0.25	0.25	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	4/8/2010	2/26/2017	18	5	27.78	1.5	13	0.68	18	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/21/2014	11/18/2016	5	2	40	0.66	1.6	0.84	1.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	4/8/2010	2/26/2017	18	2	11.11	0.039	6.0	0.050	6.5	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/8/2010	2/26/2017	18	2	11.11	3	9.3	12	22	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-108A																	
Aluminum	Yes	ug/L	10/22/2009	11/18/2016	27	2	7.41	10	20	13	27	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/18/2016	27	27	100	--	--	1.8	3.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/18/2016	27	1	3.7	0.1	0.30	0.29	0.29	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	2/24/2017	37	33	89.19	3.3	14	2.5	11	2.4	33	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/18/2016	27	13	48.15	0.2	0.49	0.26	2.7	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	2/24/2017	39	26	66.67	2.0	9.7	2.1	7.9	--	--	--	10	0	WAC 173-201A - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	Yes	ug/L	10/22/2009	2/24/2017	29	3	10.34	12.8	38	23	45	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	11/18/2016	27	1	3.7	0.1	0.50	1.0	1.0	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	11/18/2016	12	1	8.33	0.06	0.10	0.031	0.031	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	0.012	1	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	2/24/2017	31	20	64.52	4	13	0.82	130	1.6	19	DOE/RL-96-61 Rev.0, Table ES-1	52	2	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	11/18/2016	27	11	40.74	1.5	2.0	1.4	4.2	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	2/24/2017	36	0	0	0.04	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	2/24/2017	31	20	64.52	3.3	8.3	4.6	217	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-110A																	
Aluminum	Yes	ug/L	12/8/2010	11/13/2016	7	2	28.57	10	17	17	22	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/8/2010	11/13/2016	8	8	100	--	--	0.85	4.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/8/2010	11/13/2016	8	1	12.5	0.099	0.20	3.7	3.7	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	0.72	1	CWA - freshwater CCC
Chromium	Yes	ug/L	4/15/2010	11/13/2016	14	13	92.86	5	5.0	2.1	45	2.4	12	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	12/8/2010	11/13/2016	8	2	25	0.45	2.1	0.28	0.78	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	**ug/L**	**12/8/2010**	**11/13/2016**	**13**	**12**	**92.31**	**2.0**	**2.0**	**1.5**	**13**	**--**	**--**	**--**	**10**	**0**	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/15/2010	11/13/2016	13	7	53.85	12.8	20	15	785	570	1	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	12/8/2010	11/13/2016	7	2	28.57	0.17	0.20	0.40	0.41	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	4/15/2010	11/13/2016	13	13	100	--	--	6.1	97	1.6	13	DOE/RL-96-61 Rev.0, Table ES-1	52	3	CWA - freshwater CCC
Selenium	Yes	ug/L	12/8/2010	11/13/2016	7	4	57.14	0.6	1.6	0.81	3.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	4/15/2010	11/13/2016	14	1	7.14	0.039	6.0	0.050	0.050	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/15/2010	11/13/2016	13	2	15.38	1.6	9.3	11	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-111A																	
Aluminum	Yes	ug/L	11/23/2014	11/11/2016	9	4	44.44	12.9	20	21	124	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/23/2014	11/11/2016	9	8	88.89	4	4.0	3.0	3.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/23/2014	11/11/2016	9	1	11.11	0.099	0.13	0.28	0.28	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	12/22/2009	11/11/2016	29	28	96.55	5	5.0	29	541	2.4	28	DOE/RL-96-61 Rev.0, Table ES-1	74	24	CWA - freshwater CCC
Copper	Yes	ug/L	11/23/2014	11/11/2016	9	1	11.11	0.35	2.0	1.1	1.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	12/22/2009	11/11/2016	26	26	100	--	--	30	571	--	--	--	10	26	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/22/2009	2/21/2017	30	5	16.67	12.8	40	14	220	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/23/2014	11/11/2016	9	1	11.11	0.16	1.0	0.49	0.49	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/22/2009	2/21/2017	30	6	20	0.4	13	0.84	14	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/23/2014	11/11/2016	9	5	55.56	0.66	1.6	2.2	3.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/22/2009	2/21/2017	30	2	6.67	0.039	7.0	0.050	0.46	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/22/2009	2/21/2017	30	3	10	3.3	9.3	4.0	43	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-132																	
Aluminum	Yes	ug/L	8/27/2015	11/22/2016	4	3	75	20	20	19	21	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	8/27/2015	11/22/2016	4	3	75	4	4.0	1.5	2.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	Yes	ug/L	8/27/2015	11/22/2016	4	0	0	0.099	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	2/1/2017	18	18	100	--	--	11	27	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	8/27/2015	11/22/2016	4	4	100	--	--	0.60	10	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	9.9	1	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	**ug/L**	**2/3/2010**	**3/13/2017**	**33**	**33**	**100**	**--**	**--**	**8.0**	**24**	**--**	**--**	**--**	**10**	**30**	**WAC 173-201A - freshwater CCC**
Iron	Yes	ug/L	6/15/2010	2/1/2017	17	3	17.65	12.8	38	18	23	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	8/27/2015	11/22/2016	4	1	25	0.16	1.0	0.31	0.31	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/15/2010	2/1/2017	17	2	11.76	0.8	67	4.0	5.1	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	8/27/2015	11/22/2016	4	1	25	1.6	2.0	1.2	1.2	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/15/2010	2/1/2017	17	0	0	0.039	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/1/2017	17	9	52.94	3	7.5	5.3	67	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-137																	
Arsenic	Yes	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	2.6	2.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/31/2011	5/22/2014	2	0	0	0.34	1.0	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	2/24/2017	22	22	100	--	--	13	128	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	74	2	CWA - freshwater CCC
Copper	Yes	ug/L	10/31/2011	5/22/2014	2	1	50	10	10	2.3	2.3	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/15/2010	3/17/2017	30	30	100	--	--	13	145	--	--	--	10	30	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/15/2010	2/24/2017	24	3	12.5	12.8	38	18	29	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Mercury	Yes	ug/L	6/22/2011	11/18/2016	9	2	22.22	0.06	0.10	0.078	0.17	0.0030	2	DOE/RL-96-61 Rev.0, Table ES-1	0.012	2	WAC 173-201A - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nickel	Yes	ug/L	6/15/2010	2/24/2017	24	2	8.33	1.5	13	1.2	8.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/15/2010	2/24/2017	24	1	4.17	0.99	7.0	4.2	4.2	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/24/2017	24	14	58.33	3.3	20	5.0	538	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-139																	
Arsenic	Yes	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	2.6	2.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/22/2014	5/22/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	11/10/2009	2/13/2017	19	19	100	--	--	7.9	128	2.4	19	DOE/RL-96-61 Rev.0, Table ES-1	74	1	CWA - freshwater CCC
Copper	Yes	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	6.3	6.3	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	**ug/L**	**11/10/2009**	**2/13/2017**	**23**	**23**	**100**	**--**	**--**	**5.3**	**117**	**--**	**--**	**--**	**10**	**3**	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	11/10/2009	2/13/2017	19	1	5.26	12.8	38	57	57	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	11/10/2009	2/13/2017	19	2	10.53	1.3	67	1.9	7.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	11/10/2009	2/13/2017	19	3	15.79	0.93	7.0	1.5	9.0	5.3	2	DOE/RL-96-61 Rev.0, Table ES-1	2.6	2	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	11/10/2009	2/13/2017	19	12	63.16	3.3	6.0	5.2	30	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-140																	
Aluminum	Yes	ug/L	5/4/2011	11/28/2016	11	2	18.18	5	20	20	29	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	5/4/2011	11/28/2016	11	8	72.73	0.4	4.0	2.1	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/4/2011	11/28/2016	11	1	9.09	0.099	0.20	0.12	0.12	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	5/4/2011	2/13/2017	15	14	93.33	0.2	0.20	8.4	16	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Copper	Yes	ug/L	5/4/2011	11/28/2016	11	8	72.73	0.2	1.1	0.16	20	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	9.9	1	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	**ug/L**	**2/3/2010**	**2/13/2017**	**24**	**24**	**100**	**--**	**--**	**2.0**	**25**	**--**	**--**	**--**	**10**	**15**	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	5/4/2011	2/13/2017	10	2	20	12.8	30	88	149	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	5/4/2011	11/28/2016	11	2	18.18	0.1	1.0	0.17	0.39	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	5/4/2011	2/13/2017	12	4	33.33	0.2	10	0.63	1.8	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	5/4/2011	11/28/2016	11	4	36.36	0.66	2.0	0.69	2.0	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	5/4/2011	2/13/2017	15	0	0	0.039	3.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	5/4/2011	2/13/2017	12	5	41.67	4.6	9.3	5.7	39	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-200																	
Chromium	Yes	ug/L	4/26/2011	8/2/2016	22	21	95.45	5	5.0	1.4	30	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	4/26/2011	11/30/2016	22	22	100	--	--	1.5	29	--	--	--	10	13	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/26/2011	11/30/2016	23	4	17.39	19	40	21	245	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	4/26/2011	11/30/2016	23	3	13.04	1.3	13	2.9	11	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	4/26/2011	11/30/2016	23	2	8.7	0.93	6.0	1.0	4.1	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/26/2011	11/30/2016	23	4	17.39	3.3	7.0	3.9	11	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-201																	
Arsenic	Yes	ug/L	5/9/2014	8/21/2014	2	1	50	1.8	1.8	2.3	2.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/9/2014	8/21/2014	2	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	4/28/2011	8/3/2016	22	22	100	--	--	38	125	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	74	17	CWA - freshwater CCC
Copper	Yes	ug/L	5/9/2014	8/21/2014	2	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/28/2011	11/13/2016	23	23	100	--	--	30	131	--	--	--	10	23	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/28/2011	11/13/2016	23	1	4.35	12.8	40	29	29	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	4/28/2011	11/13/2016	23	4	17.39	1.5	13	2.7	4.8	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	4/28/2011	11/13/2016	23	1	4.35	0.99	6.0	5.2	5.2	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/28/2011	11/13/2016	23	0	0	3	8.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
699-73-61																	
Aluminum	Yes	ug/L	10/28/2009	1/6/2014	6	1	16.67	10	20	209	209	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/28/2009	1/6/2014	6	4	66.67	0.4	0.80	1.5	2.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/28/2009	1/6/2014	6	0	0	0.1	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	0.68	4.4	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/28/2009	1/6/2014	6	1	16.67	0.2	0.20	0.63	0.63	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/28/2009	1/6/2014	6	0	0	2	2.0	--	--	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/28/2009	1/6/2014	6	2	33.33	18	40	19	35	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/28/2009	1/6/2014	6	5	83.33	0.2	0.20	0.19	2.3	0.92	2	DOE/RL-96-61 Rev.0, Table ES-1	2.1	1	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/28/2009	1/6/2014	6	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/28/2009	1/6/2014	6	2	33.33	4	4.0	0.64	4.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/28/2009	1/6/2014	6	4	66.67	0.6	2.0	0.73	1.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC

Table D-7. Individual Monitoring Well Summary Statistics for Wells Screened at the Top of the Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	10/28/2009	1/6/2014	6	0	0	0.1	0.20	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/28/2009	1/6/2014	6	6	100	--	--	224	281	22	6	DOE/RL-96-61 Rev.0, Table ES-1	91	6	WAC 173-201A - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-8. Groundwater Summary Statistics for Wells Screened In the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Carbon-14	No	pCi/L	10/22/2009	3/23/2017	408	264	64.71	3.4	58	4.4	26,600	--	--	--	2,000	19	40 CFR 141 - federal MCL
Cesium-137	No	pCi/L	10/28/2009	3/23/2017	246	1	0.41	1.6	29	1.9	1.9	0.0084	1	Scott W. Petersen, Jan. 27,1998 Memo	200	0	40 CFR 141 - federal MCL
Gross alpha	No	pCi/L	10/22/2009	3/23/2017	194	56	28.87	0.78	7.0	0.40	13	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/22/2009	3/23/2017	194	185	95.36	1.8	3.7	1.5	344	0.0081	185	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	10/22/2009	3/23/2017	399	149	37.34	0.32	2.7	0.98	152	0.015	149	Scott W. Petersen, Jan. 27,1998 Memo	8.0	59	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/22/2009	3/23/2017	339	121	35.69	5.5	46	6.6	85	0.83	121	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/22/2009	3/23/2017	431	331	76.8	76	519	115	58,000	119	330	DOE/RL-96-61 Rev.0, Table ES-1	20,000	7	40 CFR 141 - federal MCL
Uranium-233/234	No	pCi/L	9/20/2010	11/21/2016	7	7	100	--	--	0.42	2.9	0.85	5	DOE/RL-96-61 Rev.0, Table ES-1	--	--	--
Uranium-235	No	pCi/L	9/20/2010	11/21/2016	7	2	28.57	0.068	1.00	0.075	0.38	0.11	1	Scott W. Petersen, Jan. 27,1998 Memo	--	--	--
Uranium-238	No	pCi/L	9/20/2010	11/21/2016	7	6	85.71	0.59	0.59	0.40	1.7	1.6	1	Scott W. Petersen, Jan. 27,1998 Memo	--	--	--
Volatile Organic Compounds																	
1,2,4-Trichlorobenzene	No	ug/L	9/20/2010	11/14/2016	3	1	33.33	1.0	1.0	0.65	0.65	--	--	--	1.5	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
1,2-Dichlorobenzene	No	ug/L	9/20/2010	11/14/2016	3	1	33.33	1.0	1.0	0.20	0.20	--	--	--	600	0	40 CFR 141 - federal MCL
2-Butanone	No	ug/L	10/22/2009	3/13/2017	173	2	1.16	0.47	3.0	0.70	0.71	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	11/28/2016	2/26/2017	4	4	100	--	--	11	130	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	10/22/2009	3/13/2017	173	19	10.98	0.34	5.0	0.61	8.6	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	No	ug/L	10/22/2009	1/9/2011	23	1	4.35	0.082	1.0	0.11	0.11	--	--	--	0.71	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	1/9/2011	23	5	21.74	0.084	2.0	0.95	1.1	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-8. Groundwater Summary Statistics for Wells Screened In the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chloroform	No	ug/L	10/22/2009	3/13/2017	173	103	59.54	0.10	1.0	0.14	1.8	--	--	--	1.4	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	10/22/2009	3/13/2017	173	9	5.2	0.11	1.6	0.31	5.3	--	--	--	5.0	1	40 CFR 141 - federal MCL
o-Xylene	No	ug/L	11/10/2016	11/10/2016	1	1	100	--	--	0.52	0.52	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	3/13/2017	173	120	69.36	0.16	1.0	0.47	6.0	--	--	--	0.54	119	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	10/22/2009	3/13/2017	173	1	0.58	0.062	1.0	0.14	0.14	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	10/22/2009	3/13/2017	173	1	0.58	0.11	1.0	0.52	0.52	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Semivolatile Organic Compounds																	
Bis(2-ethylhexyl) phthalate	No	ug/L	9/20/2010	1/9/2011	2	1	50	1.0	1.0	1.2	1.2	--	--	--	6.0		40 CFR 141 - federal MCL
Diethylphthalate	No	ug/L	9/20/2010	1/9/2011	2	1	50	1.0	1.0	2.2	2.2	--	--	--	12,800		WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons - gasoline range	No	ug/L	4/22/2010	11/13/2016	10	2	20	10	50	21	26	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Metals																	
Aluminum	No	ug/L	10/22/2009	4/18/2017	292	111	38.01	5	20	5.54	462	7.1	110	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	4/18/2017	301	17	5.65	0.084	3.7	0.1	1.13	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	4/18/2017	301	258	85.71	0.4	4	0.44	7.34	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	4/18/2017	509	509	100	--	--	5.14	63.8	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	4/18/2017	301	7	2.33	0.08	0.35	0.3	0.49	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/5/2010	4/18/2017	199	107	53.77	4	41	4.07	45.7	36.0	2	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-8. Groundwater Summary Statistics for Wells Screened In the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	No	ug/L	10/22/2009	4/18/2017	301	5	1.66	0.05	0.34	0.1	0.16	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/22/2009	4/18/2017	508	479	94.29	0.2	14	0.686	3,250	2.4	455	DOE/RL-96-61 Rev.0, Table ES-1	100	41	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	4/18/2017	301	75	24.92	0.05	2.7	0.07	13.7	0.92	5	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	4/18/2017	301	170	56.48	0.2	2.1	0.155	25.6	0.81	92	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/22/2009	3/23/2017	562	460	81.85	1.5	9.68	1.5	3,310	--	--	--	48.0	73	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	4/18/2017	389	164	42.16	12.8	40	13.4	7,600	570	13	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	4/18/2017	292	58	19.86	0.05	1	0.104	0.924	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/5/2010	1/9/2011	13	10	76.92	4	4	5	19	11.3	3	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	4/18/2017	418	163	39	0.2	6	0.264	235	38.5	12	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	10/22/2009	1/4/2017	60	1	1.67	0.05	0.1	0.1	0.1	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	3/5/2010	4/18/2017	285	263	92.28	0.1	2	0.15	13	3.2	94	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	4/18/2017	418	130	31.1	0.2	66.5	0.324	83.1	1.6	76	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Selenium	No	ug/L	10/22/2009	4/18/2017	292	78	26.71	0.42	2	0.68	5.8	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/22/2009	4/18/2017	509	16	3.14	0.033	7	0.04	13	5.3	3	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/22/2009	4/18/2017	386	386	100	--	--	54	471	323	6	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	10/22/2009	4/18/2017	292	14	4.79	0.014	0.9	0.02	2.4	1.7	3	DOE/RL-96-61 Rev.0, Table ES-1	0.50	12	40 CFR 141 - federal MCLG

Table D-8. Groundwater Summary Statistics for Wells Screened In the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tin	No	ug/L	3/5/2010	4/18/2017	285	44	15.44	0.05	1.3	0.1	8.4	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	10/22/2009	4/18/2017	188	184	97.87	0.067	0.23	0.095	27	9.9	2	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	4/18/2017	407	312	76.66	0.4	17	1.35	32.8	11.5	140	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	4/18/2017	418	158	37.8	1.6	30	2.05	916	21.8	21	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions/Cations																	
Cyanide	No	ug/L	6/24/2010	3/13/2017	7	1	14.29	3.1	4	6.5	6.5	8.4	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	2/26/2017	466	405	86.91	46	88	44	510	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/22/2009	2/26/2017	466	466	100	--	--	251	87,700	26,871	44	DOE/RL-96-61 Rev.0, Table ES-1	45,000	4	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	2/26/2017	465	81	17.42	9.85	312	95.3	1,661	93.7	81	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-11																	
Aluminum	No	ug/L	10/28/2009	11/30/2016	10	2	20	10	20	11	30	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/28/2009	11/30/2016	10	10	100	--	--	5.5	7.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/28/2009	11/30/2016	10	10	100	--	--	29	45	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/25/2010	11/30/2016	6	4	66.67	19	25	13	25	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/28/2009	6/11/2010	3	1	33.33	0.084	1.0	0.96	0.96	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/28/2009	11/30/2016	10	10	100	--	--	72	152	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/28/2009	11/30/2016	5	5	100	--	--	0.31	1.2	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/28/2009	11/30/2016	10	10	100	--	--	2.0	19	2.4	9	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/28/2009	11/30/2016	10	1	10	0.1	0.90	0.10	0.10	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/28/2009	11/30/2016	10	1	10	0.2	0.68	0.42	0.42	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/28/2009	11/30/2016	14	14	100	--	--	131	280	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	4/23/2012	11/30/2016	11	7	63.64	1.72	3.2	1.8	13	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	4/23/2012	11/30/2016	11	11	100	--	--	15	40	0.0081	11	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/28/2009	11/30/2016	10	8	80	2	2.0	3.2	17	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/28/2009	11/30/2016	7	6	85.71	38	38	14	91	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/28/2009	11/30/2016	10	1	10	0.1	1.0	0.13	0.13	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lithium	No	ug/L	3/25/2010	6/11/2010	2	2	100	--	--	8.2	16	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/28/2009	11/30/2016	8	5	62.5	4	4.0	1.7	7.5	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/25/2010	11/30/2016	9	9	100	--	--	1.0	3.1	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/28/2009	11/30/2016	14	14	100	--	--	12,600	87,700	26,871	9	DOE/RL-96-61 Rev.0, Table ES-1	45,000	4	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/28/2009	11/30/2016	14	2	14.29	62.4	131	174	268	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/28/2009	11/30/2016	10	3	30	0.6	2.0	0.83	2.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/28/2009	11/30/2016	10	1	10	0.1	0.90	1.3	1.3	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/28/2009	11/30/2016	8	8	100	--	--	199	312	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	10/28/2009	11/30/2016	13	11	84.62	7.8	7.9	13	46	0.83	11	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	10/28/2009	11/30/2016	5	5	100	--	--	1.6	6.0	--	--	--	0.54	5	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/28/2009	11/30/2016	15	13	86.67	170	190	330	600	119	13	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/28/2009	11/30/2016	7	7	100	--	--	2.8	6.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/28/2009	11/30/2016	8	8	100	--	--	9.8	25	12	7	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/28/2009	11/30/2016	8	1	12.5	1.6	9.3	11	11	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-20																	
Aluminum	No	ug/L	10/28/2009	2/1/2017	26	15	57.69	10	20	11	249	7.1	15	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Antimony	No	ug/L	10/28/2009	2/1/2017	26	1	3.85	0.23	2.0	0.19	0.19	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/28/2009	2/1/2017	26	24	92.31	4	4.0	0.49	3.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/28/2009	2/1/2017	26	26	100	--	--	19	29	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/5/2010	2/1/2017	16	7	43.75	6.4	25	6.0	13	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/28/2009	2/1/2017	26	2	7.69	0.099	0.20	0.10	0.16	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/28/2009	10/24/2016	15	9	60	8.01	46	9.6	29	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/28/2009	6/16/2010	3	2	66.67	1	1.0	0.64	0.73	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/28/2009	2/1/2017	26	24	92.31	4	4.0	1.4	9.5	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/28/2009	2/1/2017	26	17	65.38	0.1	0.90	0.12	1.0	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/28/2009	2/1/2017	26	14	53.85	0.2	2.0	0.21	3.1	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/28/2009	10/24/2016	16	8	50	46	88	63	190	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/28/2009	10/24/2016	9	3	33.33	1.6	3.0	1.6	3.4	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/28/2009	10/24/2016	9	9	100	--	--	7.8	32	0.0081	9	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/28/2009	2/1/2017	27	13	48.15	1.5	2.0	1.5	9.0	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/28/2009	2/1/2017	13	13	100	--	--	110	7,600	570	9	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/28/2009	2/1/2017	26	7	26.92	0.1	1.0	0.12	0.63	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lithium	No	ug/L	3/5/2010	6/16/2010	2	2	100	--	--	5.0	5.3	11	0	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/28/2009	2/1/2017	17	17	100	--	--	1.7	119	39	4	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/5/2010	2/1/2017	25	23	92	2	2.0	0.17	2.4	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/28/2009	2/1/2017	17	6	35.29	0.2	4.2	0.32	1.2	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/28/2009	10/24/2016	16	16	100	--	--	12,200	17,500	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/28/2009	10/24/2016	16	2	12.5	19.7	131	145	217	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/28/2009	2/1/2017	26	9	34.62	0.6	2.0	0.73	2.2	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/28/2009	2/1/2017	26	2	7.69	0.039	0.90	0.11	0.16	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/28/2009	2/1/2017	17	17	100	--	--	205	311	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/28/2009	10/24/2016	15	12	80	1.5	2.0	2.8	15	0.015	12	Scott W. Petersen, Jan. 27,1998 Memo	8.0	9	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/28/2009	2/1/2017	26	2	7.69	0.014	0.90	0.91	1.1	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	2	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/5/2010	2/1/2017	25	4	16	0.1	1.3	0.13	5.6	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/28/2009	10/24/2016	15	15	100	--	--	2,050	14,000	119	15	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/28/2009	2/1/2017	16	16	100	--	--	1.7	3.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/28/2009	2/1/2017	15	9	60	4.4	15	5.3	19	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/28/2009	2/1/2017	17	9	52.94	4	9.3	4.3	19	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-21																	
Aluminum	No	ug/L	12/3/2010	10/13/2016	7	3	42.86	12.9	20	25	71	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	12/3/2010	10/13/2016	7	1	14.29	0.4	1.7	1.00	1.00	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	12/3/2010	10/13/2016	7	7	100	--	--	13	24	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	12/3/2010	10/13/2016	7	1	14.29	0.1	0.20	0.38	0.38	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/11/2011	10/13/2016	5	2	40	4	15	4.4	13	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	12/3/2010	10/13/2016	7	2	28.57	4.95	50	9.1	9.2	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	12/3/2010	10/13/2016	7	6	85.71	3	3.0	19	73	2.4	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	12/3/2010	10/13/2016	7	6	85.71	0.22	0.22	0.13	0.96	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	12/3/2010	10/13/2016	7	6	85.71	0.35	0.35	0.38	2.5	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	12/3/2010	10/13/2016	11	4	36.36	46	88	84	95	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	12/3/2010	10/13/2016	7	2	28.57	1.46	3.0	1.6	3.5	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	12/3/2010	10/13/2016	7	7	100	--	--	36	57	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	7/25/2010	10/13/2016	14	10	71.43	1.5	8.0	1.7	18	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/3/2010	10/13/2016	4	4	100	--	--	343	761	570	2	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	12/3/2010	10/13/2016	7	3	42.86	0.1	0.50	0.24	0.30	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/3/2010	10/13/2016	5	5	100	--	--	103	235	39	5	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Molybdenum	No	ug/L	12/3/2010	10/13/2016	7	7	100	--	--	0.82	2.6	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/3/2010	10/13/2016	5	5	100	--	--	2.0	32	1.6	5	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	12/3/2010	10/13/2016	11	11	100	--	--	12,200	24,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	12/3/2010	10/13/2016	11	4	36.36	118	131	141	258	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	12/3/2010	10/13/2016	7	1	14.29	1.5	2.0	0.72	0.72	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/3/2010	10/13/2016	7	1	14.29	0.04	0.40	0.21	0.21	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/3/2010	10/13/2016	5	5	100	--	--	224	313	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	12/3/2010	10/13/2016	7	7	100	--	--	17	30	0.015	7	Scott W. Petersen, Jan. 27,1998 Memo	8.0	7	40 CFR 141 - federal MCL
Thallium	No	ug/L	12/3/2010	10/13/2016	7	1	14.29	0.1	0.60	1.2	1.2	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tritium	No	pCi/L	12/3/2010	10/13/2016	7	3	42.86	180	345	272	2,110	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/17/2013	10/13/2016	4	4	100	--	--	1.4	1.7	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/3/2010	10/13/2016	5	1	20	0.4	1.0	1.5	1.5	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	12/3/2010	10/13/2016	5	1	20	3.5	4.0	3.3	3.3	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-31																	
Aluminum	No	ug/L	10/22/2009	11/28/2016	17	4	23.53	10	20	15	33	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	11/28/2016	17	1	5.88	0.6	2.0	0.27	0.27	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	11/28/2016	17	16	94.12	4	4.0	1.6	3.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Barium	No	ug/L	10/22/2009	2/23/2017	21	21	100	--	--	27	40	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	11/28/2016	17	1	5.88	0.1	0.35	0.30	0.30	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/25/2010	11/28/2016	11	8	72.73	7.2	25	10	43	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.084	1.0	0.95	0.95	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/22/2009	11/28/2016	17	1	5.88	0.099	0.20	0.10	0.10	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/22/2009	2/23/2017	13	13	100	--	--	179	436	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	11/28/2016	8	6	75	0.3	1.0	0.20	0.36	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	2/23/2017	21	21	100	--	--	3.5	9.5	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	11/28/2016	17	1	5.88	0.1	0.90	0.20	0.20	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	11/28/2016	17	2	11.76	0.2	0.68	0.32	3.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	2/23/2017	19	19	100	--	--	102	240	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/22/2009	11/28/2016	15	2	13.33	1.34	4.9	1.7	1.9	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/22/2009	11/28/2016	15	15	100	--	--	18	48	0.0081	15	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	2/23/2017	15	14	93.33	3.7	3.7	4.4	9.4	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	2/23/2017	14	13	92.86	40	40	20	490	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	11/28/2016	17	2	11.76	0.1	1.0	0.30	0.38	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lithium	No	ug/L	3/25/2010	6/11/2010	2	2	100	--	--	6.2	17	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	2/23/2017	16	13	81.25	4	4.0	0.34	7.8	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/25/2010	11/28/2016	16	16	100	--	--	1.5	3.0	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	2/23/2017	16	2	12.5	0.2	4.2	0.39	0.65	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	2/23/2017	19	19	100	--	--	15,800	27,400	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	2/23/2017	19	1	5.26	9.85	131	236	236	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	11/28/2016	17	10	58.82	1.6	2.0	0.99	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/22/2009	11/28/2016	12	12	100	--	--	221	309	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	2/23/2017	13	2	15.38	0.568	2.2	1.5	1.6	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/22/2009	11/28/2016	8	8	100	--	--	24	85	0.83	8	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/22/2009	11/28/2016	17	1	5.88	0.014	0.90	1.8	1.8	1.7	1	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/25/2010	11/28/2016	16	1	6.25	0.1	1.2	5.3	5.3	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	11/28/2016	8	8	100	--	--	2.2	4.0	--	--	--	0.54	8	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	2/23/2017	19	19	100	--	--	1,200	2,100	119	19	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	11/28/2016	11	11	100	--	--	1.8	2.6	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	2/23/2017	15	13	86.67	12	15	7.2	26	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	No	ug/L	10/22/2009	2/23/2017	16	2	12.5	3.3	9.3	4.0	23	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-35/199-K-195/199-K-205																	
Acetone	No	ug/L	4/13/2011	2/1/2017	13	4	30.77	3	3.0	3.5	6.2	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	12/11/2014	11/10/2016	3	3	100	--	--	3.7	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	12/22/2009	2/1/2017	25	25	100	--	--	33	60	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	12/11/2014	2/15/2017	4	2	50	15	15	11	15	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	4/13/2011	2/1/2017	14	14	100	--	--	86	391	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	4/13/2011	2/1/2017	13	12	92.31	1	1.0	0.30	0.50	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	12/22/2009	2/1/2017	26	26	100	--	--	20	3,250	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	100	19	40 CFR 141 - federal MCL
Fluoride	No	ug/L	12/22/2009	2/15/2017	28	28	100	--	--	93	386	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	12/11/2014	11/10/2016	3	3	100	--	--	30	36	0.0081	3	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	12/22/2009	3/15/2017	39	39	100	--	--	13	3,310	--	--	--	48	28	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/22/2009	2/15/2017	26	8	30.77	18	30	19	173	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	12/22/2009	2/1/2017	25	14	56	1	4.0	2.6	14	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	12/11/2014	11/10/2016	3	3	100	--	--	1.8	3.0	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/22/2009	2/1/2017	25	4	16	0.5	4.0	1.4	5.0	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	12/22/2009	2/15/2017	28	28	100	--	--	22,100	36,700	26,871	14	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	12/22/2009	2/15/2017	28	7	25	118	131	210	1,662	94	7	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/22/2009	2/1/2017	25	1	4	0.1	5.0	9.0	9.0	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/22/2009	11/10/2016	17	17	100	--	--	215	370	323	2	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/13/2011	2/1/2017	13	1	7.69	0.74	2.0	2.7	2.7	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	4/13/2011	11/10/2016	4	4	100	--	--	7.2	76	0.83	4	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tin	No	ug/L	12/11/2014	11/10/2016	3	1	33.33	1	1.0	1.1	1.1	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	4/13/2011	2/1/2017	13	13	100	--	--	3.0	5.4	--	--	--	0.54	13	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	4/13/2011	2/1/2017	13	13	100	--	--	877	1,650	119	13	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/11/2014	11/10/2016	3	3	100	--	--	1.4	1.7	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/22/2009	2/15/2017	26	15	57.69	8	12	5.9	20	12	3	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	12/22/2009	2/1/2017	25	3	12	3.3	6.0	4.6	8.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-37																	
Acetone	No	ug/L	10/22/2009	1/9/2011	5	1	20	0.34	1.0	1.7	1.7	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/22/2009	1/9/2011	5	2	40	10	10	16	233	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	3.3	3.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	11/18/2016	17	17	100	--	--	13	32	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Bis(2-ethylhexyl) phthalate	No	ug/L	9/20/2010	1/9/2011	2	1	50	1	1.0	1.2	1.2	--	--	--	6.0	0	40 CFR 141 - federal MCL

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Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Carbon-14	No	pCi/L	10/22/2009	11/18/2016	10	1	10	4.46	55	4.5	4.5	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	1/9/2011	5	4	80	1	1.0	0.33	0.60	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	5/5/2016	16	16	100	--	--	15	65	2.4	16	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	10/22/2009	1/9/2011	5	2	40	0.2	0.20	0.30	2.2	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Diethylphthalate	No	ug/L	9/20/2010	1/9/2011	2	1	50	1	1.0	2.2	2.2	--	--	--	12,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	11/18/2016	14	13	92.86	60	60	74	210	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	9/20/2010	1/9/2011	2	2	100	--	--	1.6	3.1	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	9/20/2010	1/9/2011	2	2	100	--	--	2.9	12	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	11/18/2016	18	18	100	--	--	16	57	--	--	--	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	11/18/2016	17	2	11.76	18	38	21	25	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	3/5/2010	1/9/2011	4	2	50	4	4.0	5.9	6.0	11	0	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/5/2010	1/9/2011	4	4	100	--	--	4.3	4.5	3.2	4	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	11/18/2016	17	1	5.88	1.5	67	2.1	2.1	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	11/18/2016	14	14	100	--	--	5,800	11,100	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	11/18/2016	14	1	7.14	118	131	149	149	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	0.87	1.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL

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Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium	No	ug/L	10/22/2009	11/18/2016	17	17	100	--	--	96	254	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	11/18/2016	12	7	58.33	1.4	1.9	2.3	4.9	0.015	7	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/22/2009	11/18/2016	17	9	52.94	97.4	368	115	680	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	11/18/2016	6	6	100	--	--	2.1	2.9	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	11/18/2016	17	11	64.71	5	17	9.4	17	12	3	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	11/18/2016	17	2	11.76	3.3	30	4.2	5.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-113A																	
Aluminum	No	ug/L	11/15/2011	11/16/2016	11	2	18.18	10	20	32	110	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	11/15/2011	11/16/2016	11	1	9.09	0.084	1.7	0.13	0.13	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	11/15/2011	11/16/2016	11	9	81.82	1.2	1.2	0.84	1.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	1/31/2011	11/16/2016	13	13	100	--	--	11	17	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/15/2011	11/16/2016	8	2	25	4	10	8.0	21	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	1/31/2011	11/16/2016	7	1	14.29	3.91	56	25	25	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	1/31/2011	11/16/2016	13	10	76.92	1.1	14	0.69	10	2.4	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/15/2011	11/16/2016	11	11	100	--	--	1.0	4.4	0.81	11	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	1/31/2011	11/16/2016	13	8	61.54	46	88	54	149	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	1/31/2011	11/16/2016	7	1	14.29	0.916	2.8	1.1	1.1	--	--	--	15	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross beta	No	pCi/L	1/31/2011	11/16/2016	7	7	100	--	--	8.3	19	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	1/31/2011	11/16/2016	13	5	38.46	1.5	8.0	2.0	9.3	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	1/31/2011	11/16/2016	7	1	14.29	12.8	38	31	31	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/15/2011	11/16/2016	11	3	27.27	0.1	0.17	0.26	0.41	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	11/15/2011	11/16/2016	11	6	54.55	1	1.0	0.32	1.0	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	1/31/2011	11/16/2016	9	3	33.33	0.2	5.0	0.66	1.2	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	1/31/2011	11/16/2016	13	13	100	--	--	359	4,070	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	1/31/2011	11/16/2016	13	2	15.38	9.85	131	146	158	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/15/2011	11/16/2016	11	1	9.09	0.66	2.0	2.6	2.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	1/31/2011	11/16/2016	9	9	100	--	--	99	152	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	1/31/2011	11/16/2016	13	13	100	--	--	2.5	8.9	0.015	13	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
Tin	No	ug/L	11/15/2011	11/16/2016	11	4	36.36	0.1	1.3	0.11	1.6	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/31/2011	11/16/2016	7	1	14.29	280	519	840	840	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/20/2013	11/16/2016	7	7	100	--	--	0.28	27	9.9	1	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	1/31/2011	11/16/2016	8	3	37.5	4.4	17	2.5	3.7	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	1/31/2011	11/16/2016	9	5	55.56	9.1	9.3	4.0	14	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-114A																	
Aluminum	No	ug/L	11/15/2011	5/25/2016	10	2	20	10	20	11	35	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/15/2011	5/25/2016	10	3	30	0.4	1.7	0.44	0.93	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/16/2010	5/25/2016	13	13	100	--	--	9.3	15	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/15/2011	5/25/2016	7	3	42.86	4	15	4.1	13	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/16/2010	5/25/2016	13	4	30.77	2	14	1.2	3.6	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/15/2011	5/25/2016	10	10	100	--	--	1.9	4.9	0.81	10	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/16/2010	11/16/2016	11	4	36.36	46	88	56	110	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	6/16/2010	11/18/2015	7	7	100	--	--	10	20	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/16/2010	11/16/2016	14	3	21.43	1.5	8.0	2.2	2.6	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/15/2011	5/25/2016	10	3	30	0.1	0.50	0.11	0.15	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	11/15/2011	5/25/2016	10	8	80	0.1	1.0	0.25	0.43	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	6/16/2010	11/16/2016	11	11	100	--	--	251	1,810	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/16/2010	11/16/2016	11	1	9.09	9.85	131	131	131	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/16/2010	5/25/2016	13	1	7.69	0.04	7.0	0.23	0.23	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/16/2010	5/25/2016	9	9	100	--	--	72	112	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	1/31/2011	11/18/2015	6	6	100	--	--	3.2	9.4	0.015	6	Scott W. Petersen, Jan. 27,1998 Memo	8.0	3	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Uranium	No	ug/L	11/20/2013	5/25/2016	6	3	50	0.067	0.10	0.095	0.12	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/16/2010	5/25/2016	8	5	62.5	8	17	1.4	2.7	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	5/25/2016	9	7	77.78	4	4.0	4.4	11	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-117A																	
Aluminum	No	ug/L	10/22/2009	1/30/2017	28	7	25	5	20	15	181	7.1	7	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	1/30/2017	28	3	10.71	0.3	2.0	0.10	0.17	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	1/30/2017	28	16	57.14	0.8	4.0	0.55	1.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	1/30/2017	28	28	100	--	--	16	29	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	1/30/2017	28	2	7.14	0.1	0.35	0.30	0.49	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/28/2011	1/30/2017	14	5	35.71	4	25	5.5	30	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.084	1.0	1.1	1.1	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/22/2009	1/30/2017	28	2	7.14	0.05	0.20	0.12	0.13	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/22/2009	1/30/2017	28	27	96.43	4	4.0	1.1	9.4	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	1/30/2017	28	18	64.29	0.1	0.90	0.10	0.42	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	1/30/2017	28	15	53.57	0.2	1.1	0.16	4.0	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	1/30/2017	26	11	42.31	46	88	44	110	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	12/3/2010	10/13/2016	13	12	92.31	3.2	3.2	1.8	32	0.0081	12	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	10/22/2009	1/30/2017	26	3	11.54	1.5	8.0	1.7	2.6	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	1/30/2017	15	7	46.67	12.8	38	24	110	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	1/30/2017	28	6	21.43	0.05	1.0	0.12	0.57	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	10/22/2009	1/30/2017	17	11	64.71	0.88	4.0	0.32	4.3	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/10/2010	1/30/2017	27	19	70.37	1	2.0	0.20	1.6	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	1/30/2017	17	10	58.82	0.2	13	0.92	5.3	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	1/30/2017	26	26	100	--	--	261	6,370	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	1/30/2017	26	3	11.54	9.85	131	148	170	94	3	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/22/2009	1/30/2017	28	1	3.57	0.039	0.90	0.070	0.070	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/22/2009	1/30/2017	17	17	100	--	--	95	204	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	10/13/2016	15	11	73.33	1.6	2.0	1.3	4.0	0.015	11	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/22/2009	1/30/2017	28	1	3.57	0.014	0.90	2.4	2.4	1.7	1	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/10/2010	1/30/2017	27	8	29.63	0.1	1.3	0.13	8.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	10/13/2016	15	2	13.33	150	421	390	450	119	2	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	1/30/2017	16	15	93.75	0.23	0.23	0.31	2.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	1/30/2017	15	6	40	4.1	15	1.7	6.3	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	No	ug/L	10/22/2009	1/30/2017	17	1	5.88	1.6	9.3	16	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-125A																	
Aluminum	No	ug/L	11/11/2011	11/15/2016	11	4	36.36	10	15	11	24	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/11/2011	11/15/2016	11	11	100	--	--	3.2	5.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	2/18/2010	11/15/2016	14	14	100	--	--	32	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/11/2011	11/15/2016	8	5	62.5	15	15	6.8	20	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	2/18/2010	11/15/2016	7	5	71.43	8.21	54	10	42	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	2/18/2010	11/15/2016	14	10	71.43	3	14	3.3	16	2.4	10	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	11/11/2011	11/15/2016	11	3	27.27	0.1	0.22	0.12	0.20	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	11/11/2011	11/15/2016	11	5	45.45	0.2	0.45	0.41	0.76	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	2/18/2010	11/15/2016	12	11	91.67	72	72	55	193	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	7/28/2010	11/15/2016	7	1	14.29	1.57	7.0	3.6	3.6	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	7/28/2010	11/15/2016	7	7	100	--	--	3.9	13	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	2/18/2010	11/15/2016	17	8	47.06	1.5	9.7	2.0	5.8	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	2/18/2010	11/15/2016	8	8	100	--	--	42	2,030	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/11/2011	11/15/2016	11	1	9.09	0.1	0.50	0.15	0.15	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	2/18/2010	11/15/2016	10	8	80	4	4.1	1.9	50	39	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Molybdenum	No	ug/L	11/11/2011	11/15/2016	11	11	100	--	--	2.6	3.0	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	2/18/2010	11/15/2016	10	7	70	0.5	4.0	0.50	12	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	2/18/2010	11/15/2016	12	12	100	--	--	11,900	14,900	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	2/18/2010	11/15/2016	12	1	8.33	9.85	131	139	139	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/11/2011	11/15/2016	11	1	9.09	1.5	2.0	2.0	2.0	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	2/18/2010	11/15/2016	14	2	14.29	0.04	7.0	0.14	6.0	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	2/18/2010	11/15/2016	10	10	100	--	--	113	321	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	2/18/2010	11/15/2016	7	1	14.29	0.772	2.0	1.9	1.9	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	11/11/2011	11/15/2016	11	1	9.09	0.1	0.60	0.58	0.58	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	11/11/2011	11/15/2016	11	2	18.18	0.1	1.0	0.14	0.63	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	2/18/2010	11/15/2016	9	9	100	--	--	1,880	7,900	119	9	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/2/2013	11/15/2016	7	7	100	--	--	2.5	3.3	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	2/18/2010	11/15/2016	9	8	88.89	17	17	10	16	12	6	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	2/18/2010	11/15/2016	10	6	60	3.5	4.1	5.5	50	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-138																	
2-Butanone	No	ug/L	6/15/2010	2/13/2017	17	1	5.88	0.47	3.0	0.70	0.70	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	11/28/2016	2/13/2017	2	2	100	--	--	28	130	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Acetone	No	ug/L	6/15/2010	2/13/2017	17	3	17.65	0.34	5.0	0.65	2.3	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	2.2	2.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/13/2017	18	18	100	--	--	31	53	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/22/2010	2/13/2017	10	10	100	--	--	396	582	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/15/2010	2/13/2017	17	10	58.82	1	1.0	0.26	0.72	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/15/2010	2/13/2017	18	18	100	--	--	9.1	63	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	6/15/2010	2/13/2017	16	15	93.75	60	60	93	238	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	6/15/2010	11/28/2016	8	8	100	--	--	12	36	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	2/3/2010	2/13/2017	22	22	100	--	--	6.0	24	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/13/2017	18	7	38.89	12.8	30	16	215	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/15/2010	2/13/2017	18	3	16.67	0.7	6.0	0.43	3.8	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/15/2010	2/13/2017	18	7	38.89	1.3	67	4.2	18	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/15/2010	2/13/2017	16	16	100	--	--	20,100	27,900	26,871	3	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/13/2017	16	1	6.25	9.85	131	182	182	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/15/2010	11/28/2016	14	14	100	--	--	215	317	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/22/2010	2/13/2017	10	2	20	0.588	2.0	1.5	1.8	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	11/22/2010	11/28/2016	7	7	100	--	--	26	49	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Trichloroethene	No	ug/L	6/15/2010	2/13/2017	17	17	100	--	--	2.7	5.6	--	--	--	0.54	17	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/22/2010	2/13/2017	10	10	100	--	--	870	1,520	119	10	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/15/2010	2/13/2017	18	13	72.22	4.4	17	5.1	22	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/15/2010	2/13/2017	18	13	72.22	4.5	6.0	7.0	189	22	4	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-141																	
Arsenic	No	ug/L	5/22/2014	11/21/2016	7	7	100	--	--	3.4	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	1/7/2010	11/21/2016	25	25	100	--	--	27	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/24/2014	11/21/2016	5	4	80	15	15	16	18	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	1/7/2010	3/23/2017	28	28	100	--	--	89	314	--	--	--	2,000	0	40 CFR 141 - federal MCL
Cesium-137	No	pCi/L	7/26/2010	11/18/2015	8	1	12.5	4.84	13	1.9	1.9	0.0084	1	Scott W. Petersen, Jan. 27,1998 Memo	200	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	1/7/2010	11/21/2016	25	25	100	--	--	19	44	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	5/22/2014	11/21/2016	7	7	100	--	--	0.68	20	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	1/7/2010	11/21/2016	22	19	86.36	60	88	81	200	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	1/7/2010	3/23/2017	28	18	64.29	2.1	3.4	1.8	6.0	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	1/7/2010	3/23/2017	28	28	100	--	--	11	168	0.0081	28	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	1/7/2010	7/28/2016	24	23	95.83	2	2.0	19	48	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	1/7/2010	11/21/2016	25	3	12	12.8	38	28	34	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	No	ug/L	11/24/2014	11/21/2016	5	1	20	0.5	0.50	0.92	0.92	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	11/24/2014	11/21/2016	5	5	100	--	--	1.6	2.3	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	1/7/2010	11/21/2016	25	5	20	0.5	13	0.64	6.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	1/7/2010	11/21/2016	22	22	100	--	--	10,600	17,700	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	1/7/2010	11/21/2016	22	5	22.73	9.85	131	152	417	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/24/2014	11/21/2016	5	1	20	1.5	1.5	2.8	2.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	1/7/2010	11/21/2016	25	25	100	--	--	216	299	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	1/7/2010	3/23/2017	27	26	96.3	2.2	2.2	2.2	84	0.015	26	Scott W. Petersen, Jan. 27,1998 Memo	8.0	24	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	1/7/2010	3/23/2017	28	13	46.43	6.5	46	6.6	19	0.83	13	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	1/7/2010	3/23/2017	27	27	100	--	--	1,400	8,400	119	27	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/24/2014	11/21/2016	5	5	100	--	--	3.0	3.3	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	1/7/2010	11/21/2016	25	19	76	8.1	17	7.6	12	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	1/7/2010	11/21/2016	25	17	68	3.5	7.0	3.7	45	22	3	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-142																	
Aluminum	No	ug/L	10/22/2009	11/15/2016	14	9	64.29	10	15	10	100	7.1	9	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	11/15/2016	14	2	14.29	0.6	1.7	0.11	0.19	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	11/15/2016	14	13	92.86	0.4	0.40	3.9	6.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Barium	No	ug/L	10/22/2009	11/15/2016	15	15	100	--	--	5.1	29	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/8/2010	11/15/2016	8	3	37.5	6.4	19	4.4	7.0	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.082	1.0	0.11	0.11	--	--	--	0.71	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.084	1.0	0.95	0.95	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2009	11/15/2016	16	16	100	--	--	139	276	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	6/11/2010	3	2	66.67	1	1.0	0.91	1.2	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	11/15/2016	15	12	80	0.2	13	0.93	14	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	11/15/2016	14	4	28.57	0.07	0.22	0.070	1.6	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	11/15/2016	14	3	21.43	0.2	1.1	0.39	9.1	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	11/15/2016	14	14	100	--	--	142	273	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	12/22/2009	11/15/2016	14	3	21.43	1.13	3.3	0.97	3.5	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	12/22/2009	11/15/2016	14	11	78.57	2.73	3.7	2.2	31	0.0081	11	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	11/15/2016	9	2	22.22	1.5	9.7	3.3	13	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	11/15/2016	8	6	75	16	18	18	403	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	11/15/2016	14	3	21.43	0.1	0.50	0.11	0.47	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	10/22/2009	11/15/2016	10	5	50	0.88	4.0	0.26	2.8	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/8/2010	11/15/2016	13	13	100	--	--	0.15	4.7	3.2	10	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nickel	No	ug/L	10/22/2009	11/15/2016	10	3	30	0.2	4.2	0.46	1.1	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	11/15/2016	14	14	100	--	--	1,310	8,410	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	11/15/2016	14	1	7.14	62.4	131	153	153	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	11/15/2016	14	2	14.29	0.6	2.0	0.68	1.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/22/2009	11/15/2016	10	10	100	--	--	135	183	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	11/15/2016	16	1	6.25	0.585	2.7	1.4	1.4	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/22/2009	11/15/2016	14	1	7.14	0.014	0.55	0.66	0.66	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/8/2010	11/15/2016	13	2	15.38	0.1	1.3	0.15	0.45	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	11/15/2016	16	3	18.75	98.7	330	220	325	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	11/15/2016	10	10	100	--	--	1.0	1.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	11/15/2016	9	9	100	--	--	9.1	33	12	8	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	11/15/2016	10	1	10	3.5	9.3	13	13	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-144																	
Arsenic	No	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	3.7	3.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/1/2010	11/16/2016	15	15	100	--	--	32	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	4/1/2010	11/16/2016	8	7	87.5	54.6	55	17	54	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	4/1/2010	5/25/2016	14	14	100	--	--	15	55	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Copper	No	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	2.6	2.6	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/1/2010	11/16/2016	14	13	92.86	60	60	90	200	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	1/31/2011	11/16/2016	7	1	14.29	1.89	2.9	3.7	3.7	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	1/31/2011	11/16/2016	7	7	100	--	--	5.5	96	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/1/2010	11/16/2016	15	15	100	--	--	20	56	--	--	--	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/1/2010	11/16/2016	15	1	6.67	12.8	40	40	40	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/1/2010	11/16/2016	15	2	13.33	1.5	13	8.0	83	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	4/1/2010	11/16/2016	14	14	100	--	--	14,000	18,600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/1/2010	11/16/2016	14	2	14.29	9.85	131	174	201	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	4/1/2010	11/16/2016	15	15	100	--	--	241	283	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/1/2010	11/16/2016	14	9	64.29	1.47	1.6	1.6	5.7	0.015	9	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	4/1/2010	11/16/2016	14	14	100	--	--	13,000	58,000	119	14	DOE/RL-96-61 Rev.0, Table ES-1	20,000	5	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/1/2010	11/16/2016	15	13	86.67	12	17	9.6	16	12	12	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/1/2010	11/16/2016	15	12	80	4	7.0	4.2	226	22	3	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-146																	
Barium	No	ug/L	6/16/2010	3/23/2017	14	14	100	--	--	13	25	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	6/5/2014	6/5/2014	1	1	100	--	--	0.30	0.30	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	No	ug/L	6/16/2010	5/25/2016	13	12	92.31	5	5.0	3.4	28	2.4	12	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	6/5/2014	6/5/2014	1	1	100	--	--	8.6	8.6	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/16/2010	5/25/2016	12	10	83.33	60	88	48	160	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	6/16/2010	3/23/2017	8	5	62.5	1.77	3.0	1.5	6.5	0.0081	5	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/16/2010	3/23/2017	14	13	92.86	8	8.0	2.6	21	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/16/2010	3/23/2017	14	2	14.29	12.8	38	23	29	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	6/16/2010	5/25/2016	12	12	100	--	--	930	4,430	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/16/2010	5/25/2016	12	3	25	9.85	131	150	191	94	3	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/16/2010	3/23/2017	14	14	100	--	--	111	164	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Vanadium	No	ug/L	6/16/2010	3/23/2017	14	8	57.14	5	17	4.5	5.9	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	3/23/2017	14	11	78.57	3.3	5.0	6.4	916	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-147																	
Arsenic	No	ug/L	11/24/2014	11/24/2014	1	1	100	--	--	2.2	2.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/16/2010	11/21/2016	14	14	100	--	--	25	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/22/2010	11/21/2016	7	3	42.86	8.01	53	17	34	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/16/2010	5/25/2016	13	13	100	--	--	10	34	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/24/2014	11/24/2014	1	1	100	--	--	26	26	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Fluoride	No	ug/L	6/16/2010	11/21/2016	13	12	92.31	60	60	81	200	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/21/2016	8	2	25	1.41	3.2	1.5	1.6	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/21/2016	8	6	75	3.1	3.3	3.9	6.3	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/16/2010	11/21/2016	14	14	100	--	--	9.0	33	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/16/2010	11/21/2016	14	3	21.43	12.8	38	19	106	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/16/2010	11/21/2016	14	1	7.14	0.7	6.0	10	10	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/16/2010	11/21/2016	14	4	28.57	1.5	13	3.6	9.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/16/2010	11/21/2016	13	13	100	--	--	6,020	12,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/16/2010	11/21/2016	13	1	7.69	9.85	131	168	168	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/16/2010	11/21/2016	14	14	100	--	--	182	270	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/22/2010	11/21/2016	11	1	9.09	0.511	2.3	8.8	8.8	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
Tritium	No	pCi/L	11/22/2010	11/21/2016	7	6	85.71	290	290	538	1,220	119	6	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/16/2010	11/21/2016	14	11	78.57	10	17	6.1	13	12	4	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	11/21/2016	14	10	71.43	5	8.3	4.8	62	22	3	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-148																	
Arsenic	No	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	5.2	5.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/16/2010	11/21/2016	14	14	100	--	--	29	37	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Carbon-14	No	pCi/L	11/22/2010	11/21/2016	7	3	42.86	8.31	58	20	54	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/16/2010	5/25/2016	13	13	100	--	--	4.5	59	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	7.1	7.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/16/2010	11/21/2016	13	13	100	--	--	74	340	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/21/2016	8	1	12.5	1.76	3.3	2.0	2.0	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/21/2016	8	8	100	--	--	2.7	12	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/16/2010	11/21/2016	14	13	92.86	8	8.0	3.1	62	--	--	--	48	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/16/2010	11/21/2016	14	1	7.14	12.8	38	74	74	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	6/16/2010	11/21/2016	13	13	100	--	--	11,200	15,500	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/16/2010	11/21/2016	13	2	15.38	9.85	131	126	176	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/16/2010	11/21/2016	14	14	100	--	--	230	268	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	11/22/2010	11/21/2016	7	1	14.29	5.8	38	24	24	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	11/22/2010	11/21/2016	7	7	100	--	--	1,460	2,500	119	7	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/16/2010	11/21/2016	14	13	92.86	17	17	14	19	12	13	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	11/21/2016	14	10	71.43	3.3	7.0	5.6	42	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-161																	
Aluminum	No	ug/L	11/22/2010	11/21/2016	13	1	7.69	10	20	462	462	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	11/22/2010	11/21/2016	13	8	61.54	1.2	1.7	0.75	2.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/16/2010	11/21/2016	14	14	100	--	--	11	19	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/2/2011	11/21/2016	8	3	37.5	4	15	4.8	29	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/16/2010	11/21/2016	14	12	85.71	3.3	13	1.7	15	2.4	11	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	11/22/2010	11/21/2016	13	1	7.69	0.1	0.22	0.34	0.34	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	11/22/2010	11/21/2016	13	13	100	--	--	0.62	17	0.81	11	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/16/2010	11/21/2016	12	9	75	46	60	75	120	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/21/2016	8	1	12.5	1.02	3.3	0.40	0.40	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/21/2016	8	8	100	--	--	18	26	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/16/2010	11/21/2016	14	11	78.57	2	8.0	3.0	14	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/22/2010	11/21/2016	13	7	53.85	0.2	0.50	0.15	0.78	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	6/16/2010	11/21/2016	9	1	11.11	0.2	4.0	18	18	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/22/2010	11/21/2016	13	11	84.62	0.1	1.0	0.72	2.3	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/16/2010	11/21/2016	9	3	33.33	0.2	4.0	0.70	1.3	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/16/2010	11/21/2016	12	12	100	--	--	487	4,870	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/16/2010	11/21/2016	12	1	8.33	9.85	131	269	269	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/22/2010	11/21/2016	13	1	7.69	0.6	2.0	2.6	2.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium	No	ug/L	6/16/2010	11/21/2016	9	9	100	--	--	95	162	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	6/16/2010	11/21/2016	14	12	85.71	1.1	2.0	5.8	13	0.015	12	Scott W. Petersen, Jan. 27,1998 Memo	8.0	9	40 CFR 141 - federal MCL
Thallium	No	ug/L	11/22/2010	11/21/2016	13	1	7.69	0.1	0.60	1.4	1.4	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	11/22/2010	11/21/2016	13	2	15.38	0.1	1.0	0.14	3.5	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/22/2010	11/21/2016	7	1	14.29	93.6	394	124	124	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/20/2013	11/21/2016	7	7	100	--	--	0.50	0.85	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/16/2010	11/21/2016	8	7	87.5	12	12	3.1	6.7	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	11/21/2016	9	9	100	--	--	3.6	20	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-173																	
2-Propanol	No	ug/L	2/1/2017	2/1/2017	1	1	100	--	--	34	34	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	3/10/2010	2/1/2017	27	5	18.52	0.34	5.0	0.65	8.6	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	3/10/2010	4/18/2017	11	5	45.45	10	17	15	56	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	3/10/2010	4/18/2017	11	1	9.09	0.6	2.0	1.1	1.1	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	3/10/2010	4/18/2017	11	10	90.91	4	4.0	2.4	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	3/10/2010	4/18/2017	40	40	100	--	--	32	53	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	3/10/2010	4/18/2017	11	1	9.09	0.1	0.35	0.32	0.32	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/21/2011	4/18/2017	12	7	58.33	7.2	25	9.0	16	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Carbon-14	No	pCi/L	1/13/2011	2/1/2017	29	29	100	--	--	274	685	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	3/10/2010	2/1/2017	27	16	59.26	1	1.0	0.18	0.49	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	3/10/2010	4/18/2017	41	41	100	--	--	14	1,010	2.4	41	DOE/RL-96-61 Rev.0, Table ES-1	100	20	40 CFR 141 - federal MCL
Cobalt	No	ug/L	3/10/2010	4/18/2017	11	2	18.18	0.1	0.90	0.10	0.27	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	3/10/2010	4/18/2017	11	9	81.82	0.2	0.20	0.23	20	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	1/13/2011	2/1/2017	28	28	100	--	--	62	290	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	3/10/2010	3/15/2017	54	54	100	--	--	8.8	974	--	--	--	48	38	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/22/2010	4/18/2017	43	11	25.58	12.8	40	15	106	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	3/10/2010	4/18/2017	11	4	36.36	0.1	1.0	0.18	0.74	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	4/22/2010	4/18/2017	37	4	10.81	0.7	4.1	1.1	6.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	6/8/2011	1/4/2017	22	1	4.55	0.05	0.10	0.10	0.10	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Methylene chloride	No	ug/L	3/10/2010	2/1/2017	27	2	7.41	0.11	1.6	1.6	2.5	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	3/10/2010	4/18/2017	11	11	100	--	--	1.2	3.2	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/22/2010	4/18/2017	37	3	8.11	0.4	13	0.98	15	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	1/13/2011	2/1/2017	28	28	100	--	--	20,100	24,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	1/13/2011	2/1/2017	27	7	25.93	9.85	312	134	255	94	7	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
o-Xylene	No	ug/L	11/10/2016	11/10/2016	1	1	100	--	--	0.52	0.52	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Selenium	No	ug/L	3/10/2010	4/18/2017	11	4	36.36	0.6	2.0	0.76	5.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	4/22/2010	4/18/2017	29	29	100	--	--	54	319	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	1/13/2011	2/1/2017	10	1	10	0.82	1.9	1.7	1.7	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	1/13/2011	11/10/2016	7	7	100	--	--	14	47	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	3/10/2010	4/18/2017	11	1	9.09	0.1	0.60	1.7	1.7	1.7	1	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/10/2010	4/18/2017	11	2	18.18	0.1	1.2	0.46	0.72	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	3/10/2010	2/1/2017	27	1	3.7	0.062	1.0	0.14	0.14	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	3/10/2010	2/1/2017	27	27	100	--	--	2.8	5.3	--	--	--	0.54	27	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/13/2011	2/1/2017	29	29	100	--	--	813	1,850	119	29	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	7/16/2014	4/18/2017	5	5	100	--	--	1.6	3.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/22/2010	4/18/2017	43	33	76.74	10	17	8.5	23	12	14	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	3/10/2010	2/1/2017	27	1	3.7	0.11	1.0	0.52	0.52	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/22/2010	4/18/2017	37	10	27.03	3	7.5	5.7	19	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-178																	
Barium	No	ug/L	11/5/2009	5/25/2016	13	13	100	--	--	22	56	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/5/2009	5/25/2016	12	12	100	--	--	94	405	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	11/5/2009	5/25/2016	13	13	100	--	--	16	122	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	100	1	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Fluoride	No	ug/L	11/5/2009	5/25/2016	12	8	66.67	46	88	50	170	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	11/5/2009	11/18/2015	6	1	16.67	2.2	4.9	1.8	1.8	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	11/5/2009	11/18/2015	6	6	100	--	--	4.0	30	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	11/5/2009	5/25/2016	16	16	100	--	--	15	117	--	--	--	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	11/5/2009	5/25/2016	13	2	15.38	18	30	56	91	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	11/5/2009	5/25/2016	13	1	7.69	2	4.0	5.3	5.3	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	11/5/2009	5/25/2016	13	3	23.08	1.5	5.0	3.5	8.0	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	11/5/2009	5/25/2016	12	12	100	--	--	11,100	18,100	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	11/5/2009	5/25/2016	12	3	25	9.85	131	185	230	94	3	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/5/2009	5/25/2016	13	13	100	--	--	182	471	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/5/2009	5/25/2016	13	8	61.54	1.65	2.0	1.4	4.3	0.015	8	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	11/5/2009	5/25/2016	13	13	100	--	--	980	4,000	119	13	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	11/5/2009	5/25/2016	13	6	46.15	5	12	4.2	5.8	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	11/5/2009	5/25/2016	13	12	92.31	6	6.0	5.0	32	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-183																	
2-Butanone	No	ug/L	6/10/2011	11/28/2016	25	1	4	0.52	3.0	0.71	0.71	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/24/2011	11/28/2016	21	2	9.52	10	20	20	59	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Antimony	No	ug/L	10/24/2011	11/28/2016	21	1	4.76	0.6	1.7	0.51	0.51	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/24/2011	11/28/2016	21	20	95.24	1.7	1.7	1.8	5.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	7/20/2011	2/23/2017	25	25	100	--	--	39	64	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/24/2011	11/28/2016	14	11	78.57	15	15	13	46	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	7/20/2011	2/23/2017	24	24	100	--	--	253	555	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/10/2011	11/28/2016	25	11	44	0.3	1.0	0.28	0.40	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	7/20/2011	2/23/2017	25	25	100	--	--	2.9	11	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/24/2011	11/28/2016	21	3	14.29	0.1	0.22	0.11	0.16	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/24/2011	11/28/2016	21	12	57.14	0.2	0.56	0.36	3.2	0.81	4	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	7/20/2011	2/23/2017	21	21	100	--	--	82	200	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	7/20/2011	2/23/2017	25	24	96	3.7	3.7	5.0	10	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	7/20/2011	2/23/2017	13	2	15.38	16	30	21	31	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/24/2011	11/28/2016	21	2	9.52	0.1	0.50	0.12	0.23	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	7/20/2011	2/23/2017	17	1	5.88	0.2	4.0	0.48	0.48	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/10/2011	11/28/2016	25	2	8	0.27	1.6	1.7	1.8	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	10/24/2011	11/28/2016	21	20	95.24	0.1	0.10	1.1	3.5	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	7/20/2011	2/23/2017	17	7	41.18	0.2	1.6	0.35	4.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	7/20/2011	2/23/2017	21	21	100	--	--	23,900	27,000	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	7/20/2011	2/23/2017	21	5	23.81	9.85	131	178	263	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/24/2011	11/28/2016	21	5	23.81	1.5	2.0	1.3	2.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	7/20/2011	11/28/2016	14	14	100	--	--	199	265	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	7/20/2011	2/23/2017	25	2	8	0.57	2.0	1.2	1.6	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	7/20/2011	11/28/2016	22	21	95.45	45.1	45	32	76	0.83	21	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/24/2011	11/28/2016	21	1	4.76	0.05	0.55	1.5	1.5	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/24/2011	11/28/2016	21	2	9.52	0.1	1.0	0.27	4.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	6/10/2011	11/28/2016	25	25	100	--	--	2.9	5.1	--	--	--	0.54	25	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	7/20/2011	2/23/2017	25	25	100	--	--	1,130	2,020	119	25	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/22/2013	11/28/2016	13	13	100	--	--	1.4	2.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	7/20/2011	2/23/2017	15	15	100	--	--	9.3	13	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	7/20/2011	2/23/2017	17	2	11.76	3.3	8.3	2.1	4.8	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-186																	
Acetone	No	ug/L	5/11/2011	11/13/2016	7	1	14.29	0.34	5.0	0.61	0.61	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/10/2011	11/13/2016	21	19	90.48	10	14	10	111	7.1	19	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/10/2011	11/13/2016	21	2	9.52	0.084	1.7	0.11	0.18	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	10/10/2011	11/13/2016	21	21	100	--	--	2.5	5.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	5/11/2011	11/13/2016	22	22	100	--	--	25	34	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/10/2011	11/13/2016	14	7	50	6.4	10	8.9	16	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	5/11/2011	11/13/2016	22	20	90.91	34.9	55	18	151	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	5/11/2011	11/13/2016	7	5	71.43	1	1.0	0.63	1.8	--	--	--	1.4	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	5/11/2011	11/13/2016	22	22	100	--	--	7.2	32	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/10/2011	11/13/2016	21	4	19.05	0.07	0.22	0.070	3.8	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/10/2011	11/13/2016	21	7	33.33	0.2	1.1	0.28	1.5	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	5/11/2011	11/13/2016	21	19	90.48	72	72	78	250	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/11/2011	11/13/2016	22	22	100	--	--	3.9	31	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	5/11/2011	11/13/2016	10	9	90	20	20	34	150	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/10/2011	11/13/2016	21	5	23.81	0.1	0.50	0.10	0.24	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	5/11/2011	11/13/2016	14	13	92.86	0.3	0.30	1.6	100	39	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	5/11/2011	11/13/2016	7	1	14.29	0.27	1.0	0.38	0.38	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	10/10/2011	11/13/2016	21	21	100	--	--	0.77	6.2	3.2	4	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	5/11/2011	11/13/2016	14	3	21.43	0.2	4.2	0.46	9.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	5/11/2011	11/13/2016	21	21	100	--	--	1,650	9,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	5/11/2011	11/13/2016	21	6	28.57	9.85	131	167	427	94	6	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/10/2011	11/13/2016	21	3	14.29	0.66	2.0	0.72	2.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	5/11/2011	11/13/2016	22	1	4.55	0.039	5.1	0.30	0.30	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	5/11/2011	11/13/2016	14	14	100	--	--	178	279	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	5/11/2011	11/13/2016	22	3	13.64	0.379	2.0	1.4	1.6	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tin	No	ug/L	10/10/2011	11/13/2016	21	2	9.52	0.1	1.3	0.10	0.29	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total petroleum hydrocarbons - gasoline range	No	ug/L	10/10/2011	11/13/2016	6	2	33.33	10	50	21	26	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	5/11/2011	11/13/2016	7	3	42.86	0.16	1.0	0.47	0.64	--	--	--	0.54	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	5/11/2011	11/13/2016	22	6	27.27	260	360	121	1,560	119	6	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/22/2013	11/13/2016	13	13	100	--	--	1.9	2.8	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	5/11/2011	11/13/2016	12	11	91.67	8.1	8.1	5.2	15	12	7	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	5/11/2011	11/13/2016	14	1	7.14	3.5	9.3	14	14	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-187																	
Aluminum	No	ug/L	10/25/2011	11/13/2016	21	4	19.05	10	20	10	180	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/25/2011	11/13/2016	21	20	95.24	1.7	1.7	3.5	5.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/26/2011	11/13/2016	24	24	100	--	--	31	47	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Boron	No	ug/L	10/25/2011	11/13/2016	14	8	57.14	15	15	13	20	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	ug/L	4/26/2011	11/13/2016	8	1	12.5	0.3	1.0	0.21	0.21	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	4/26/2011	11/13/2016	24	24	100	--	--	4.6	23	2.4	24	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/25/2011	11/13/2016	21	6	28.57	0.1	0.22	0.12	0.20	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/25/2011	11/13/2016	21	11	52.38	0.2	0.45	0.22	0.95	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/26/2011	11/13/2016	20	20	100	--	--	134	280	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	4/26/2011	11/13/2016	24	20	83.33	2	8.0	2.8	53	--	--	--	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/26/2011	11/13/2016	12	8	66.67	30	30	34	837	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/25/2011	11/13/2016	21	4	19.05	0.1	0.50	0.14	0.19	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	4/26/2011	11/13/2016	16	11	68.75	1	1.0	0.49	36	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/25/2011	11/13/2016	21	21	100	--	--	3.7	9.4	3.2	21	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/26/2011	11/13/2016	16	15	93.75	5.1	5.1	0.90	17	1.6	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	4/26/2011	11/13/2016	20	20	100	--	--	15,700	24,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/26/2011	11/13/2016	20	7	35	9.85	131	95	308	94	7	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/25/2011	11/13/2016	21	6	28.57	1.5	2.0	1.5	3.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	4/26/2011	11/13/2016	24	2	8.33	0.1	5.1	0.088	13	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium	No	ug/L	4/26/2011	11/13/2016	16	16	100	--	--	175	242	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/26/2011	11/13/2016	24	7	29.17	0.656	1.9	1.2	4.5	0.015	7	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	4/26/2011	11/13/2016	24	24	100	--	--	16	65	0.83	24	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/25/2011	11/13/2016	21	1	4.76	0.1	0.60	0.63	0.63	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/25/2011	11/13/2016	21	3	14.29	0.1	1.0	0.14	1.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	4/26/2011	11/13/2016	8	5	62.5	1	1.0	1.5	1.6	--	--	--	0.54	5	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	4/26/2011	11/13/2016	24	23	95.83	250	250	280	1,000	119	23	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/22/2013	11/13/2016	13	13	100	--	--	2.7	3.3	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/26/2011	11/13/2016	14	14	100	--	--	9.0	15	12	13	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/26/2011	11/13/2016	16	3	18.75	3.5	8.3	4.0	5.0	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-188																	
Arsenic	No	ug/L	8/13/2014	11/21/2014	2	2	100	--	--	2.1	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/14/2011	11/30/2016	16	16	100	--	--	33	51	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	6/14/2011	11/30/2016	16	16	100	--	--	51	103	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/14/2011	11/30/2016	6	3	50	1	1.0	0.22	0.32	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/14/2011	8/31/2016	15	15	100	--	--	9.0	44	2.4	15	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	6/14/2011	11/30/2016	15	15	100	--	--	344	500	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	6/14/2011	11/30/2016	15	15	100	--	--	8.3	44	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/14/2011	11/30/2016	16	12	75	12.8	30	16	242	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/14/2011	11/30/2016	16	13	81.25	1	4.0	1.0	32	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/14/2011	11/30/2016	16	6	37.5	1.5	10	3.6	8.0	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/14/2011	11/30/2016	15	15	100	--	--	17,700	21,700	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/14/2011	11/30/2016	15	1	6.67	19.7	131	172	172	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/14/2011	11/30/2016	16	16	100	--	--	170	312	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	6/14/2011	11/30/2016	16	2	12.5	0.317	2.1	1.3	1.6	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	6/14/2011	11/30/2016	16	15	93.75	6.3	6.3	9.6	37	0.83	15	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	6/14/2011	11/30/2016	6	5	83.33	1	1.0	1.5	2.0	--	--	--	0.54	5	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	6/14/2011	11/30/2016	16	13	81.25	280	340	370	638	119	13	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/14/2011	11/30/2016	16	16	100	--	--	9.2	15	12	8	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/14/2011	11/30/2016	16	4	25	3	8.3	5.4	21	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-191																	
Acetone	No	ug/L	6/10/2011	11/13/2016	8	1	12.5	0.34	5.0	1.5	1.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	11/9/2011	11/13/2016	21	10	47.62	10	20	5.5	45	7.1	9	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	11/9/2011	11/13/2016	21	4	19.05	0.6	2.0	0.23	0.58	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	11/9/2011	11/13/2016	21	20	95.24	1.7	1.7	2.9	4.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/10/2011	11/13/2016	23	23	100	--	--	27	40	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	11/9/2011	11/13/2016	21	1	4.76	0.1	0.35	0.30	0.30	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/9/2011	11/13/2016	14	9	64.29	6.4	25	7.1	22	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	6/10/2011	11/13/2016	23	7	30.43	7.97	55	4.4	8.3	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/10/2011	11/13/2016	8	4	50	1	1.0	0.54	0.72	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/10/2011	11/13/2016	23	21	91.3	1.1	4.0	2.9	11	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	11/9/2011	11/13/2016	21	3	14.29	0.05	0.90	0.10	0.19	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	11/9/2011	11/13/2016	21	15	71.43	0.2	1.1	0.19	3.4	0.81	10	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/10/2011	11/13/2016	21	21	100	--	--	148	340	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	6/10/2011	11/13/2016	23	19	82.61	2	8.0	2.3	10	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/10/2011	11/13/2016	11	7	63.64	12.8	38	13	95	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/9/2011	11/13/2016	21	1	4.76	0.05	1.0	0.24	0.24	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	6/10/2011	11/13/2016	15	8	53.33	0.2	1.0	0.38	36	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/10/2011	11/13/2016	8	1	12.5	0.27	1.0	1.5	1.5	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	11/9/2011	11/13/2016	21	21	100	--	--	5.7	13	3.2	21	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/10/2011	11/13/2016	15	9	60	0.2	4.2	0.36	8.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	6/10/2011	11/13/2016	21	21	100	--	--	11,300	22,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/10/2011	11/13/2016	21	4	19.05	9.85	131	151	186	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/9/2011	11/13/2016	21	5	23.81	1	2.0	0.72	5.0	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/10/2011	11/13/2016	23	1	4.35	0.039	5.1	0.040	0.040	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/10/2011	11/13/2016	15	15	100	--	--	194	253	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	6/10/2011	11/13/2016	23	3	13.04	0.322	2.0	0.98	3.4	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	11/9/2011	11/13/2016	21	1	4.76	0.014	0.90	0.020	0.020	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	0	40 CFR 141 - federal MCLG
Tin	No	ug/L	11/9/2011	11/13/2016	21	2	9.52	0.05	1.3	0.12	4.2	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	6/10/2011	11/13/2016	23	23	100	--	--	3,900	7,910	119	23	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/22/2013	11/13/2016	13	13	100	--	--	2.0	2.8	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/10/2011	11/13/2016	13	10	76.92	4.4	15	7.0	12	12	6	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/10/2011	11/13/2016	15	1	6.67	3.5	9.3	10	10	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-194																	
1,2,4-Trichlorobenzene	No	ug/L	11/14/2016	11/14/2016	1	1	100	--	--	0.65	0.65	--	--	--	1.5	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
1,2-Dichlorobenzene	No	ug/L	11/14/2016	11/14/2016	1	1	100	--	--	0.20	0.20	--	--	--	600	0	40 CFR 141 - federal MCL
Acetone	No	ug/L	5/11/2011	11/14/2016	22	1	4.55	0.34	5.0	3.1	3.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/26/2011	11/14/2016	21	12	57.14	10	20	14	55	7.1	12	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	10/26/2011	11/14/2016	21	21	100	--	--	4.1	6.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	5/11/2011	11/14/2016	22	22	100	--	--	23	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/26/2011	11/14/2016	14	8	57.14	10	15	8.0	19	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	5/11/2011	11/14/2016	22	3	13.64	3.53	56	5.6	8.6	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	5/11/2011	11/14/2016	22	12	54.55	1	1.0	0.14	1.2	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	5/11/2011	11/14/2016	22	22	100	--	--	7.3	19	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/26/2011	11/14/2016	21	4	19.05	0.054	0.22	0.15	14	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/26/2011	11/14/2016	21	16	76.19	0.2	0.56	0.35	1.3	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	5/11/2011	11/14/2016	19	19	100	--	--	178	323	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/11/2011	11/14/2016	21	21	100	--	--	5.6	15	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	5/11/2011	11/14/2016	20	11	55	20	40	22	224	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/26/2011	11/14/2016	21	2	9.52	0.1	0.50	0.11	0.30	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	5/11/2011	11/14/2016	20	13	65	1	4.0	0.52	12	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	5/11/2011	11/14/2016	22	3	13.64	0.27	1.6	0.31	5.3	--	--	--	5.0	1	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	10/26/2011	11/14/2016	21	21	100	--	--	6.1	8.7	3.2	21	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	5/11/2011	11/14/2016	20	14	70	0.5	5.0	0.70	14	1.6	8	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	5/11/2011	11/14/2016	19	19	100	--	--	9,430	14,600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	5/11/2011	11/14/2016	19	4	21.05	9.85	131	169	211	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/26/2011	11/14/2016	21	13	61.9	1.5	2.0	1.2	3.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	5/11/2011	11/14/2016	22	2	9.09	0.033	5.1	0.18	0.29	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	5/11/2011	11/14/2016	20	20	100	--	--	252	364	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	5/11/2011	11/14/2016	22	2	9.09	0.56	2.0	1.6	1.8	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/26/2011	11/14/2016	21	1	4.76	0.05	0.55	0.13	0.13	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	0	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/26/2011	11/14/2016	21	5	23.81	0.1	1.0	0.12	6.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	5/11/2011	11/14/2016	22	13	59.09	260	380	640	1,650	119	13	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/19/2013	11/14/2016	13	13	100	--	--	2.7	3.7	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	5/11/2011	11/14/2016	20	20	100	--	--	11	20	12	19	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	5/11/2011	11/14/2016	20	3	15	2	5.0	6.2	13	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-204																	
2-Propanol	No	ug/L	2/26/2017	2/26/2017	1	1	100	--	--	11	11	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	6/9/2016	3/13/2017	10	3	30	0.55	0.55	0.86	3.0	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	12/15/2015	12/11/2016	2	2	100	--	--	28	99	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	12/15/2015	12/11/2016	2	1	50	2	2.0	0.24	0.24	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	12/15/2015	12/11/2016	2	1	50	4	4.0	2.0	2.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Barium	No	ug/L	12/15/2015	2/26/2017	7	7	100	--	--	31	59	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	12/15/2015	12/11/2016	2	1	50	25	25	11	11	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	4/17/2015	3/13/2017	19	19	100	--	--	5,130	26,600	--	--	--	2,000	19	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/9/2016	3/13/2017	10	10	100	--	--	0.43	0.63	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	12/15/2015	2/26/2017	7	7	100	--	--	4.5	16	2.4	7	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	12/15/2015	12/11/2016	2	1	50	0.9	0.90	0.41	0.41	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	12/15/2015	12/11/2016	2	1	50	2	2.0	0.48	0.48	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cyanide	No	ug/L	12/11/2016	3/13/2017	4	1	25	3.1	3.1	6.5	6.5	8.4	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	12/15/2015	2/26/2017	15	15	100	--	--	180	260	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	4/17/2015	12/11/2016	7	7	100	--	--	2.6	5.6	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	4/17/2015	12/11/2016	7	7	100	--	--	8.2	12	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/17/2015	3/13/2017	18	15	83.33	1.5	1.5	1.6	7.7	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/15/2015	2/26/2017	7	7	100	--	--	44	290	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	12/15/2015	12/11/2016	2	1	50	1	1.0	0.29	0.29	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/15/2015	2/26/2017	7	6	85.71	4	4.0	1.2	120	39	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	12/15/2015	12/11/2016	2	1	50	2	2.0	1.5	1.5	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/15/2015	2/26/2017	7	1	14.29	1.6	10	6.2	6.2	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	12/15/2015	2/26/2017	15	15	100	--	--	35,000	44,300	26,871	15	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	12/15/2015	2/26/2017	15	1	6.67	125	125	282	282	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/15/2015	2/26/2017	7	1	14.29	0.9	3.0	0.050	0.050	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/15/2015	12/11/2016	2	2	100	--	--	350	396	323	2	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	4/17/2015	12/11/2016	7	1	14.29	9.09	37	9.9	9.9	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tin	No	ug/L	12/15/2015	12/11/2016	2	1	50	1.2	1.2	1.4	1.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	6/9/2016	3/13/2017	10	10	100	--	--	1.8	5.3	--	--	--	0.54	10	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	4/17/2015	2/26/2017	17	17	100	--	--	718	13,100	119	17	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/15/2015	12/11/2016	2	2	100	--	--	5.7	7.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/15/2015	2/26/2017	7	6	85.71	15	15	7.3	21	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	12/15/2015	2/26/2017	7	1	14.29	3	7.5	9.7	9.7	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-221																	
Arsenic	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	2.3	2.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	35	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	31	31	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	11/13/2015	1/30/2017	5	5	100	--	--	75	1,930	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	15	15	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Copper	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	0.72	0.72	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	180	180	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	11/13/2015	1/30/2017	5	4	80	1.08	1.1	2.1	6.7	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	11/13/2015	1/30/2017	5	5	100	--	--	9.5	30	0.0081	5	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	11/13/2015	1/30/2017	5	5	100	--	--	6.9	32	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	26	26	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	4.1	4.1	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	1.1	1.1	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	30,500	30,500	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	315	315	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/13/2015	1/30/2017	5	3	60	0.845	1.4	2.7	8.7	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	11/13/2015	11/13/2015	1	1	100	--	--	64	64	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tin	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	1.2	1.2	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/13/2015	1/30/2017	5	5	100	--	--	569	30,100	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	2	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	14	14	9.9	1	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	4.5	4.5	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-222																	
Aluminum	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	40	223	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/13/2015	10/20/2016	2	1	50	4	4.0	2.6	2.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	29	39	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/13/2015	1/30/2017	6	6	100	--	--	166	239	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	11	21	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	0.98	1.2	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	140	180	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	11/13/2015	1/30/2017	6	6	100	--	--	14	344	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	11/13/2015	1/30/2017	6	6	100	--	--	5.4	20	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	81	241	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/13/2015	10/20/2016	2	1	50	1	1.0	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	20	23	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/13/2015	10/20/2016	2	1	50	2	2.0	9.1	9.1	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	2.2	2.4	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	14,200	24,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	11/13/2015	10/20/2016	2	1	50	125	125	138	138	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Selenium	No	ug/L	11/13/2015	10/20/2016	2	1	50	1.6	1.6	2.1	2.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	216	295	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/13/2015	1/30/2017	6	6	100	--	--	3.9	152	0.015	6	Scott W. Petersen, Jan. 27,1998 Memo	8.0	4	40 CFR 141 - federal MCL
Tritium	No	pCi/L	11/13/2015	1/30/2017	6	1	16.67	298	441	403	403	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	1.6	2.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	11/13/2015	10/20/2016	2	1	50	15	15	5.6	5.6	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
699-72-73																	
Aluminum	No	ug/L	10/22/2009	10/28/2016	11	4	36.36	10	20	20	51	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/22/2009	10/28/2016	11	11	100	--	--	3.1	5.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	10/28/2016	11	11	100	--	--	21	34	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	3/5/2010	10/28/2016	8	7	87.5	25	25	18	25	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	6/11/2010	3	1	33.33	0.084	1.0	0.98	0.98	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	10/28/2016	11	11	100	--	--	3.8	12	2.4	11	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	10/28/2016	11	1	9.09	0.1	0.90	0.14	0.14	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	10/28/2016	11	3	27.27	0.2	0.68	0.22	0.56	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	3/5/2010	10/28/2016	11	11	100	--	--	200	510	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/22/2009	10/28/2016	11	7	63.64	2	3.7	2.6	10	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	No	ug/L	3/5/2010	10/28/2016	8	7	87.5	40	40	39	230	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	10/28/2016	11	1	9.09	0.1	1.0	0.35	0.35	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/5/2010	6/11/2010	2	2	100	--	--	6.3	19	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	3/5/2010	10/28/2016	8	8	100	--	--	1.4	17	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/5/2010	10/28/2016	10	10	100	--	--	3.4	6.0	3.2	10	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	3/5/2010	10/28/2016	8	4	50	0.8	4.0	0.33	0.52	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	3/5/2010	10/28/2016	11	11	100	--	--	7,080	24,900	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	3/5/2010	10/28/2016	11	2	18.18	9.85	131	164	239	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	10/28/2016	11	7	63.64	2	2.0	1.7	4.0	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	3/5/2010	10/28/2016	8	8	100	--	--	124	209	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	5/11/2010	10/28/2016	9	7	77.78	9.53	16	11	52	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/22/2009	10/28/2016	11	1	9.09	0.1	0.90	0.86	0.86	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/5/2010	10/28/2016	10	2	20	0.1	1.2	0.17	3.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	6/11/2010	3	2	66.67	1	1.0	0.89	0.98	--	--	--	0.54	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	3/5/2010	10/28/2016	10	10	100	--	--	1,540	12,000	119	10	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	10/28/2016	8	8	100	--	--	1.7	2.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL

Table D-9. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Vanadium	No	ug/L	3/5/2010	10/28/2016	8	7	87.5	15	15	12	18	12	7	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	3/5/2010	10/28/2016	8	1	12.5	4	9.3	2.1	2.1	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-10. Groundwater Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	Yes	ug/L	10/22/2009	4/18/2017	294	41	13.95	5	20	10	680	7.1	41	DOE/RL-96-61 Rev.0, Table ES-1	87.0	4	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	4/18/2017	303	263	86.8	0.4	4	0.408	7.91	7.9	1	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	4/18/2017	303	6	1.98	0.05	0.34	0.1	0.81	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	1	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	4/18/2017	511	471	92.17	0.2	14	0.537	5,220	2.4	429	DOE/RL-96-61 Rev.0, Table ES-1	74.0	48	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	4/18/2017	303	145	47.85	0.1	2.1	0.204	19.9	0.81	70	DOE/RL-96-61 Rev.0, Table ES-1	9.9	4	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	3/23/2017	562	460	81.85	1.5	9.68	1.5	3,310	--	--	--	10.0	269	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	4/18/2017	393	69	17.56	12.8	40	12.8	654	570	2	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	4/18/2017	294	40	13.61	0.05	1	0.102	1	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	4/18/2017	423	118	27.9	0.1	133	0.208	38.3	1.6	64	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	4/18/2017	294	76	25.85	0.3	2	0.61	5.6	10.5		DOE/RL-96-61 Rev.0, Table ES-1	5.0	1	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	4/18/2017	513	10	1.95	0.033	7	0.039	40	5.3	4	DOE/RL-96-61 Rev.0, Table ES-1	2.6	5	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	4/18/2017	423	145	34.28	0.8	30	1.82	547	21.8	10	DOE/RL-96-61 Rev.0, Table ES-1	91.0	1	WAC 173-201A - freshwater CCC
Cation																	
Chloride	No	ug/L	10/22/2009	2/26/2017	466	466	100	--	--	798	50,000	--	--	--	230,000	0	CWA - freshwater CCC
Cyanide	No	ug/L	6/24/2010	3/13/2017	7	1	14.29	3.1	4	6.5	6.5	8.4	0	DOE/RL-96-61 Rev.0, Table ES-1	5.2	1	WAC 173-201A - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-11																	
Aluminum	Yes	ug/L	10/28/2009	11/30/2016	10	2	20	10	20	44	146	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/28/2009	11/30/2016	10	9	90	0.4	0.40	5.6	7.9	7.9	1	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/28/2009	11/30/2016	10	1	10	0.1	0.20	0.11	0.11	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/28/2009	11/30/2016	10	9	90	0.2	0.20	2.0	19	2.4	8	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/28/2009	11/30/2016	10	1	10	0.2	0.68	0.38	0.38	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	ug/L	10/28/2009	11/30/2016	10	8	80	2	2.0	3.2	17	--	--	--	10	2	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/28/2009	11/30/2016	7	2	28.57	12.8	38	20	111	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/28/2009	11/30/2016	10	0	0	0.1	1.0	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/28/2009	6/11/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/28/2009	11/30/2016	8	0	0	0.2	4.0	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/28/2009	11/30/2016	10	3	30	0.6	2.0	0.63	4.0	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/28/2009	11/30/2016	10	0	0	0.1	0.90	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/28/2009	11/30/2016	8	1	12.5	1.6	9.3	12	12	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-20																	
Aluminum	Yes	ug/L	10/28/2009	2/1/2017	26	5	19.23	10	20	15	53	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/28/2009	2/1/2017	26	23	88.46	1.7	4.0	0.54	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/28/2009	2/1/2017	26	1	3.85	0.099	0.20	0.21	0.21	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	10/28/2009	2/1/2017	26	22	84.62	0.2	4.0	1.5	6.6	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/28/2009	2/1/2017	26	15	57.69	0.2	2.0	0.21	1.1	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/28/2009	2/1/2017	27	13	48.15	1.5	2.0	1.5	9.0	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/28/2009	2/1/2017	13	3	23.08	12.8	38	26	64	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/28/2009	2/1/2017	26	3	11.54	0.1	1.0	0.10	0.52	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/28/2009	6/16/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/28/2009	2/1/2017	17	4	23.53	0.2	4.2	0.21	1.1	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/28/2009	2/1/2017	26	10	38.46	1.5	2.0	0.66	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/28/2009	2/1/2017	26	1	3.85	0.039	0.90	0.050	0.050	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/28/2009	2/1/2017	17	4	23.53	1.6	9.3	4.1	36	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-21																	
Aluminum	Yes	ug/L	12/3/2010	10/13/2016	7	3	42.86	12.9	20	15	18	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/3/2010	10/13/2016	7	1	14.29	0.4	1.7	0.92	0.92	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/3/2010	10/13/2016	7	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	12/3/2010	10/13/2016	7	6	85.71	2	2.0	1.6	24	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	12/3/2010	10/13/2016	7	5	71.43	0.2	0.35	0.21	1.0	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	7/25/2010	10/13/2016	14	10	71.43	1.5	8.0	1.7	18	--	--	--	10	7	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/3/2010	10/13/2016	4	4	100	--	--	74	575	570	1	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	Yes	ug/L	12/3/2010	10/13/2016	7	0	0	0.1	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/3/2010	10/13/2016	5	5	100	--	--	2.9	6.7	1.6	5	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	12/3/2010	10/13/2016	7	0	0	0.6	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/3/2010	10/13/2016	7	0	0	0.04	0.40	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/3/2010	10/13/2016	5	0	0	1.6	4.0	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-31																	
Aluminum	Yes	ug/L	10/22/2009	11/28/2016	17	4	23.53	10	20	25	366	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/28/2016	17	16	94.12	4	4.0	1.3	2.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	11/28/2016	17	1	5.88	0.05	0.20	0.10	0.10	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	2/23/2017	21	21	100	--	--	2.6	14	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/28/2016	17	3	17.65	0.1	0.68	0.25	2.6	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	2/23/2017	15	14	93.33	3.7	3.7	4.4	9.4	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	2/23/2017	14	4	28.57	12.8	40	19	408	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	11/28/2016	17	2	11.76	0.05	1.0	0.29	0.33	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	12/31/2013	4	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	2/23/2017	16	2	12.5	0.1	4.2	0.44	0.48	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	11/28/2016	17	10	58.82	1.6	2.0	0.61	3.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	2/23/2017	21	0	0	0.039	1.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	Yes	ug/L	10/22/2009	2/23/2017	16	3	18.75	2	9.3	2.1	23	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-35/199-K-195/199-K-205																	
Aluminum	Yes	ug/L	12/11/2014	11/10/2016	3	0	0	15	15	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/11/2014	11/10/2016	3	3	100	--	--	3.6	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/11/2014	11/10/2016	3	0	0	0.11	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	12/22/2009	2/1/2017	26	26	100	--	--	20	3,360	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	74	21	CWA - freshwater CCC
Copper	Yes	ug/L	12/11/2014	11/10/2016	3	0	0	0.35	0.35	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	12/22/2009	3/15/2017	39	39	100	--	--	13	3,310	--	--	--	10	39	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/22/2009	2/15/2017	26	6	23.08	18	30	20	654	570	1	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	12/11/2014	11/10/2016	3	0	0	0.5	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	12/22/2009	4/15/2010	13	0	0	0.05	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/22/2009	2/1/2017	25	3	12	0.5	5.0	1.2	38	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	12/11/2014	11/10/2016	3	0	0	1.5	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/22/2009	2/1/2017	25	1	4	0.1	5.0	1.2	1.2	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/22/2009	2/1/2017	25	1	4	3.3	6.0	9.3	9.3	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-37																	
Aluminum	Yes	ug/L	10/22/2009	1/9/2011	5	2	40	10	10	76	232	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	3.2	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

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Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	5/5/2016	16	16	100	--	--	17	57	2.4	16	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.2	0.43	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	11/18/2016	18	18	100	--	--	16	57	--	--	--	10	18	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	11/18/2016	17	1	5.88	18	38	32	32	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	11/18/2016	17	2	11.76	1.5	13	1.8	4.7	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	1.1	1.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	11/18/2016	17	0	0	0.2	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	11/18/2016	17	2	11.76	3.3	30	3.9	5.1	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-113A																	
Aluminum	Yes	ug/L	11/15/2011	11/16/2016	11	1	9.09	10	20	18	18	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/15/2011	11/16/2016	11	9	81.82	1.2	1.2	0.81	1.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/15/2011	11/16/2016	11	1	9.09	0.099	0.10	0.11	0.11	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	1/31/2011	11/16/2016	13	9	69.23	1.1	14	0.58	11	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/15/2011	11/16/2016	11	11	100	--	--	1.5	8.3	0.81	11	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	ug/L	1/31/2011	11/16/2016	13	5	38.46	1.5	8.0	2.0	9.3	--	--	--	10	0	WAC 173-201A - freshwater CCC

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Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	Yes	ug/L	1/31/2011	11/16/2016	7	1	14.29	12.8	38	16	16	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/15/2011	11/16/2016	11	6	54.55	0.1	0.17	0.11	0.27	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	1/31/2011	11/16/2016	9	6	66.67	4	4.2	0.40	14	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/15/2011	11/16/2016	11	1	9.09	0.66	2.0	2.1	2.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	1/31/2011	11/16/2016	13	0	0	0.039	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	1/31/2011	11/16/2016	9	9	100	--	--	5.0	23	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-114A																	
Aluminum	Yes	ug/L	11/15/2011	11/16/2016	11	0	0	10	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/15/2011	11/16/2016	11	4	36.36	0.95	1.7	0.41	0.88	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/15/2011	11/16/2016	11	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/16/2010	11/16/2016	14	3	21.43	0.2	14	1.2	2.5	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/15/2011	11/16/2016	11	11	100	--	--	3.0	7.1	0.81	11	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/16/2010	11/16/2016	14	3	21.43	1.5	8.0	2.2	2.6	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/16/2010	11/16/2016	8	0	0	18	38	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/15/2011	11/16/2016	11	5	45.45	0.5	0.50	0.14	0.23	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/16/2010	11/16/2016	10	0	0	0.2	5.0	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/15/2011	11/16/2016	11	0	0	1.5	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/16/2010	11/16/2016	14	0	0	0.04	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	Yes	ug/L	6/16/2010	11/16/2016	10	8	80	3.5	4.0	3.6	8.6	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-117A																	
Aluminum	Yes	ug/L	10/22/2009	1/30/2017	28	4	14.29	5	20	19	680	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87	1	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	1/30/2017	28	18	64.29	0.8	4.0	0.47	1.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	1/30/2017	28	1	3.57	0.05	0.20	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	1/30/2017	28	26	92.86	1	4.0	0.97	3.8	2.4	7	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	1/30/2017	28	14	50	0.2	1.1	0.21	4.0	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	1/30/2017	26	3	11.54	1.5	8.0	1.7	2.6	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	1/30/2017	15	3	20	12.8	38	26	48	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	1/30/2017	28	5	17.86	0.05	1.0	0.17	0.51	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	1/30/2017	17	9	52.94	0.4	13	0.62	7.3	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	1/30/2017	28	2	7.14	0.3	2.0	0.63	2.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	1/30/2017	28	0	0	0.039	0.90	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	1/30/2017	17	2	11.76	1.6	9.3	5.8	13	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-125A																	
Aluminum	Yes	ug/L	11/11/2011	11/15/2016	11	1	9.09	10	20	17	17	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/11/2011	11/15/2016	11	11	100	--	--	3.1	4.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	Yes	ug/L	11/11/2011	11/15/2016	11	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	2/18/2010	11/15/2016	15	11	73.33	3	14	2.2	5.7	2.4	10	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/11/2011	11/15/2016	11	4	36.36	0.2	0.45	0.41	0.76	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	2/18/2010	11/15/2016	17	8	47.06	1.5	9.7	2.0	5.8	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	2/18/2010	11/15/2016	9	1	11.11	20	38	18	18	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/11/2011	11/15/2016	11	1	9.09	0.1	0.50	0.11	0.11	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	2/18/2010	11/15/2016	11	5	45.45	0.5	4.0	0.56	12	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/11/2011	11/15/2016	11	0	0	1.5	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	2/18/2010	11/15/2016	15	0	0	0.04	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	2/18/2010	11/15/2016	11	5	45.45	3.5	4.1	4.0	28	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-138																	
Arsenic	Yes	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	1.8	1.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/19/2014	11/19/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	2/13/2017	18	17	94.44	14	14	8.2	19	2.4	17	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	3.1	3.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	2/3/2010	2/13/2017	22	22	100	--	--	6.0	24	--	--	--	10	12	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/15/2010	2/13/2017	18	5	27.78	12.8	38	26	41	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/15/2010	2/13/2017	18	6	33.33	1.3	67	2.6	7.0	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	6/15/2010	2/13/2017	18	0	0	0.93	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/13/2017	18	11	61.11	3.3	6.0	3.0	21	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-141																	
Aluminum	Yes	ug/L	11/24/2014	11/21/2016	5	0	0	15	15	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	5/22/2014	11/21/2016	7	7	100	--	--	3.4	3.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/22/2014	11/21/2016	7	0	0	0.11	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	1/7/2010	11/21/2016	25	25	100	--	--	18	45	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	5/22/2014	11/21/2016	7	7	100	--	--	3.2	17	0.81	7	DOE/RL-96-61 Rev.0, Table ES-1	9.9	1	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	1/7/2010	7/28/2016	24	23	95.83	2	2.0	19	48	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	1/7/2010	11/21/2016	25	4	16	12.8	38	20	28	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/24/2014	11/21/2016	5	0	0	0.5	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	1/7/2010	11/21/2016	25	5	20	0.5	13	0.64	7.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/24/2014	11/21/2016	5	1	20	1.5	1.5	2.3	2.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	1/7/2010	11/21/2016	25	1	4	0.1	7.0	24	24	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	1/7/2010	11/21/2016	25	14	56	3.3	7.0	4.2	25	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-142																	
Aluminum	Yes	ug/L	10/22/2009	11/15/2016	15	0	0	5	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	11/15/2016	15	15	100	--	--	0.55	5.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	Yes	ug/L	10/22/2009	11/15/2016	15	0	0	0.055	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	11/15/2016	16	13	81.25	0.2	13	0.54	5,220	2.4	4	DOE/RL-96-61 Rev.0, Table ES-1	74	1	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	11/15/2016	15	2	13.33	0.1	1.1	0.34	20	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	1	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	11/15/2016	9	2	22.22	1.5	9.7	3.3	13	--	--	--	10	2	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	11/15/2016	9	2	22.22	12.8	20	22	30	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	11/15/2016	15	2	13.33	0.1	0.50	0.12	0.45	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	6/11/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	11/15/2016	11	2	18.18	0.2	4.2	0.42	1.1	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	11/15/2016	15	2	13.33	0.3	2.0	0.78	2.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	11/15/2016	16	0	0	0.039	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	11/15/2016	11	0	0	0.8	9.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-144																	
Arsenic	Yes	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	2.8	2.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/22/2014	5/22/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	4/1/2010	5/25/2016	14	14	100	--	--	21	49	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	5/22/2014	5/22/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/1/2010	11/16/2016	15	15	100	--	--	20	56	--	--	--	10	15	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/1/2010	11/16/2016	15	3	20	12.8	40	38	158	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nickel	Yes	ug/L	4/1/2010	11/16/2016	15	1	6.67	1.5	13	9.0	9.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	4/1/2010	11/16/2016	15	0	0	0.99	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/1/2010	11/16/2016	15	11	73.33	3.3	7.0	4.0	17	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-146																	
Arsenic	Yes	ug/L	6/5/2014	6/5/2014	1	0	0	1.8	1.8	--	--	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	6/5/2014	6/5/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/16/2010	5/25/2016	13	10	76.92	3.4	5.0	3.4	28	2.4	10	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	6/5/2014	6/5/2014	1	1	100	--	--	6.7	6.7	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/16/2010	3/23/2017	14	13	92.86	8	8.0	2.6	21	--	--	--	10	3	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/16/2010	3/23/2017	14	3	21.43	12.8	30	40	65	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/16/2010	3/23/2017	14	1	7.14	1.5	13	12	12	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/16/2010	3/23/2017	14	0	0	0.93	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/16/2010	3/23/2017	14	13	92.86	4.1	4.1	3.8	547	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-147																	
Arsenic	Yes	ug/L	11/24/2014	11/24/2014	1	1	100	--	--	2.5	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/24/2014	11/24/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/16/2010	5/25/2016	13	13	100	--	--	10	34	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/24/2014	11/24/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	**No**	**ug/L**	**6/16/2010**	**11/21/2016**	**14**	**14**	**100**	**--**	**--**	**9.0**	**33**	**--**	**--**	**--**	**10**	**13**	**WAC 173-340-720(4)(b)(iii)(A) and (B)**
Iron	Yes	ug/L	6/16/2010	11/21/2016	14	3	21.43	12.8	38	20	48	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/16/2010	11/21/2016	14	4	28.57	1.5	13	3.5	10	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/16/2010	11/21/2016	14	0	0	0.99	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/16/2010	11/21/2016	14	9	64.29	5	8.3	3.6	85	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-148																	
Arsenic	Yes	ug/L	5/22/2014	5/22/2014	1	1	100	--	--	4.9	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/22/2014	5/22/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/16/2010	5/25/2016	13	13	100	--	--	4.5	54	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	5/22/2014	5/22/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/16/2010	11/21/2016	14	13	92.86	8	8.0	3.1	62	--	--	--	**10**	**10**	**WAC 173-340-720(4)(b)(iii)(A) and (B)**
Iron	Yes	ug/L	6/16/2010	11/21/2016	14	1	7.14	12.8	38	24	24	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/16/2010	11/21/2016	14	1	7.14	1.5	13	2.6	2.6	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/16/2010	11/21/2016	14	1	7.14	0.99	7.0	4.4	4.4	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/16/2010	11/21/2016	14	10	71.43	3.3	5.0	4.9	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-161																	
Aluminum	Yes	ug/L	11/22/2010	11/21/2016	13	2	15.38	5	20	10	14	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/22/2010	11/21/2016	13	10	76.92	1.7	1.7	0.98	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	Yes	ug/L	11/22/2010	11/21/2016	13	1	7.69	0.05	0.30	0.81	0.81	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	1	CWA - freshwater CCC
Chromium	Yes	ug/L	6/16/2010	11/21/2016	14	12	85.71	3.3	13	2.8	15	2.4	12	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/22/2010	11/21/2016	13	13	100	--	--	0.24	13	0.81	10	DOE/RL-96-61 Rev.0, Table ES-1	9.9	2	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/16/2010	11/21/2016	14	11	78.57	2	8.0	3.0	14	--	--	--	10	1	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/16/2010	11/21/2016	7	1	14.29	30	38	18	18	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/22/2010	11/21/2016	13	5	38.46	0.05	0.50	0.18	1.0	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/16/2010	11/21/2016	9	3	33.33	0.2	4.0	0.72	1.3	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/22/2010	11/21/2016	13	3	23.08	0.6	2.0	1.7	2.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/16/2010	11/21/2016	14	0	0	0.04	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/16/2010	11/21/2016	9	8	88.89	6	6.0	3.0	17	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-173																	
Aluminum	Yes	ug/L	3/10/2010	4/18/2017	11	3	27.27	10	20	11	78	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	3/10/2010	4/18/2017	11	10	90.91	4	4.0	2.6	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	3/10/2010	4/18/2017	11	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	3/10/2010	4/18/2017	41	41	100	--	--	12	997	2.4	41	DOE/RL-96-61 Rev.0, Table ES-1	74	23	CWA - freshwater CCC
Copper	Yes	ug/L	3/10/2010	4/18/2017	11	11	100	--	--	0.24	8.9	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	3/10/2010	3/15/2017	54	54	100	--	--	8.8	974	--	--	--	10	53	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/22/2010	4/18/2017	42	5	11.9	12.8	40	13	97	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	Yes	ug/L	3/10/2010	4/18/2017	11	3	27.27	0.1	1.0	0.18	0.28	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	6/8/2011	11/10/2016	21	0	0	0.06	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	4/22/2010	4/18/2017	37	3	8.11	0.4	133	1.1	11	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	3/10/2010	4/18/2017	11	4	36.36	1.5	2.0	0.69	2.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	3/10/2010	4/18/2017	40	1	2.5	0.04	7.0	5.9	5.9	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/22/2010	4/18/2017	37	13	35.14	3	7.5	5.2	20	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-178																	
Chromium	Yes	ug/L	11/5/2009	5/25/2016	14	14	100	--	--	17	120	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	1	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	11/5/2009	5/25/2016	16	16	100	--	--	15	117	--	--	--	10	16	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	11/5/2009	5/25/2016	14	1	7.14	18	30	26	26	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	11/5/2009	5/25/2016	14	2	14.29	1.5	5.0	10	11	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	11/5/2009	5/25/2016	14	1	7.14	1	6.0	40	40	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	11/5/2009	5/25/2016	14	13	92.86	6	6.0	3.8	26	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-183																	
Aluminum	Yes	ug/L	10/24/2011	11/28/2016	21	2	9.52	10	20	14	60	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/24/2011	11/28/2016	21	20	95.24	1.7	1.7	1.8	4.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/24/2011	11/28/2016	21	0	0	0.1	0.27	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	7/20/2011	2/23/2017	25	25	100	--	--	5.1	11	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Copper	Yes	ug/L	10/24/2011	11/28/2016	21	10	47.62	0.2	0.56	0.22	2.1	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	7/20/2011	2/23/2017	25	24	96	3.7	3.7	5.0	10	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	7/20/2011	2/23/2017	13	1	7.69	16	30	59	59	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/24/2011	11/28/2016	21	0	0	0.1	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	7/20/2011	2/23/2017	17	4	23.53	0.2	4.0	0.34	1.4	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/24/2011	11/28/2016	21	2	9.52	1.5	2.0	1.3	1.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	7/20/2011	2/23/2017	25	1	4	0.04	4.0	0.039	0.039	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	7/20/2011	2/23/2017	17	1	5.88	2	8.3	4.9	4.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-186																	
Aluminum	Yes	ug/L	10/10/2011	11/13/2016	21	4	19.05	10	20	14	33	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/10/2011	11/13/2016	21	21	100	--	--	1.8	6.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/10/2011	11/13/2016	21	0	0	0.099	0.11	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	5/11/2011	11/13/2016	22	22	100	--	--	6.6	290	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	74	1	CWA - freshwater CCC
Copper	Yes	ug/L	10/10/2011	11/13/2016	21	2	9.52	0.2	1.1	0.37	1.9	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	5/11/2011	11/13/2016	22	22	100	--	--	3.9	31	--	--	--	10	17	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	5/11/2011	11/13/2016	10	2	20	12.8	30	19	53	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/10/2011	11/13/2016	21	3	14.29	0.1	0.50	0.21	0.54	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	5/11/2011	11/13/2016	14	4	28.57	0.2	4.2	0.31	9.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Selenium	Yes	ug/L	10/10/2011	11/13/2016	21	4	19.05	0.66	2.0	0.72	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	5/11/2011	11/13/2016	22	0	0	0.039	5.1	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	5/11/2011	11/13/2016	14	2	14.29	3.5	9.3	15	22	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-187																	
Aluminum	Yes	ug/L	10/25/2011	11/13/2016	21	1	4.76	10	20	73	73	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/25/2011	11/13/2016	21	20	95.24	1.7	1.7	3.5	5.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/25/2011	11/13/2016	21	0	0	0.1	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	4/26/2011	11/13/2016	24	23	95.83	2	2.0	1.5	16	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/25/2011	11/13/2016	21	5	23.81	0.2	0.45	0.40	0.64	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/26/2011	11/13/2016	24	20	83.33	2	8.0	2.8	53	--	--	--	10	3	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/26/2011	11/13/2016	12	2	16.67	20	30	20	32	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/25/2011	11/13/2016	21	0	0	0.1	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	4/26/2011	11/13/2016	16	14	87.5	0.2	5.1	1.3	10	1.6	11	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/25/2011	11/13/2016	21	6	28.57	1.5	2.0	1.7	3.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	4/26/2011	11/13/2016	24	1	4.17	0.04	5.1	0.15	0.15	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/26/2011	11/13/2016	16	0	0	3.5	8.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-188																	
Arsenic	Yes	ug/L	8/13/2014	11/21/2014	2	2	100	--	--	3.0	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	6/14/2011	8/31/2016	15	15	100	--	--	6.2	46	2.4	15	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	6/14/2011	11/30/2016	15	15	100	--	--	8.3	44	--	--	--	10	13	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/14/2011	11/30/2016	16	4	25	12.8	30	19	153	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/14/2011	11/30/2016	16	6	37.5	1.5	10	3.7	6.0	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/14/2011	11/30/2016	16	1	6.25	0.99	5.1	6.3	6.3	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/14/2011	11/30/2016	16	1	6.25	3	8.3	5.6	5.6	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-191																	
Aluminum	Yes	ug/L	11/9/2011	11/13/2016	21	5	23.81	5	20	18	61	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/9/2011	11/13/2016	21	20	95.24	4	4.0	2.0	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/9/2011	11/13/2016	21	0	0	0.05	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/10/2011	11/13/2016	23	21	91.3	1.1	4.0	3.3	23	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/9/2011	11/13/2016	21	13	61.9	0.1	1.1	0.20	3.5	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/10/2011	11/13/2016	23	19	82.61	2	8.0	2.3	10	--	--	--	10	1	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/10/2011	11/13/2016	11	1	9.09	12.8	38	17	17	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/9/2011	11/13/2016	21	2	9.52	0.05	1.0	0.36	0.77	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/10/2011	11/13/2016	15	8	53.33	0.2	4.2	0.42	7.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/9/2011	11/13/2016	21	5	23.81	1	2.0	0.83	5.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	1	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/10/2011	11/13/2016	23	0	0	0.039	5.1	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	Yes	ug/L	6/10/2011	11/13/2016	15	1	6.67	3.5	9.3	11	11	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-194																	
Aluminum	Yes	ug/L	10/26/2011	11/14/2016	21	0	0	10	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/26/2011	11/14/2016	21	21	100	--	--	3.9	5.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/26/2011	11/14/2016	21	0	0	0.1	0.27	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	5/11/2011	11/14/2016	22	22	100	--	--	6.6	22	2.4	22	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/26/2011	11/14/2016	21	12	57.14	0.2	0.56	0.21	1.1	0.81	4	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	5/11/2011	11/14/2016	21	21	100	--	--	5.6	15	--	--	--	10	12	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	5/11/2011	11/14/2016	20	0	0	12.8	40	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/26/2011	11/14/2016	21	1	4.76	0.1	0.50	0.25	0.25	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	5/11/2011	11/14/2016	20	11	55	0.5	5.0	0.72	12	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/26/2011	11/14/2016	21	10	47.62	1.5	2.0	1.4	2.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	5/11/2011	11/14/2016	22	0	0	0.033	5.1	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	5/11/2011	11/14/2016	20	1	5	2	8.3	5.4	5.4	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-204																	
Aluminum	Yes	ug/L	12/15/2015	12/11/2016	2	0	0	19	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/15/2015	12/11/2016	2	1	50	4	4.0	2.5	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/15/2015	12/11/2016	2	0	0	0.13	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	12/15/2015	2/26/2017	7	6	85.71	4	4.0	2.6	5.5	2.4	6	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	12/15/2015	12/11/2016	2	1	50	2	2.0	0.57	0.57	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/17/2015	3/13/2017	18	15	83.33	1.5	1.5	1.6	7.7	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/15/2015	2/26/2017	7	1	14.29	16	38	54	54	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	12/15/2015	12/11/2016	2	0	0	0.2	1.0	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/15/2015	2/26/2017	7	2	28.57	1.6	10	2.5	6.1	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	12/15/2015	12/11/2016	2	0	0	0.42	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/15/2015	2/26/2017	7	1	14.29	0.9	3.0	0.060	0.060	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/15/2015	2/26/2017	7	0	0	3	7.5	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-221																	
Aluminum	Yes	ug/L	11/13/2015	11/13/2015	1	0	0	17.3	17	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	2.2	2.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/13/2015	11/13/2015	1	0	0	0.1	0.10	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	14	14	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	0.77	0.77	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	11/13/2015	1/30/2017	5	5	100	--	--	6.9	32	--	--	--	10	3	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	11/13/2015	11/13/2015	1	0	0	12.8	13	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	0.23	0.23	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nickel	Yes	ug/L	11/13/2015	11/13/2015	1	1	100	--	--	1.2	1.2	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/13/2015	11/13/2015	1	0	0	1.6	1.6	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	11/13/2015	11/13/2015	1	0	0	0.82	0.82	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	11/13/2015	11/13/2015	1	0	0	9.3	9.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-222																	
Aluminum	Yes	ug/L	11/13/2015	10/20/2016	2	1	50	17.3	17	24	24	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/13/2015	10/20/2016	2	1	50	4	4.0	2.5	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/13/2015	10/20/2016	2	0	0	0.1	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	11/13/2015	10/20/2016	2	2	100	--	--	8.4	19	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/13/2015	10/20/2016	2	1	50	0.68	0.68	0.45	0.45	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	11/13/2015	1/30/2017	6	6	100	--	--	5.4	20	--	--	--	10	5	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	11/13/2015	10/20/2016	2	1	50	12.8	13	36	36	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/13/2015	10/20/2016	2	0	0	0.17	1.0	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	11/13/2015	10/20/2016	2	1	50	2	2.0	1.3	1.3	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/13/2015	10/20/2016	2	1	50	1.6	1.6	2.5	2.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	11/13/2015	10/20/2016	2	0	0	0.82	0.90	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	11/13/2015	10/20/2016	2	0	0	7.5	9.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC

Table D-11. Individual Monitoring Well Summary Statistics for Wells Screened in the Upper Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
699-72-73																	
Aluminum	Yes	ug/L	10/22/2009	10/28/2016	11	1	9.09	10	20	37	37	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	10/28/2016	11	11	100	--	--	2.9	5.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	10/28/2016	11	0	0	0.1	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	10/28/2016	11	11	100	--	--	3.9	12	2.4	11	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	10/28/2016	11	1	9.09	0.2	0.68	0.38	0.38	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	10/28/2016	11	7	63.64	2	3.7	2.6	10	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	10/28/2016	9	4	44.44	12.8	40	22	48	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	10/28/2016	11	1	9.09	0.1	1.0	0.30	0.30	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	12/31/2013	4	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	10/28/2016	9	3	33.33	0.4	4.0	0.22	0.48	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	10/28/2016	11	7	63.64	1.6	2.0	2.0	2.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	10/28/2016	11	0	0	0.04	0.90	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	10/28/2016	9	2	22.22	4	9.3	1.8	7.0	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-12. Groundwater Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Carbon-14	No	pCi/L	10/22/2009	3/23/2017	208	150	72	3.7	57	5.7	6,140	--	--	--	2,000	16	40 CFR 141 - federal MCL
Gross alpha	No	pCi/L	6/11/2010	3/23/2017	116	32	27.59	0.532	4.4	1.82	8.4	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/11/2010	3/23/2017	116	110	95	2.0	3.7	2.8	47	0.0081	110	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	10/22/2009	3/23/2017	215	25	12	0.43	2.2	0.63	8.1	0.015	25	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/22/2009	3/23/2017	168	46	27.38	5.5	42.3	6.1	84.2	0.83	46	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/22/2009	3/23/2017	267	256	96	200	344	160	935,000	119	256	DOE/RL-96-61 Rev.0, Table ES-1	20,000	44	40 CFR 141 - federal MCL
Volatile Organic Compounds																	
2-Butanone	No	ug/L	10/22/2009	3/13/2017	95	3	3.16	0.47	3	0.5	0.65	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	10/13/2016	2/23/2017	8	5	62.5	5	250	8.76	120	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	10/22/2009	3/13/2017	95	7	7.37	0.34	5	1.4	2.8	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	No	ug/L	10/22/2009	1/10/2011	16	3	18.75	0.082	1	0.1	0.16	--	--	--	0.71	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromomethane	No	ug/L	10/22/2009	1/10/2011	16	3	18.75	0.084	1	0.19	1.1	--	--	--	11.2	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	ug/L	10/22/2009	3/13/2017	95	1	1.05	0.063	1	1.1	1.1	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	ug/L	10/22/2009	3/13/2017	95	64	67.37	0.3	1	0.2	8.3	--	--	--	1.4	15	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	10/22/2009	3/13/2017	95	6	6.32	0.11	1.6	1.1	4.31	--	--	--	5.0	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	10/22/2009	3/13/2017	95	2	2.11	0.062	1	0.13	0.35	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	3/13/2017	96	64	66.67	0.21	1	0.18	9.48	--	--	--	0.54	62	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-12. Groundwater Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Semivolatile Organic Compounds																	
Bis(2-ethylhexyl) phthalate	No	ug/L	9/20/2010	1/10/2011	6	1	16.67	1.0	1.0	11	11	--	--	--	6.0	1	40 CFR 141 - federal MCL
Pesticides																	
Aldrin	No	ug/L	6/22/2010	1/10/2011	9	2	22.22	0.010	0.010	0.12	0.65	--	--	--	0.0026	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons - diesel range	No	ug/L	6/22/2010	11/29/2016	27	1	3.7	16	220	27	27	--	--	--	100	41	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - gasoline range	No	ug/L	6/22/2010	11/29/2016	24	2	8.33	10	50	32	38	--	--	--	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Aluminum	No	ug/L	10/22/2009	12/9/2016	87	32	36.78	5	20	10.2	430	7.1	32	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	12/9/2016	99	6	6.06	0.3	15	0.15	5.6	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	12/9/2016	98	94	95.92	1.7	4	1.77	9	7.9	1	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	3/23/2017	292	292	100	--	--	17	67.4	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	12/9/2016	99	3	3.03	0.05	1	0.45	4.8	2.3	1	DOE/RL-96-61 Rev.0, Table ES-1	4.0	1	40 CFR 141 - federal MCL
Boron	No	ug/L	3/8/2010	2/15/2017	65	35	53.85	7.2	41	5.41	852	36.0	10	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/22/2009	12/9/2016	99	2	2.02	0.05	1	0.19	5	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/22/2009	3/13/2017	294	286	97.28	3	14	1.9	261	2.4	283	DOE/RL-96-61 Rev.0, Table ES-1	100	13	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	12/9/2016	99	17	17.17	0.05	2.7	0.0819	5	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	12/9/2016	99	66	66.67	0.1	2.4	0.274	62	0.81	44	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-12. Groundwater Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	10/22/2009	3/23/2017	349	337	96.56	1.5	8	1.5	353	--	--		48.0	73	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	3/23/2017	261	62	23.75	12.8	40	12.8	1600	570	3	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	12/9/2016	86	27	31.4	0.05	1	0.104	3.4	0.92	6	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/8/2010	1/10/2011	14	10	71.43	4	4	4	20	11.3	2	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	3/23/2017	271	46	16.97	0.2	6	0.33	162	38.5	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	10/22/2009	4/17/2014	22	1	4.55	0.03	0.2	0.162	0.162	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	3/8/2010	12/9/2016	84	82	97.62	0.1	4	1.27	16	3.2	36	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	3/23/2017	271	77	28.41	0.2	66.5	0.356	57.8	1.6	63	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Selenium	No	ug/L	10/22/2009	12/9/2016	86	28	32.56	0.6	2	0.666	2.8	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/22/2009	3/23/2017	292	8	2.74	0.039	7	0.04	20	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/22/2009	3/23/2017	253	253	100	--	--	162	438	323	22	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	10/22/2009	12/9/2016	86	2	2.33	0.014	0.9	0.64	0.64	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	2	40 CFR 141 - federal MCLG
Tin	No	ug/L	3/8/2010	12/9/2016	84	17	20.24	0.05	39	0.116	5.8	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	10/22/2009	12/9/2016	62	62	100	--	--	1.75	7.36	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	3/23/2017	267	229	85.77	4.4	17	5.1	34	11.5	132	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	3/23/2017	271	135	49.82	1.6	30	3.8	398	21.8	41	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-12. Groundwater Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Anions/Cations																	
Fluoride	No	ug/L	10/22/2009	2/23/2017	291	268	92.1	30	88	51.3	450	1,047		DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/22/2009	2/23/2017	291	291	100	--	--	4,030	75,300	26,871	32	DOE/RL-96-61 Rev.0, Table ES-1	45,000	6	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	2/23/2017	291	48	16.49	9.85	131	127	821	93.7	48	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-116A																	
Aluminum	No	ug/L	6/16/2010	11/16/2016	12	1	8.33	10	20	180	180	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/31/2011	11/16/2016	11	11	100	--	--	2.7	4.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/16/2010	11/16/2016	14	14	100	--	--	17	31	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	6/16/2010	11/16/2016	9	3	33.33	10	19	5.4	7.1	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	1/31/2011	11/16/2016	7	4	57.14	8.16	54	18	48	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/16/2010	11/16/2016	14	12	85.71	13	14	4.1	11	2.4	12	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	10/31/2011	11/16/2016	11	11	100	--	--	2.1	8.8	0.81	11	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/16/2010	11/16/2016	12	9	75	60	88	72	170	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/16/2016	8	1	12.5	1.68	3.3	4.0	4.0	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/16/2016	8	8	100	--	--	5.6	14	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/16/2010	11/16/2016	14	12	85.71	3.7	8.0	2.5	11	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/31/2011	11/16/2016	11	2	18.18	0.1	0.50	0.13	0.22	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Lithium	No	ug/L	6/16/2010	6/16/2010	1	1	100	--	--	4.0	4.0	11	0	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	6/16/2010	11/16/2016	12	11	91.67	4	4.0	2.3	3.4	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/16/2010	11/16/2016	10	1	10	0.2	5.0	1.4	1.4	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/16/2010	11/16/2016	12	12	100	--	--	4,030	14,600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	6/16/2010	11/16/2016	12	2	16.67	9.85	131	127	131	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/16/2010	11/16/2016	10	10	100	--	--	162	316	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	1/31/2011	11/16/2016	7	6	85.71	1.5	1.5	1.7	4.2	0.015	6	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tin	No	ug/L	6/16/2010	11/16/2016	12	1	8.33	0.1	39	0.12	0.12	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/31/2011	11/16/2016	7	7	100	--	--	1,420	4,380	119	7	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/20/2013	11/16/2016	7	7	100	--	--	1.9	3.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/16/2010	11/16/2016	9	7	77.78	12	17	8.7	10	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	11/16/2016	10	8	80	3.5	4.0	4.2	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-120A																	
Arsenic	No	ug/L	1/31/2011	11/16/2016	12	12	100	--	--	2.4	3.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/1/2010	11/16/2016	14	14	100	--	--	27	33	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/15/2011	11/16/2016	7	4	57.14	15	15	6.8	21	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	4/1/2010	11/16/2016	8	2	25	7.87	55	14	17	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	4/1/2010	11/16/2016	14	12	85.71	3	13	2.3	18	2.4	11	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	1/31/2011	11/16/2016	12	11	91.67	0.2	0.20	0.65	44	0.81	9	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/1/2010	11/16/2016	13	7	53.85	46	88	96	160	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	7/26/2010	11/16/2016	8	8	100	--	--	5.3	11	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	4/1/2010	11/16/2016	14	12	85.71	1.5	3.7	1.8	6.5	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	1/31/2011	11/16/2016	12	10	83.33	0.1	0.17	0.12	3.3	0.92	4	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	1/31/2011	11/16/2016	12	11	91.67	0.1	0.10	1.6	1.9	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/1/2010	11/16/2016	9	2	22.22	0.2	4.0	1.5	6.1	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	4/1/2010	11/16/2016	13	13	100	--	--	12,400	15,100	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/1/2010	11/16/2016	13	1	7.69	9.85	131	128	128	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	1/31/2011	11/16/2016	12	2	16.67	1	2.0	0.71	0.72	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	4/1/2010	11/16/2016	9	9	100	--	--	243	293	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/1/2010	11/16/2016	8	3	37.5	0.954	2.1	1.4	2.2	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	1/31/2011	11/16/2016	12	1	8.33	0.05	0.60	0.64	0.64	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	1/31/2011	11/16/2016	12	2	16.67	0.05	1.0	0.12	0.72	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	4/1/2010	11/16/2016	13	13	100	--	--	5,600	7,900	119	13	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/21/2013	11/16/2016	6	6	100	--	--	2.2	2.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/1/2010	11/16/2016	9	7	77.78	12	17	9.2	9.6	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/1/2010	11/16/2016	9	8	88.89	4	4.0	7.8	24	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-145																	
Arsenic	No	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	2.7	2.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Barium	No	ug/L	2/18/2010	11/16/2016	15	15	100	--	--	32	38	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	2/18/2010	11/16/2016	8	7	87.5	53.8	54	9.6	42	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	2/18/2010	5/25/2016	14	14	100	--	--	6.1	66	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	3.8	3.8	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	2/18/2010	11/16/2016	14	12	85.71	60	88	52	325	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/16/2016	8	1	12.5	1.64	4.3	2.0	2.0	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/16/2016	8	8	100	--	--	3.9	11	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	2/18/2010	11/16/2016	14	14	100	--	--	3.1	74	--	--	--	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	2/18/2010	11/16/2016	15	2	13.33	12.8	38	19	24	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	2/18/2010	11/16/2016	15	4	26.67	1.5	13	3.3	7.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	2/18/2010	11/16/2016	14	14	100	--	--	12,300	22,400	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	2/18/2010	11/16/2016	14	1	7.14	9.85	131	150	150	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	2/18/2010	11/16/2016	15	15	100	--	--	254	305	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	2/18/2010	11/16/2016	8	1	12.5	5.8	16	7.3	7.3	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	2/18/2010	11/16/2016	15	15	100	--	--	6,270	62,000	119	15	DOE/RL-96-61 Rev.0, Table ES-1	20,000	10	40 CFR 141 - federal MCL
Vanadium	No	ug/L	2/18/2010	11/16/2016	15	11	73.33	10	17	7.9	19	12	6	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	2/18/2010	11/16/2016	15	10	66.67	3.3	6.0	6.0	34	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-151																	
2-Propanol	No	ug/L	10/13/2016	10/13/2016	1	1	100	--	--	76	76	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aldrin	No	ug/L	6/24/2010	1/10/2011	3	1	33.33	0.01	0.010	0.12	0.12	--	--	--	0.0026	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/22/2009	10/13/2016	17	6	35.29	10	20	13	47	7.1	6	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/22/2009	10/13/2016	17	2	11.76	0.3	1.7	0.15	0.16	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/22/2009	10/13/2016	17	17	100	--	--	4.2	5.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	10/13/2016	18	18	100	--	--	26	38	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/22/2009	10/13/2016	17	1	5.88	0.1	0.35	0.45	0.45	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Bis(2-ethylhexyl) phthalate	No	ug/L	9/20/2010	1/10/2011	2	1	50	1	1.0	11	11	--	--	--	6.0	1	40 CFR 141 - federal MCL
Boron	No	ug/L	3/8/2010	10/13/2016	12	6	50	7.2	41	8.5	13	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bromodichloromethane	No	ug/L	10/22/2009	1/10/2011	5	3	60	0.088	1.0	0.10	0.16	--	--	--	0.71	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2009	10/13/2016	15	11	73.33	8.02	48	13	41	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	10/13/2016	17	17	100	--	--	1.3	8.3	--	--	--	1.4	14	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	10/13/2016	18	18	100	--	--	2.6	31	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	10/13/2016	17	1	5.88	0.07	0.22	0.20	0.20	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	10/13/2016	17	11	64.71	0.2	1.1	0.27	3.2	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/22/2009	10/13/2016	17	17	100	--	--	69	380	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross alpha	No	pCi/L	9/20/2010	1/10/2011	2	1	50	2.2	2.2	2.6	2.6	--	--	--	15	0	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	10/13/2016	17	14	82.35	2	8.0	2.4	26	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	10/13/2016	12	2	16.67	12.8	38	29	36	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/22/2009	10/13/2016	17	5	29.41	0.1	0.20	0.17	0.52	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Lithium	No	ug/L	3/8/2010	1/10/2011	4	3	75	4	4.0	4.2	8.0	11	0	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/22/2009	10/13/2016	14	6	42.86	0.3	6.0	0.33	30	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	10/22/2009	10/13/2016	17	1	5.88	0.11	1.0	1.1	1.1	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	3/8/2010	10/13/2016	16	16	100	--	--	6.1	9.2	3.2	16	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/22/2009	10/13/2016	14	6	42.86	0.4	4.2	0.36	5.0	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/22/2009	10/13/2016	17	17	100	--	--	5,580	20,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	10/13/2016	17	2	11.76	9.85	131	174	252	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	10/13/2016	17	10	58.82	0.6	2.0	0.73	2.8	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/22/2009	10/13/2016	18	1	5.56	0.039	4.0	0.35	0.35	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/22/2009	10/13/2016	14	14	100	--	--	213	311	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/22/2009	10/13/2016	17	2	11.76	0.599	2.2	1.4	4.6	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/22/2009	10/13/2016	15	2	13.33	5.8	10	10	12	0.83	2	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tin	No	ug/L	3/8/2010	10/13/2016	16	7	43.75	0.05	1.3	0.14	5.8	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2009	10/13/2016	17	1	5.88	0.21	1.0	0.18	0.18	--	--	--	0.54	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	10/13/2016	17	17	100	--	--	940	3,900	119	17	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	10/13/2016	12	12	100	--	--	2.0	3.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/22/2009	10/13/2016	13	12	92.31	12	12	15	34	12	12	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	10/13/2016	14	1	7.14	1.6	30	16	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-152																	
Aldrin	No	ug/L	6/22/2010	1/9/2011	3	1	33.33	0.01	0.010	0.65	0.65	--	--	--	0.0026	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	10	272	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	4.3	4.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/22/2009	10/26/2016	13	13	100	--	--	23	36	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Bromomethane	No	ug/L	10/22/2009	1/9/2011	5	2	40	0.25	1.0	0.19	1.1	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2009	10/26/2016	10	3	30	8.01	50	7.8	22	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2009	5/17/2012	6	5	83.33	1	1.0	0.49	1.8	--	--	--	1.4	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/22/2009	10/26/2016	13	13	100	--	--	28	75	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/22/2009	1/9/2011	5	2	40	0.1	0.10	0.11	0.15	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/22/2009	1/9/2011	5	1	20	0.2	0.56	0.28	0.28	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Fluoride	No	ug/L	10/22/2009	10/26/2016	16	16	100	--	--	67	260	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	9/21/2010	1/9/2011	2	1	50	2.1	2.1	3.2	3.2	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	9/21/2010	1/9/2011	2	2	100	--	--	6.1	6.7	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/22/2009	10/26/2016	18	18	100	--	--	28	73	--	--	--	48	11	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/22/2009	10/26/2016	13	2	15.38	18	40	46	81	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	3/8/2010	1/9/2011	4	2	50	4	4.0	4.6	5.0	11	0	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/8/2010	1/9/2011	4	4	100	--	--	4.5	16	3.2	4	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/22/2009	10/26/2016	16	16	100	--	--	7,480	15,500	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/22/2009	10/26/2016	16	5	31.25	9.85	131	134	230	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	0.67	1.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/22/2009	10/26/2016	13	2	15.38	0.2	6.0	0.48	4.6	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/22/2009	10/26/2016	13	13	100	--	--	213	303	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	10/22/2009	10/26/2016	10	1	10	6.3	41	40	40	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	10/22/2009	5/17/2012	6	1	16.67	0.062	1.0	0.35	0.35	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/22/2009	10/26/2016	12	11	91.67	200	200	160	1,510	119	11	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	1.8	2.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Vanadium	No	ug/L	10/22/2009	10/26/2016	13	13	100	--	--	13	27	12	13	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/22/2009	10/26/2016	13	7	53.85	3.3	7.0	4.5	48	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-153																	
Arsenic	No	ug/L	11/24/2014	11/24/2014	1	1	100	--	--	2.4	2.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	7/26/2010	3/23/2017	15	15	100	--	--	25	31	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	7/26/2010	3/23/2017	8	6	75	8.37	57	9.8	27	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	7/26/2010	5/25/2016	14	14	100	--	--	16	27	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/24/2014	11/24/2014	1	1	100	--	--	26	26	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	7/26/2010	5/25/2016	13	13	100	--	--	122	260	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	8/12/2010	3/23/2017	8	1	12.5	1.97	3.3	1.8	1.8	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	8/12/2010	3/23/2017	8	7	87.5	3.4	3.4	4.7	15	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	7/26/2010	3/23/2017	15	15	100	--	--	14	31	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	7/26/2010	3/23/2017	15	1	6.67	12.8	38	44	44	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	7/26/2010	3/23/2017	15	5	33.33	1.5	13	4.0	9.0	1.6	5	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	7/26/2010	5/25/2016	13	13	100	--	--	9,960	12,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	7/26/2010	5/25/2016	13	2	15.38	9.85	131	160	175	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	7/26/2010	3/23/2017	15	15	100	--	--	242	281	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tritium	No	pCi/L	7/26/2010	3/23/2017	8	8	100	--	--	570	1,410	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	7/26/2010	3/23/2017	15	13	86.67	17	17	9.2	21	12	9	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	7/26/2010	3/23/2017	15	12	80	3	8.3	3.9	86	22	5	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-154																	
Arsenic	No	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	4.4	4.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	29	67	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	1/7/2010	5/25/2016	14	14	100	--	--	24	92	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	1/7/2010	11/21/2016	13	12	92.31	60	60	180	310	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/21/2016	8	3	37.5	2.1	3.3	2.9	3.3	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/21/2016	8	8	100	--	--	5.0	6.9	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	25	96	--	--	--	48	11	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	1/7/2010	11/21/2016	15	2	13.33	12.8	38	22	382	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	1/7/2010	11/21/2016	15	1	6.67	1	6.0	7.3	7.3	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	1/7/2010	11/21/2016	15	4	26.67	1.5	13	2.4	8.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	1/7/2010	11/21/2016	13	13	100	--	--	10,600	14,200	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	1/7/2010	11/21/2016	13	2	15.38	9.85	131	146	208	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	255	435	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tritium	No	pCi/L	1/7/2010	11/21/2016	8	4	50	200	344	834	2,450	119	4	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	1/7/2010	11/21/2016	15	13	86.67	12	17	8.3	17	12	10	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	1/7/2010	11/21/2016	15	10	66.67	3.3	7.0	5.3	27	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-157																	
Antimony	No	ug/L	10/29/2009	11/23/2014	5	1	20	0.6	3.7	5.6	5.6	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/29/2009	11/23/2014	5	4	80	1.8	1.8	1.8	9.0	7.9	1	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/29/2009	11/14/2016	26	26	100	--	--	30	42	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	10/29/2009	11/23/2014	5	1	20	0.1	0.28	4.8	4.8	2.3	1	DOE/RL-96-61 Rev.0, Table ES-1	4.0	1	40 CFR 141 - federal MCL
Boron	No	ug/L	3/8/2010	6/11/2010	2	2	100	--	--	71	155	36	2	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/29/2009	11/23/2014	5	1	20	0.2	0.34	5.0	5.0	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/29/2009	11/14/2016	10	7	70	8.18	54	9.2	64	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/29/2009	6/11/2010	3	2	66.67	1	1.0	0.48	0.86	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/29/2009	8/1/2016	25	25	100	--	--	1.9	57	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/29/2009	11/23/2014	5	1	20	0.1	2.7	5.0	5.0	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/29/2009	11/23/2014	5	1	20	0.2	2.1	5.4	5.4	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/29/2009	11/14/2016	24	21	87.5	30	88	65	210	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/11/2010	11/14/2016	8	2	25	1.87	4.4	2.6	2.6	--	--	--	15	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Gross beta	No	pCi/L	6/11/2010	11/14/2016	8	7	87.5	3.7	3.7	3.4	10	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/29/2009	11/14/2016	15	14	93.33	8	8.0	1.7	56	--	--	--	48	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/29/2009	11/14/2016	26	12	46.15	12.8	40	19	500	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	3/8/2010	6/11/2010	2	2	100	--	--	5.8	20	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/29/2009	11/14/2016	26	6	23.08	0.7	6.0	5.3	18	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	3/8/2010	6/11/2010	2	2	100	--	--	2.9	9.0	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/29/2009	11/14/2016	26	7	26.92	1.5	67	2.7	8.1	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/29/2009	11/14/2016	24	24	100	--	--	8,990	41,922	26,871	5	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/29/2009	11/14/2016	24	4	16.67	9.85	131	150	201	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/29/2009	6/11/2010	3	3	100	--	--	1.6	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/29/2009	11/14/2016	26	1	3.85	0.2	7.0	1.0	1.0	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/29/2009	11/14/2016	26	26	100	--	--	275	438	323	15	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/29/2009	11/14/2016	10	2	20	0.569	2.0	1.2	2.6	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/29/2009	11/14/2016	8	2	25	6.4	16	18	56	0.83	2	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/29/2009	11/14/2016	31	31	100	--	--	1,520	290,000	119	31	DOE/RL-96-61 Rev.0, Table ES-1	20,000	7	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/29/2009	6/11/2010	3	3	100	--	--	3.1	3.7	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Vanadium	No	ug/L	10/29/2009	11/14/2016	26	17	65.38	4.4	17	5.1	15	12	5	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/29/2009	11/14/2016	26	2	7.69	3	8.3	3.8	12	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-163																	
Arsenic	No	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	3.8	3.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	30	36	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	1/7/2010	11/21/2016	8	4	50	8.3	56	11	69	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	1/7/2010	5/25/2016	14	14	100	--	--	3.7	78	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	3.1	3.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	1/7/2010	11/21/2016	13	12	92.31	60	60	174	310	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/16/2010	11/21/2016	8	3	37.5	2	2.7	2.2	6.4	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/16/2010	11/21/2016	8	8	100	--	--	2.8	16	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	2.1	81	--	--	--	48	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	1/7/2010	11/21/2016	15	3	20	19	40	25	58	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	1/7/2010	11/21/2016	15	3	20	1.5	13	1.9	9.0	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	1/7/2010	11/21/2016	13	13	100	--	--	13,100	15,500	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	1/7/2010	11/21/2016	13	2	15.38	9.85	131	127	165	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	262	310	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Technetium-99	No	pCi/L	1/7/2010	11/21/2016	8	1	12.5	6.4	30	7.2	7.2	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	1/7/2010	11/21/2016	8	8	100	--	--	1,860	5,200	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	1/7/2010	11/21/2016	15	13	86.67	12	17	11	16	12	12	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	1/7/2010	11/21/2016	15	12	80	3.3	7.0	5.1	105	22	5	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-165																	
2-Butanone	No	ug/L	6/15/2010	2/23/2017	12	2	16.67	0.47	2.0	0.50	0.65	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	11/29/2016	2/23/2017	2	1	50	5	5.0	120	120	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	6/15/2010	2/23/2017	12	3	25	0.34	5.0	1.8	2.8	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/18/2014	11/18/2014	1	1	100	--	--	2.1	2.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/23/2017	24	24	100	--	--	35	57	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	1/4/2011	2/23/2017	18	18	100	--	--	159	780	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/15/2010	2/23/2017	12	7	58.33	1	1.0	0.24	0.51	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/15/2010	3/13/2017	26	26	100	--	--	9.1	261	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	100	7	40 CFR 141 - federal MCL
Copper	No	ug/L	9/27/2011	11/18/2014	2	2	100	--	--	6.1	11	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/15/2010	2/23/2017	22	20	90.91	60	72	72	230	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/15/2010	11/29/2016	8	2	25	1.75	2.8	2.8	4.7	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/15/2010	11/29/2016	8	8	100	--	--	14	47	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	2/3/2010	3/13/2017	32	32	100	--	--	7.8	353	--	--	--	48	11	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/23/2017	24	11	45.83	12.8	40	15	190	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/15/2010	2/23/2017	24	7	29.17	0.7	6.0	0.89	7.7	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	ug/L	6/22/2011	4/17/2014	6	1	16.67	0.03	0.20	0.16	0.16	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	2.0	0	40 CFR 141 - federal MCL
Methylene chloride	No	ug/L	6/15/2010	2/23/2017	12	2	16.67	0.27	1.0	1.6	2.8	--	--	--	5.0	0	40 CFR 141 - federal MCL
Nickel	No	ug/L	6/15/2010	2/23/2017	24	12	50	1.6	13	3.2	58	1.6	12	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/15/2010	2/23/2017	22	22	100	--	--	17,400	27,400	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/23/2017	22	4	18.18	9.85	131	184	486	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/15/2010	11/29/2016	17	17	100	--	--	219	350	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	1/4/2011	11/29/2016	7	7	100	--	--	25	37	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - diesel range	No	ug/L	1/4/2011	11/29/2016	10	1	10	16	70	27	27	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - gasoline range	No	ug/L	1/4/2011	11/29/2016	7	2	28.57	10	50	32	38	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	6/15/2010	2/23/2017	12	12	100	--	--	3.0	4.7	--	--	--	0.54	12	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/4/2011	2/23/2017	17	17	100	--	--	930	1,520	119	17	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/15/2010	2/23/2017	24	21	87.5	15	17	8.6	25	12	10	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	No	ug/L	6/15/2010	2/23/2017	24	15	62.5	3	20	5.0	100	22	3	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-166																	
Acetone	No	ug/L	6/15/2010	2/7/2017	15	1	6.67	1	5.0	1.4	1.4	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	7/16/2014	7/16/2014	1	1	100	--	--	2.5	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/7/2017	24	24	100	--	--	35	62	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/22/2010	2/7/2017	8	8	100	--	--	336	688	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/15/2010	2/7/2017	15	7	46.67	1	1.0	0.32	0.41	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/15/2010	2/7/2017	26	25	96.15	13	13	3.5	40	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	7/16/2014	7/16/2014	1	1	100	--	--	19	19	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/15/2010	2/7/2017	22	19	86.36	46	60	51	220	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/15/2010	11/19/2015	7	3	42.86	1.62	2.9	2.5	8.4	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/15/2010	11/19/2015	7	7	100	--	--	9.8	35	0.0081	7	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/15/2010	2/7/2017	28	26	92.86	8	8.0	3.1	66	--	--	--	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/7/2017	24	1	4.17	12.8	40	31	31	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/15/2010	2/7/2017	24	2	8.33	1	6.0	2.4	3.6	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/15/2010	2/7/2017	15	1	6.67	0.27	1.6	1.7	1.7	--	--	--	5.0	0	40 CFR 141 - federal MCL
Nickel	No	ug/L	6/15/2010	2/7/2017	24	6	25	1.5	13	2.8	11	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	6/15/2010	2/7/2017	22	22	100	--	--	21,400	24,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/7/2017	22	4	18.18	9.85	131	145	209	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/15/2010	2/7/2017	24	2	8.33	0.99	7.0	1.0	4.1	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/15/2010	2/7/2017	23	23	100	--	--	199	286	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/22/2010	2/7/2017	8	1	12.5	0.67	1.9	1.8	1.8	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	11/22/2010	11/19/2015	6	5	83.33	6.9	6.9	27	42	0.83	5	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	6/15/2010	2/7/2017	15	14	93.33	1	1.0	3.3	4.7	--	--	--	0.54	14	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/22/2010	2/7/2017	8	8	100	--	--	1,130	1,660	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/15/2010	2/7/2017	24	17	70.83	4.4	17	5.1	25	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/15/2010	2/7/2017	24	22	91.67	3.3	3.3	6.7	82	22	10	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-171																	
Arsenic	No	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	3.8	3.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/16/2010	3/23/2017	14	14	100	--	--	22	26	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/22/2010	3/23/2017	7	1	14.29	3.91	53	5.7	5.7	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/16/2010	5/25/2016	13	13	100	--	--	14	54	2.4	13	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	6/16/2010	5/25/2016	11	10	90.91	60	60	176	330	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	6/16/2010	3/23/2017	8	8	100	--	--	3.9	8.4	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	4/1/2010	3/23/2017	15	15	100	--	--	11	69	--	--	--	48	4	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/16/2010	3/23/2017	14	2	14.29	18	38	13	113	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/16/2010	3/23/2017	14	1	7.14	0.26	6.0	1.0	1.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/16/2010	3/23/2017	14	2	14.29	1.5	67	3.6	9.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/16/2010	5/25/2016	11	11	100	--	--	12,200	14,200	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/16/2010	5/25/2016	11	2	18.18	9.85	131	160	188	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/16/2010	3/23/2017	14	1	7.14	0.93	7.0	20	20	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/16/2010	3/23/2017	14	14	100	--	--	255	312	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/22/2010	3/23/2017	7	7	100	--	--	2,110	5,990	119	7	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/16/2010	3/23/2017	14	13	92.86	17	17	12	16	12	13	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/16/2010	3/23/2017	14	13	92.86	3.3	3.3	5.2	100	22	4	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-182																	
Aluminum	No	ug/L	6/22/2010	1/9/2011	3	2	66.67	10	10	10	15	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	6/22/2010	11/24/2014	5	5	100	--	--	3.2	4.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/6/2010	11/21/2016	15	15	100	--	--	32	45	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	6/22/2010	11/24/2014	5	1	20	0.05	0.28	0.50	0.50	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Bromomethane	No	ug/L	6/22/2010	1/9/2011	3	1	33.33	0.25	0.25	0.94	0.94	--	--	--	11	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	ug/L	6/22/2010	1/9/2011	3	3	100	--	--	0.93	1.1	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/6/2010	11/17/2015	14	14	100	--	--	33	84	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	6/22/2010	11/24/2014	5	1	20	0.1	2.7	0.082	0.082	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	6/22/2010	11/24/2014	5	2	40	0.1	2.4	0.38	6.9	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/6/2010	11/21/2016	13	12	92.31	60	60	113	220	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	9/20/2010	1/9/2011	2	1	50	3.3	3.3	2.4	2.4	--	--	--	15	0	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/6/2010	11/21/2016	15	15	100	--	--	26	81	--	--	--	48	8	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/6/2010	11/21/2016	15	3	20	12.8	40	13	42	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lithium	No	ug/L	6/22/2010	1/9/2011	3	2	66.67	4	4.0	8.0	16	11	1	DOE/RL-96-61 Rev.0, Table 5-2 (Table ES-1 off by 1E+03 for lithium)	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/6/2010	11/21/2016	15	1	6.67	0.7	6.0	1.0	1.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	6/22/2010	1/9/2011	3	3	100	--	--	4.2	4.5	3.2	3	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/6/2010	11/21/2016	15	3	20	1.5	10	3.2	4.8	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/6/2010	11/21/2016	13	13	100	--	--	12,000	19,900	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	6/22/2010	1/9/2011	3	3	100	--	--	1.3	1.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium	No	ug/L	6/6/2010	11/21/2016	15	15	100	--	--	239	350	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	6/22/2010	11/21/2016	14	1	7.14	0.57	2.2	1.9	1.9	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	6/6/2010	11/21/2016	15	15	100	--	--	538	4,300	119	15	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	9/20/2010	1/9/2011	2	2	100	--	--	2.3	2.3	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/6/2010	11/21/2016	15	15	100	--	--	11	28	12	14	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/6/2010	11/21/2016	15	7	46.67	3.3	8.3	5.2	398	22	4	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-185																	
2-Butanone	No	ug/L	5/10/2011	3/13/2017	30	1	3.33	0.47	3.0	0.60	0.60	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	11/22/2016	2/23/2017	2	1	50	250	250	74	74	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	5/10/2011	3/13/2017	30	2	6.67	0.55	5.0	1.4	2.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	12/20/2011	11/22/2016	21	7	33.33	5	20	11	207	7.1	7	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	12/20/2011	11/22/2016	21	19	90.48	1.7	1.7	2.0	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	5/10/2011	2/23/2017	25	25	100	--	--	31	56	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	12/6/2013	11/22/2016	13	9	69.23	15	15	11	57	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	5/10/2011	3/13/2017	30	30	100	--	--	175	6,140	--	--	--	2,000	5	40 CFR 141 - federal MCL
Chloroform	No	ug/L	5/10/2011	3/13/2017	30	15	50	0.3	1.0	0.20	0.47	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	5/10/2011	2/23/2017	26	25	96.15	5.1	5.1	5.1	13	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cobalt	No	ug/L	12/20/2011	11/22/2016	21	8	38.1	0.1	0.22	0.10	0.42	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	12/20/2011	11/22/2016	21	14	66.67	0.1	0.35	0.31	1.9	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	5/10/2011	2/23/2017	26	26	100	--	--	92	232	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/10/2011	3/13/2017	28	26	92.86	2	8.0	2.8	10	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	5/10/2011	2/23/2017	13	3	23.08	20	30	130	891	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	12/20/2011	11/22/2016	21	4	19.05	0.05	0.50	0.10	0.26	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	5/10/2011	2/23/2017	17	7	41.18	1	4.1	0.40	162	39	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	5/10/2011	3/13/2017	30	2	6.67	0.27	1.6	1.7	4.3	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	12/20/2011	11/22/2016	21	21	100	--	--	1.3	3.7	3.2	3	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	5/10/2011	2/23/2017	17	11	64.71	0.5	1.6	0.39	10	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	5/10/2011	2/23/2017	26	26	100	--	--	19,000	75,300	26,871	8	DOE/RL-96-61 Rev.0, Table ES-1	45,000	4	40 CFR 141 - federal MCL
Nitrite	No	ug/L	5/10/2011	2/23/2017	26	7	26.92	9.85	131	144	275	94	7	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	12/20/2011	11/22/2016	21	1	4.76	1	2.0	2.4	2.4	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	5/10/2011	11/22/2016	15	15	100	--	--	224	364	323	2	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	5/10/2011	2/23/2017	25	2	8	0.429	1.9	3.0	3.1	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	5/10/2011	11/22/2016	23	20	86.96	34	42	34	64	0.83	20	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tin	No	ug/L	12/20/2011	11/22/2016	21	5	23.81	0.05	1.0	0.24	3.2	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	5/10/2011	3/13/2017	30	30	100	--	--	2.9	9.5	--	--	--	0.54	30	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	5/10/2011	3/13/2017	30	26	86.67	304	329	332	1,100	119	26	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/6/2013	11/22/2016	13	13	100	--	--	2.3	7.4	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	5/10/2011	2/23/2017	15	15	100	--	--	6.3	14	12	9	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	5/10/2011	2/23/2017	17	2	11.76	3.3	8.3	5.8	10	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-189																	
Arsenic	No	ug/L	5/28/2014	5/28/2014	1	1	100	--	--	5.2	5.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/23/2011	11/18/2016	22	22	100	--	--	24	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	6/23/2011	11/18/2016	22	22	100	--	--	66	3,260	--	--	--	2,000	8	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/23/2011	6/23/2011	1	1	100	--	--	1.1	1.1	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/23/2011	8/2/2016	21	19	90.48	5	5.0	2.4	42	2.4	19	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	6/23/2011	11/18/2016	18	18	100	--	--	72	220	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/10/2011	11/18/2016	6	1	16.67	1.74	4.2	3.2	3.2	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/10/2011	11/18/2016	6	6	100	--	--	4.2	17	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	6/23/2011	11/18/2016	21	21	100	--	--	1.5	35	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/23/2011	11/18/2016	22	4	18.18	19	40	20	148	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Manganese	No	ug/L	6/23/2011	11/18/2016	22	1	4.55	1	4.1	0.79	0.79	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/23/2011	11/18/2016	22	3	13.64	1.3	13	4.5	7.2	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/23/2011	11/18/2016	18	18	100	--	--	6,460	43,400	26,871	9	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/23/2011	11/18/2016	18	4	22.22	125	131	165	262	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	6/23/2011	11/18/2016	22	22	100	--	--	165	257	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	6/23/2011	11/18/2016	22	3	13.64	0.477	2.0	0.99	3.9	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	6/23/2011	11/18/2016	22	3	13.64	5.5	34	6.1	25	0.83	3	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	6/23/2011	11/18/2016	22	21	95.45	337	337	510	47,900	119	21	DOE/RL-96-61 Rev.0, Table ES-1	20,000	9	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/23/2011	11/18/2016	22	21	95.45	10	10	7.7	14	12	8	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/23/2011	11/18/2016	22	1	4.55	3.3	8.3	9.9	9.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-202																	
Aluminum	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	98	430	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	10/13/2014	10/27/2016	3	1	33.33	1.7	1.7	0.19	0.19	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	3.0	3.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	32	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	45	108	36	3	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Carbon tetrachloride	No	ug/L	10/13/2014	10/16/2015	2	1	50	0.13	0.13	1.1	1.1	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/13/2014	1/30/2017	10	10	100	--	--	1,500	3,170	--	--	--	2,000	3	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/13/2014	10/16/2015	2	2	100	--	--	0.82	0.91	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	19	160	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	2	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/13/2014	10/27/2016	3	2	66.67	0.22	0.22	0.26	0.58	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	1.9	7.5	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	150	450	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/13/2014	1/30/2017	10	5	50	1.92	3.0	2.0	6.9	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/13/2014	1/30/2017	10	10	100	--	--	14	38	0.0081	10	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/13/2014	1/30/2017	10	10	100	--	--	3.3	12	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	166	1,600	570	2	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/13/2014	10/27/2016	3	2	66.67	0.17	0.17	0.21	0.78	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	3.8	15	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	1.9	4.1	3.2	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	1.8	10	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	11,500	28,300	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	10/13/2014	10/27/2016	3	1	33.33	19.7	125	174	174	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/13/2014	10/27/2016	3	1	33.33	1.6	1.6	1.3	1.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	10/13/2014	10/27/2016	3	1	33.33	0.82	0.82	0.040	0.040	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	230	277	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/13/2014	1/30/2017	10	1	10	0.568	1.5	8.1	8.1	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/13/2014	10/27/2016	3	2	66.67	33.4	33	42	72	0.83	2	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/13/2014	10/27/2016	3	1	33.33	0.014	0.55	0.64	0.64	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/13/2014	10/27/2016	3	1	33.33	1.1	1.3	4.9	4.9	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	10/13/2014	10/16/2015	2	1	50	0.07	0.070	0.13	0.13	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/13/2014	10/16/2015	2	1	50	0.25	0.25	0.25	0.25	--	--	--	0.54	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/13/2014	1/30/2017	10	10	100	--	--	18,500	47,900	119	10	DOE/RL-96-61 Rev.0, Table ES-1	20,000	9	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	3.3	4.1	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	8.3	11	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-203																	
Aluminum	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	15	86	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	12/15/2015	12/9/2016	2	1	50	1.7	1.7	0.17	0.17	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	3.6	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	36	40	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	12/15/2015	12/9/2016	2	1	50	11	11	7.6	7.6	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	4/17/2015	12/9/2016	8	8	100	--	--	58	683	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	20	29	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	12/15/2015	12/9/2016	2	1	50	0.07	0.070	0.27	0.27	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	12/15/2015	12/9/2016	2	1	50	1.1	1.1	1.2	1.2	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	210	210	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	4/17/2015	12/9/2016	8	3	37.5	1.56	2.7	2.0	2.3	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	4/17/2015	12/9/2016	8	8	100	--	--	5.0	7.1	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/17/2015	12/9/2016	8	8	100	--	--	10	28	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	28	178	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	12/15/2015	12/9/2016	2	1	50	0.16	0.16	0.24	0.24	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/15/2015	12/9/2016	2	1	50	0.3	0.30	20	20	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	2.0	2.8	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/15/2015	12/9/2016	2	1	50	4.2	4.2	3.2	3.2	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	14,600	16,400	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	12/15/2015	12/9/2016	2	1	50	1.6	1.6	1.2	1.2	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	239	240	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	4/17/2015	12/9/2016	8	8	100	--	--	802	1,460	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	2.1	2.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	9.5	13	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-207																	
Aluminum	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	15	16	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	4.3	4.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	38	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	786	852	36	2	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	82	97	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/16/2015	10/20/2016	2	1	50	0.1	0.10	0.16	0.16	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	8/27/2015	1/30/2017	7	7	100	--	--	260	290	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/16/2015	10/20/2016	2	1	50	2.98	3.0	3.3	3.3	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/16/2015	10/20/2016	2	2	100	--	--	18	28	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	8/27/2015	1/30/2017	7	7	100	--	--	74	120	--	--	--	48	7	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Manganese	No	ug/L	10/16/2015	10/20/2016	2	1	50	1	1.0	1.2	1.2	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	4.3	4.5	3.2	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/16/2015	10/20/2016	2	1	50	0.5	0.50	0.56	0.56	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	8/27/2015	1/30/2017	7	7	100	--	--	39,800	48,700	26,871	7	DOE/RL-96-61 Rev.0, Table ES-1	45,000	2	40 CFR 141 - federal MCL
Nitrite	No	ug/L	8/27/2015	1/30/2017	7	1	14.29	125	125	164	164	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/16/2015	10/20/2016	2	1	50	2	2.0	1.9	1.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	296	341	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	10/16/2015	10/20/2016	2	2	100	--	--	38	84	0.83	2	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	8/27/2015	1/30/2017	7	7	100	--	--	345,000	935,000	119	7	DOE/RL-96-61 Rev.0, Table ES-1	20,000	7	40 CFR 141 - federal MCL
Uranium	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	4.6	5.0	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	10	12	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-208																	
Aluminum	No	ug/L	11/18/2015	11/21/2016	2	1	50	17.3	17	180	180	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	11/18/2015	11/21/2016	2	1	50	1.7	1.7	0.57	0.57	55	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	3.7	4.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	39	41	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Boron	No	ug/L	4/17/2015	11/21/2016	3	3	100	--	--	30	258	36	2	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	9.3	12	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/18/2015	11/21/2016	2	1	50	0.68	0.68	62	62	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/17/2015	11/21/2016	8	8	100	--	--	104	240	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	11/18/2015	11/21/2016	2	1	50	1.74	1.7	2.6	2.6	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	11/18/2015	11/21/2016	2	2	100	--	--	4.9	7.1	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/17/2015	11/21/2016	8	8	100	--	--	7.4	41	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/17/2015	11/21/2016	3	3	100	--	--	36	50	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	0.42	3.4	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	11/18/2015	11/21/2016	2	1	50	0.88	0.88	0.74	0.74	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	4.8	4.8	3.2	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	4/17/2015	11/21/2016	8	8	100	--	--	15,100	28,700	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/18/2015	11/21/2016	2	1	50	1.6	1.6	1.6	1.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	320	344	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	4/17/2015	11/21/2016	8	1	12.5	0.637	1.4	0.63	0.63	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	4/17/2015	11/21/2016	8	8	100	--	--	10,100	83,500	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	2	40 CFR 141 - federal MCL

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Uranium	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	2.8	2.9	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/17/2015	11/21/2016	3	2	66.67	4.4	4.4	7.8	13	12	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	27	180	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-209																	
Aluminum	No	ug/L	11/11/2015	11/15/2016	2	1	50	15	15	16	16	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	6.1	6.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	28	34	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	3/5/2015	11/15/2016	3	3	100	--	--	3.3	4.7	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	0.36	1.4	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/20/2015	11/15/2016	8	8	100	--	--	311	350	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	11/11/2015	11/15/2016	2	2	100	--	--	3.3	5.2	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	11/11/2015	11/15/2016	2	2	100	--	--	3.0	8.8	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/20/2015	11/15/2016	8	8	100	--	--	2.8	3.6	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	11/11/2015	11/15/2016	2	1	50	30	30	43	43	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	11/11/2015	11/15/2016	2	1	50	1	1.0	9.1	9.1	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	8.4	8.8	3.2	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	0.76	1.9	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	4/20/2015	11/15/2016	8	8	100	--	--	12,800	13,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	277	278	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	3.6	4.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	19	19	12	2	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-210																	
Aluminum	No	ug/L	11/24/2014	11/21/2016	3	2	66.67	17.3	17	22	46	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/24/2014	11/21/2016	3	2	66.67	4	4.0	3.1	3.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	32	39	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	11/24/2014	11/24/2014	1	1	100	--	--	13	13	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	11/24/2014	11/21/2016	3	1	33.33	0.1	0.20	0.19	0.19	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	11/24/2014	11/21/2016	3	3	100	--	--	81	236	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	27	31	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/24/2014	11/21/2016	3	2	66.67	0.68	0.68	15	30	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	159	180	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	11/24/2014	11/21/2016	9	9	100	--	--	22	26	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	11/24/2014	11/21/2016	3	1	33.33	0.17	1.0	2.3	2.3	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	11/24/2014	11/21/2016	3	2	66.67	0.88	0.88	1.3	2.5	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Molybdenum	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	2.4	2.9	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	20,800	22,600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	240	304	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	11/24/2014	11/21/2016	9	2	22.22	0.545	1.4	1.3	2.1	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tin	No	ug/L	11/24/2014	11/21/2016	3	1	33.33	1.1	1.2	1.7	1.7	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	11/24/2014	11/21/2016	9	9	100	--	--	1,400	3,970	119	9	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	2.1	2.6	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Zinc	No	ug/L	11/24/2014	11/21/2016	3	2	66.67	9.3	9.3	69	75	22	2	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-223																	
2-Propanol	No	ug/L	2/2/2017	2/2/2017	1	1	100	--	--	8.8	8.8	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	9/28/2016	2/2/2017	4	4	100	--	--	32	37	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	9/28/2016	2/2/2017	3	3	100	--	--	108	158	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	9/28/2016	2/2/2017	3	3	100	--	--	0.33	0.41	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	9/28/2016	2/2/2017	5	5	100	--	--	4.7	16	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	9/28/2016	2/15/2017	6	6	100	--	--	140	210	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	9/28/2016	3/15/2017	10	10	100	--	--	6.6	16	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/28/2016	2/15/2017	5	3	60	30	30	98	202	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Manganese	No	ug/L	9/28/2016	2/2/2017	4	3	75	2	2.0	2.4	8.8	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/28/2016	2/15/2017	6	6	100	--	--	21,200	24,800	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/28/2016	2/15/2017	6	2	33.33	125	125	217	821	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	9/28/2016	2/2/2017	3	3	100	--	--	4.3	4.9	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/28/2016	2/2/2017	3	3	100	--	--	1,170	1,660	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/28/2016	2/15/2017	5	5	100	--	--	8.8	9.7	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-224																	
2-Propanol	No	ug/L	2/2/2017	2/2/2017	1	1	100	--	--	10	10	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	9/28/2016	2/2/2017	3	1	33.33	3	3.0	2.0	2.0	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	9/28/2016	2/2/2017	4	4	100	--	--	40	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	2/15/2017	2/15/2017	1	1	100	--	--	9.7	9.7	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	9/28/2016	2/2/2017	3	3	100	--	--	281	459	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	9/28/2016	2/2/2017	3	2	66.67	0.3	0.30	0.27	0.38	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	9/28/2016	2/2/2017	5	5	100	--	--	97	130	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	100	4	40 CFR 141 - federal MCL
Fluoride	No	ug/L	9/28/2016	2/15/2017	6	6	100	--	--	130	210	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	9/28/2016	3/15/2017	10	10	100	--	--	97	130	--	--	--	48	10	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/28/2016	2/15/2017	5	2	40	16	30	195	360	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-13. Individual Monitoring Well Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Manganese	No	ug/L	9/28/2016	2/2/2017	4	2	50	2	2.0	3.9	5.7	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/28/2016	2/15/2017	6	6	100	--	--	22,600	23,500	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/28/2016	2/15/2017	6	2	33.33	125	125	220	821	94	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	9/28/2016	2/2/2017	3	1	33.33	1.1	1.2	1.2	1.2	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	9/28/2016	2/2/2017	3	3	100	--	--	3.1	5.5	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/28/2016	2/2/2017	3	3	100	--	--	912	1,110	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/28/2016	2/15/2017	5	4	80	15	15	12	13	12	4	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-14. Groundwater Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Pesticide																	
Aldrin	No	ug/L	6/22/2010	1/10/2011	9	2	22.22	0.010	0.010	0.12	0.65	--			0.0019	2	WAC 173-201A - freshwater CCC
Metals																	
Aluminum	Yes	ug/L	10/22/2009	12/9/2016	87	4	4.6	5	20	14.5	33.8	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	12/9/2016	98	94	95.92	1.7	4	1.7	6.41	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	12/9/2016	99	2	2.02	0.05	1	0.12	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	3/13/2017	294	286	97.28	3	14	1.8	255	2.4	280	DOE/RL-96-61 Rev.0, Table ES-1	74.0	24	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	12/9/2016	99	61	61.62	0.1	10	0.21	18.8	0.81	34	DOE/RL-96-61 Rev.0, Table ES-1	9.9	1	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	3/23/2017	349	337	96.56	1.5	8.0	1.5	353	--	--	--	10.0	197	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	3/23/2017	262	38	14.5	12.8	43.6	13.1	229	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	12/9/2016	86	14	16.28	0.05	1	0.082	2.6	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	1	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	4/17/2014	22	1	4.55	0.06	0.2	0.116	0.116	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	0.012	1	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	3/23/2017	272	67	24.63	0.2	66.5	0.374	43.8	1.6	50	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	12/9/2016	86	27	31.4	0.6	2	0.707	3.29	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	3/23/2017	293	3	1.02	0.039	7	1.03	10	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	3/23/2017	272	137	50.37	1.6	30	3.99	477	21.8	33	DOE/RL-96-61 Rev.0, Table ES-1	91.0	4	WAC 173-201A - freshwater CCC

Table D-14. Groundwater Summary Statistics for Wells Screened through the Entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Anions																	
Chloride	No	ug/L	10/22/2009	2/23/2017	291	291	100	--	--	4,810	51,000	--	--	--	230,000	0	CWA - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services

CCC = criteria continuous concentration

CMC = criteria maximum concentration

CWA = *Clean Water Act of 1977*

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-116A																	
Aluminum	Yes	ug/L	6/16/2010	11/16/2016	12	0	0	5	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/31/2011	11/16/2016	11	11	100	--	--	2.4	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/31/2011	11/16/2016	11	0	0	0.05	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/16/2010	11/16/2016	14	12	85.71	13	14	4.1	10	2.4	12	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/31/2011	11/16/2016	11	11	100	--	--	2.6	6.1	0.81	11	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	ug/L	6/16/2010	11/16/2016	14	12	85.71	3.7	8.0	2.5	11	--	--	--	10	1	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/16/2010	11/16/2016	8	0	0	18	38	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/31/2011	11/16/2016	11	4	36.36	0.1	0.50	0.10	0.26	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/16/2010	11/16/2016	10	1	10	0.2	5.0	1.3	1.3	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/31/2011	11/16/2016	11	0	0	1	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/16/2010	11/16/2016	14	0	0	0.04	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/16/2010	11/16/2016	10	6	60	3.5	4.0	4.2	11	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-120A																	
Aluminum	Yes	ug/L	1/31/2011	11/16/2016	12	0	0	5	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	1/31/2011	11/16/2016	12	12	100	--	--	2.3	3.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	1/31/2011	11/16/2016	12	0	0	0.05	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	4/1/2010	11/16/2016	14	12	85.71	3	13	2.8	17	2.4	12	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	1/31/2011	11/16/2016	12	11	91.67	0.2	0.20	0.77	4.2	0.81	9	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	ug/L	4/1/2010	11/16/2016	14	12	85.71	1.5	3.7	1.8	6.5	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/1/2010	11/16/2016	7	1	14.29	30	38	23	23	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	1/31/2011	11/16/2016	12	4	33.33	0.1	0.50	0.082	0.35	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	4/1/2010	11/16/2016	9	2	22.22	0.2	4.0	1.5	5.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	1/31/2011	11/16/2016	12	2	16.67	1	2.0	0.71	0.83	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	4/1/2010	11/16/2016	14	0	0	0.04	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/1/2010	11/16/2016	9	9	100	--	--	5.9	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-145																	
Arsenic	Yes	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	2.6	2.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/19/2014	11/19/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	2/18/2010	5/25/2016	14	14	100	--	--	6.0	69	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	2.3	2.3	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	**No**	ug/L	2/18/2010	11/16/2016	14	14	100	--	--	3.1	74	--	--	--	10	10	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	2/18/2010	11/16/2016	15	3	20	12.8	38	16	36	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	2/18/2010	11/16/2016	15	4	26.67	1.5	13	3.2	6.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	2/18/2010	11/16/2016	15	0	0	0.99	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	2/18/2010	11/16/2016	15	9	60	3.3	7.0	5.2	44	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-151																	
Aluminum	Yes	ug/L	10/22/2009	10/13/2016	17	3	17.65	10	20	15	19	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/22/2009	10/13/2016	17	17	100	--	--	4.1	6.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	10/13/2016	17	1	5.88	0.099	0.20	0.12	0.12	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	10/13/2016	18	18	100	--	--	2.7	24	2.4	18	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	10/13/2016	17	11	64.71	0.2	1.1	0.26	3.3	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	10/13/2016	17	14	82.35	2	8.0	2.4	26	--	--	--	10	3	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	10/13/2016	12	3	25	12.8	38	19	229	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	10/13/2016	17	2	11.76	0.1	0.20	0.62	2.6	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	1	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	1/10/2011	5	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	10/13/2016	14	6	42.86	0.8	4.2	0.38	4.3	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	10/13/2016	17	9	52.94	0.6	2.0	0.71	2.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	10/13/2016	18	0	0	0.039	4.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	10/13/2016	14	1	7.14	1.6	30	360	360	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-152																	
Aluminum	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	10	10	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	Yes	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	4.2	4.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/22/2009	10/26/2016	14	14	100	--	--	28	71	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/22/2009	1/9/2011	5	1	20	0.2	0.38	0.26	0.26	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/22/2009	10/26/2016	18	18	100	--	--	28	73	--	--	--	10	18	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/22/2009	10/26/2016	14	2	14.29	18	44	32	62	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/22/2009	1/9/2011	5	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/22/2009	10/26/2016	14	1	7.14	1.5	67	8.0	8.0	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/22/2009	1/9/2011	5	5	100	--	--	0.86	1.7	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/22/2009	10/26/2016	14	0	0	0.2	6.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/22/2009	10/26/2016	14	10	71.43	3.3	6.0	4.2	477	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-153																	
Arsenic	Yes	ug/L	11/24/2014	11/24/2014	1	0	0	1.8	1.8	--	--	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/24/2014	11/24/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	7/26/2010	5/25/2016	14	14	100	--	--	16	31	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/24/2014	11/24/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	7/26/2010	3/23/2017	15	15	100	--	--	14	31	--	--	--	10	15	WAC 173-201A - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	Yes	ug/L	7/26/2010	3/23/2017	15	2	13.33	12.8	38	21	34	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	7/26/2010	3/23/2017	15	5	33.33	1.5	13	3.9	8.0	1.6	5	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	7/26/2010	3/23/2017	15	0	0	0.99	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	7/26/2010	3/23/2017	15	12	80	3	8.3	5.0	35	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-154																	
Arsenic	Yes	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	4.8	4.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	8/25/2014	8/25/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	1/7/2010	5/25/2016	14	14	100	--	--	24	88	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	3	CWA - freshwater CCC
Copper	Yes	ug/L	8/25/2014	8/25/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	25	96	--	--	--	10	15	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	1/7/2010	11/21/2016	15	4	26.67	12.8	38	38	79	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	1/7/2010	11/21/2016	15	2	13.33	1.3	13	3.4	5.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	1/7/2010	11/21/2016	15	0	0	0.93	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	1/7/2010	11/21/2016	15	11	73.33	3.3	6.0	4.0	27	22	1	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-157																	
Aluminum	Yes	ug/L	10/29/2009	6/11/2010	3	0	0	10	10	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/29/2009	11/23/2014	5	4	80	1.8	1.8	1.7	5.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/29/2009	11/23/2014	5	0	0	0.2	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	10/29/2009	8/1/2016	25	25	100	--	--	1.8	56	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/29/2009	11/23/2014	5	0	0	0.2	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/29/2009	11/14/2016	15	14	93.33	8	8.0	1.7	56	--	--	--	10	7	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/29/2009	11/14/2016	26	1	3.85	12.8	40	27	27	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/29/2009	6/11/2010	3	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	10/29/2009	6/11/2010	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/29/2009	11/14/2016	26	7	26.92	1.5	67	2.7	6.0	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/29/2009	6/11/2010	3	3	100	--	--	1.7	3.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/29/2009	11/14/2016	26	0	0	0.2	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/29/2009	11/14/2016	26	3	11.54	3	8.3	4.0	9.3	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-163																	
Arsenic	Yes	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	4.7	4.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	8/25/2014	8/25/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	1/7/2010	5/25/2016	14	14	100	--	--	3.8	78	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	1	CWA - freshwater CCC
Copper	Yes	ug/L	8/25/2014	8/25/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	1/7/2010	11/21/2016	15	15	100	--	--	2.1	81	--	--	--	10	10	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	1/7/2010	11/21/2016	15	2	13.33	12.8	40	25	37	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	1/7/2010	11/21/2016	15	2	13.33	1.5	13	3.4	11	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	1/7/2010	11/21/2016	15	0	0	0.99	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	1/7/2010	11/21/2016	15	11	73.33	3.3	6.0	5.0	22	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-165																	
Arsenic	Yes	ug/L	11/18/2014	11/18/2014	1	1	100	--	--	3.7	3.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	9/27/2011	11/18/2014	2	0	0	0.34	1.0	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	3/13/2017	26	26	100	--	--	8.9	255	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	74	9	CWA - freshwater CCC
Copper	Yes	ug/L	9/27/2011	11/18/2014	2	1	50	10	10	8.2	8.2	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	2/3/2010	3/13/2017	32	32	100	--	--	7.8	353	--	--	--	10	28	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/15/2010	2/23/2017	24	7	29.17	12.8	40	20	200	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Mercury	Yes	ug/L	6/22/2011	4/17/2014	6	1	16.67	0.06	0.20	0.12	0.12	0.0030	1	DOE/RL-96-61 Rev.0, Table ES-1	0.012	1	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/15/2010	2/23/2017	24	12	50	1.6	13	0.71	44	1.6	11	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/15/2010	2/23/2017	24	1	4.17	0.99	7.0	1.9	1.9	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/23/2017	24	14	58.33	3	20	4.7	50	22	4	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-166																	
Arsenic	Yes	ug/L	7/16/2014	7/16/2014	1	1	100	--	--	2.8	2.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	7/16/2014	7/16/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	2/7/2017	26	26	100	--	--	3.3	47	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	7/16/2014	7/16/2014	1	1	100	--	--	19	19	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	1	WAC 173-201A - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	6/15/2010	2/7/2017	28	26	92.86	8	8.0	3.1	66	--	--	--	10	10	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/15/2010	2/7/2017	24	3	12.5	18	40	19	21	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/15/2010	2/7/2017	24	4	16.67	1.5	13	2.1	9.4	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/15/2010	2/7/2017	24	1	4.17	0.99	7.0	1.0	1.0	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/7/2017	24	19	79.17	3.3	6.0	4.7	149	22	12	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-171																	
Arsenic	Yes	ug/L	8/25/2014	8/25/2014	1	1	100	--	--	3.7	3.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	8/25/2014	8/25/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	4/1/2010	5/25/2016	14	14	100	--	--	16	62	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	8/25/2014	8/25/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/1/2010	3/23/2017	15	15	100	--	--	11	69	--	--	--	10	15	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/1/2010	3/23/2017	15	3	20	19	38	23	45	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	4/1/2010	3/23/2017	15	2	13.33	1.5	67	3.5	9.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	4/1/2010	3/23/2017	15	1	6.67	0.93	7.0	10	10	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	1	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/1/2010	3/23/2017	15	14	93.33	3.3	3.3	5.0	78	22	5	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-182																	
Aluminum	Yes	ug/L	6/22/2010	1/9/2011	3	0	0	10	10	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	6/22/2010	11/24/2014	5	5	100	--	--	3.4	5.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cadmium	Yes	ug/L	6/22/2010	11/24/2014	5	0	0	0.2	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/6/2010	11/17/2015	14	14	100	--	--	32	83	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	3	CWA - freshwater CCC
Copper	Yes	ug/L	6/22/2010	11/24/2014	5	3	60	0.2	2.1	0.22	4.1	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/6/2010	11/21/2016	15	15	100	--	--	26	81	--	--	--	10	15	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/6/2010	11/21/2016	15	2	13.33	12.8	40	18	26	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	6/22/2010	1/9/2011	3	0	0	0.2	0.20	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Mercury	Yes	ug/L	6/22/2010	1/9/2011	3	0	0	0.1	0.10	--	--	0.0030	0	DOE/RL-96-61 Rev.0, Table ES-1	0.012	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/6/2010	11/21/2016	15	3	20	1.5	10	3.2	4.8	1.6	3	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	6/22/2010	1/9/2011	3	3	100	--	--	1.9	2.1	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/6/2010	11/21/2016	15	0	0	0.2	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/6/2010	11/21/2016	15	12	80	3.3	4.0	4.0	338	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-185																	
Aluminum	Yes	ug/L	12/20/2011	11/22/2016	21	0	0	5	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/20/2011	11/22/2016	21	20	95.24	1.7	1.7	1.7	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/20/2011	11/22/2016	21	0	0	0.05	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	5/10/2011	2/23/2017	26	25	96.15	5.1	5.1	4.8	11	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	12/20/2011	11/22/2016	21	12	57.14	0.1	0.45	0.21	1.6	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	5/10/2011	3/13/2017	28	26	92.86	2	8.0	2.8	10	--	--	--	10	0	WAC 173-201A - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	Yes	ug/L	5/10/2011	2/23/2017	13	2	15.38	20	30	18	26	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	12/20/2011	11/22/2016	21	0	0	0.05	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	5/10/2011	2/23/2017	17	10	58.82	0.5	4.0	0.37	7.0	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	12/20/2011	11/22/2016	21	3	14.29	1	2.0	1.1	2.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	5/10/2011	2/23/2017	25	0	0	0.05	5.1	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	5/10/2011	2/23/2017	17	1	5.88	3.3	8.3	5.7	5.7	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-189																	
Arsenic	Yes	ug/L	5/28/2014	5/28/2014	1	1	100	--	--	3.6	3.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/28/2014	5/28/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/23/2011	8/2/2016	21	18	85.71	5	5.0	2.1	38	2.4	14	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	5/28/2014	5/28/2014	1	0	0	2.1	2.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/23/2011	11/18/2016	21	21	100	--	--	1.5	35	--	--	--	10	8	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/23/2011	11/18/2016	22	1	4.55	12.8	40	38	38	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/23/2011	11/18/2016	22	1	4.55	1.3	13	3.1	3.1	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/23/2011	11/18/2016	22	0	0	0.93	6.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/23/2011	11/18/2016	22	1	4.55	3.3	8.3	9.5	9.5	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-202																	
Aluminum	Yes	ug/L	10/13/2014	10/27/2016	3	0	0	12.9	17	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	Yes	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	2.4	2.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/13/2014	10/27/2016	3	0	0	0.099	0.10	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	4.7	10	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/13/2014	10/27/2016	3	1	33.33	0.68	1.1	0.60	0.60	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/13/2014	1/30/2017	10	10	100	--	--	3.3	12	--	--	--	10	1	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/13/2014	10/27/2016	3	0	0	12.8	16	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/13/2014	10/27/2016	3	1	33.33	0.17	0.17	0.41	0.41	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/13/2014	10/27/2016	3	3	100	--	--	1.1	9.9	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/13/2014	10/27/2016	3	0	0	0.66	1.6	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/13/2014	10/27/2016	3	0	0	0.039	0.82	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	10/13/2014	10/27/2016	3	0	0	8.3	9.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-203																	
Aluminum	Yes	ug/L	12/15/2015	12/9/2016	2	1	50	14	14	34	34	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	3.7	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	12/15/2015	12/9/2016	2	0	0	0.099	0.10	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	12/15/2015	12/9/2016	2	2	100	--	--	20	28	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	12/15/2015	12/9/2016	2	0	0	0.68	1.1	--	--	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/17/2015	12/9/2016	8	8	100	--	--	10	28	--	--	--	10	7	WAC 173-201A - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	Yes	ug/L	12/15/2015	12/9/2016	2	1	50	16	16	13	13	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	12/15/2015	12/9/2016	2	0	0	0.16	0.17	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/15/2015	12/9/2016	2	0	0	0.8	4.2	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	12/15/2015	12/9/2016	2	1	50	1.6	1.6	1.2	1.2	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/15/2015	12/9/2016	2	0	0	0.039	0.82	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/15/2015	12/9/2016	2	0	0	9.1	9.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-207																	
Aluminum	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	15	15	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	4.4	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	0.11	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/16/2015	10/20/2016	2	2	100	--	--	85	95	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74	2	CWA - freshwater CCC
Copper	Yes	ug/L	10/16/2015	10/20/2016	2	1	50	0.35	0.35	0.36	0.36	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	8/27/2015	1/30/2017	7	7	100	--	--	74	120	--	--	--	10	7	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	30	30	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	0.5	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	0.5	0.50	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	1.5	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	0.1	0.40	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	Yes	ug/L	10/16/2015	10/20/2016	2	0	0	3.5	3.5	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-208																	
Aluminum	Yes	ug/L	11/18/2015	11/21/2016	2	0	0	14	17	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	3.3	4.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/18/2015	11/21/2016	2	0	0	0.099	0.10	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	7.2	12	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/18/2015	11/21/2016	2	2	100	--	--	5.6	6.5	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/17/2015	11/21/2016	8	8	100	--	--	7.4	41	--	--	--	10	3	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/17/2015	11/21/2016	3	0	0	12.8	16	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/18/2015	11/21/2016	2	1	50	0.16	0.16	0.56	0.56	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	11/18/2015	11/21/2016	2	0	0	0.8	4.2	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/18/2015	11/21/2016	2	1	50	1.6	1.6	1.5	1.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	11/18/2015	11/21/2016	2	0	0	0.039	0.82	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	11/18/2015	11/21/2016	2	1	50	9.1	9.1	17	17	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-209																	
Aluminum	Yes	ug/L	11/11/2015	11/15/2016	2	0	0	15	15	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	6.0	6.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/11/2015	11/15/2016	2	0	0	0.11	0.30	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	3.8	4.0	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	0.40	0.49	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/20/2015	11/15/2016	8	8	100	--	--	2.8	3.6	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	11/11/2015	11/15/2016	2	0	0	30	30	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	11/11/2015	11/15/2016	2	0	0	0.5	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	11/11/2015	11/15/2016	2	2	100	--	--	0.65	0.67	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/11/2015	11/15/2016	2	0	0	1.5	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	11/11/2015	11/15/2016	2	0	0	0.1	0.40	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
199-K-210																	
Aluminum	Yes	ug/L	11/24/2014	11/21/2016	3	0	0	12.9	20	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/24/2014	11/21/2016	3	2	66.67	4	4.0	3.6	3.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/24/2014	11/21/2016	3	1	33.33	0.1	0.20	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	30	33	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	4.5	8.6	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	11/24/2014	11/21/2016	9	9	100	--	--	22	26	--	--	--	10	9	WAC 173-201A - freshwater CCC
Lead	Yes	ug/L	11/24/2014	11/21/2016	3	2	66.67	1	1.0	0.24	0.62	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	11/24/2014	11/21/2016	3	0	0	0.4	2.0	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/24/2014	11/21/2016	3	0	0	1.6	2.0	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Silver	Yes	ug/L	11/24/2014	11/21/2016	3	0	0	0.82	0.90	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	11/24/2014	11/21/2016	3	3	100	--	--	11	29	22	2	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-223																	
Chromium	Yes	ug/L	9/28/2016	2/2/2017	5	5	100	--	--	5.3	15	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	9/28/2016	3/15/2017	10	10	100	--	--	6.6	16	--	--	--	10	2	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	9/28/2016	2/15/2017	5	0	0	30	30	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	9/28/2016	2/2/2017	4	0	0	1.5	1.5	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	9/28/2016	2/2/2017	4	0	0	1	1.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	9/28/2016	2/2/2017	4	0	0	3.3	3.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-224																	
Chromium	Yes	ug/L	9/28/2016	2/2/2017	5	5	100	--	--	97	170	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74	5	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	9/28/2016	3/15/2017	10	10	100	--	--	97	130	--	--	--	10	10	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	9/28/2016	2/15/2017	5	1	20	16	30	18	18	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	9/28/2016	2/2/2017	4	0	0	1.5	10	--	--	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	9/28/2016	2/2/2017	4	0	0	1	3.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC

Table D-15. Individual Monitoring Well Summary Statistics for Wells Screened through thee entire Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	Yes	ug/L	9/28/2016	2/2/2017	4	0	0	3	6.0	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services

CCC = criteria continuous concentration

CMC = criteria maximum concentration

CWA = *Clean Water Act of 1977*

Table D-16. Groundwater Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Carbon-14	No	pCi/L	1/4/2011	2/24/2017	62	62	100	--	--	84.4	782	--	--	--	2,000	0	40 CFR 141 - federal MCL
Gross alpha	No	pCi/L	6/15/2010	11/29/2016	8	4	50	2.2	4.8	1.42	6.97	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/15/2010	11/29/2016	8	8	100	--	--	13.9	36	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	--	40 CFR 141 - federal MCL
Nickel-63	No	pCi/L	1/4/2011	2/24/2017	58	6	10.34	0.366	2.1	0.92	4.7	0.015	6	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	1/4/2011	11/29/2016	53	51	96.23	34.6	36.8	14	66.3	0.83	51	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	1/4/2011	2/24/2017	61	60	98.36	340	340	350	1800	119	60	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	1/4/2011	2/24/2017	62	62	100	--	--	84.4	782	--	--	--	2,000	0	40 CFR 141 - federal MCL
Volatile Organic Compounds																	
2-Butanone	No	ug/L	6/15/2010	2/24/2017	51	3	5.88	0.47	3	0.47	0.98	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	2/13/2017	2/24/2017	2	1	50	250	250	19	19	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	6/15/2010	2/24/2017	51	7	13.73	0.34	5	0.6	11.2	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon disulfide	No	ug/L	6/15/2010	2/24/2017	51	1	1.96	0.05	1.6	0.31	0.31	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	ug/L	6/15/2010	2/24/2017	51	28	54.9	1	1	0.25	0.7	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/15/2010	2/24/2017	51	3	5.88	0.27	1.6	0.33	1.1	--	--	--	5.0	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	6/15/2010	2/24/2017	51	51	100	--	--	0.7	6.49	--	--	--	0.54	51	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons - diesel range	No	ug/L	1/4/2011	11/29/2016	18	2	11.11	16	70	36	83.2	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - gasoline range	No	ug/L	1/4/2011	11/29/2016	18	4	22.22	10	50	17	53	--	--	--	1,000	0	WAC 173-340-900,Table 720-1

Table D-16. Groundwater Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	No	ug/L	10/24/2011	11/13/2016	22	5	22.73	10	20	10.3	117	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/24/2011	11/13/2016	25	25	100	--	--	1.8	5.29	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/24/2017	75	75	100	--	--	34	82.8	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/24/2011	11/13/2016	15	11	73.33	15	15	11.9	66.3	36.0	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/24/2011	11/13/2016	25	1	4	0.05	0.34	0.18	0.18	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/15/2010	2/24/2017	75	75	100	--	--	5.7	67	2.4	75	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/24/2011	11/13/2016	25	1	4	0.05	2.7	0.65	0.65	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/24/2011	11/13/2016	25	19	76	0.2	2.1	0.21	6.8	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	2/3/2010	2/24/2017	79	79	100	--	--	4.6	95	--	--	--	48.0	5	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/24/2017	63	21	33.33	12.8	40	18.8	426	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/24/2011	11/13/2016	22	2	9.09	0.05	0.5	0.36	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	6/15/2010	2/24/2017	67	15	22.39	0.1	6	0.42	14.3	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/24/2011	11/13/2016	22	22	100	--	--	1.47	3.23	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/15/2010	2/24/2017	67	30	44.78	0.5	66.5	0.115	41.3	1.6	23	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Selenium	No	ug/L	10/24/2011	11/13/2016	22	1	4.55	1	2	1.6	1.6	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/15/2010	2/24/2017	75	5	6.67	0.04	7	1.8	15	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-16. Groundwater Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium	No	ug/L	6/15/2010	11/29/2016	62	62	100	--	--	208	362	323	8	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	10/24/2011	11/13/2016	22	3	13.64	0.05	0.6	0.698	0.97	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	3	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/24/2011	11/13/2016	22	2	9.09	0.05	1	2.2	2.7	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	12/6/2013	11/29/2016	15	15	100	--	--	2.1	3.63	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/15/2010	2/24/2017	65	60	92.31	10	15	5.7	24	11.5	35	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/15/2010	2/24/2017	67	30	44.78	2	8.3	5	362	21.8	6	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Fluoride	No	ug/L	6/15/2010	2/24/2017	70	70	100	--	--	80.6	357	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	6/15/2010	2/24/2017	70	70	100	--	--	13800	43400	26,871	18	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/24/2017	70	18	25.71	9.85	131	65.7	4010	93.7	17	DOE/RL-96-61 Rev.0, Table ES-1	3,300	1	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-168																	
2-Butanone	No	ug/L	6/15/2010	2/13/2017	16	1	6.25	0.47	3.0	0.47	0.47	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	6/15/2010	2/13/2017	16	1	6.25	0.34	5.0	4.8	4.8	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	2.5	2.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/15/2010	2/13/2017	26	26	100	--	--	34	67	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	1/4/2011	2/13/2017	14	14	100	--	--	220	532	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/15/2010	2/13/2017	16	8	50	1	1.0	0.30	0.52	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/15/2010	2/13/2017	27	27	100	--	--	8.5	67	2.4	27	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	6.8	6.8	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/15/2010	2/13/2017	23	23	100	--	--	83	357	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	6/15/2010	11/29/2016	8	4	50	2.2	4.8	1.4	7.0	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	6/15/2010	11/29/2016	8	8	100	--	--	14	36	0.0081	8	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	-	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	2/3/2010	2/13/2017	31	31	100	--	--	7.8	95	--	--	--	48	5	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/15/2010	2/13/2017	26	6	23.08	12.8	40	26	426	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/15/2010	2/13/2017	26	4	15.38	0.7	6.0	1.8	14	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/15/2010	2/13/2017	16	1	6.25	0.27	1.6	1.1	1.1	--	--	--	5.0	0	40 CFR 141 - federal MCL
Nickel	No	ug/L	6/15/2010	2/13/2017	26	10	38.46	1.5	10	1.7	11	1.6	10	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	6/15/2010	2/13/2017	23	23	100	--	--	17,400	24,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/15/2010	2/13/2017	23	5	21.74	62.4	131	152	216	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/15/2010	2/13/2017	26	2	7.69	0.99	7.0	4.1	15	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/15/2010	11/29/2016	24	24	100	--	--	214	294	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	1/4/2011	2/13/2017	9	1	11.11	0.694	2.1	3.7	3.7	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	1/4/2011	11/29/2016	7	7	100	--	--	31	66	0.83	7	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - diesel range	No	ug/L	1/4/2011	11/29/2016	12	1	8.33	16	70	83	83	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - gasoline range	No	ug/L	1/4/2011	11/29/2016	12	2	16.67	10	50	24	53	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	6/15/2010	2/13/2017	16	16	100	--	--	3.3	6.0	--	--	--	0.54	16	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	1/4/2011	2/13/2017	12	12	100	--	--	1,100	1,800	119	12	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/15/2010	2/13/2017	26	24	92.31	10	15	5.7	24	12	8	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/15/2010	2/13/2017	26	22	84.62	3.3	6.0	5.0	362	22	5	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-184																	
2-Butanone	No	ug/L	5/11/2011	2/24/2017	26	2	7.69	0.47	3.0	0.55	0.98	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	2/24/2017	2/24/2017	1	1	100	--	--	19	19	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Acetone	No	ug/L	5/11/2011	2/24/2017	26	4	15.38	0.34	5.0	0.60	2.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	8/13/2014	2/6/2015	3	3	100	--	--	1.8	3.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	5/11/2011	2/24/2017	26	26	100	--	--	47	83	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	2/6/2015	2/6/2015	1	1	100	--	--	14	14	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon disulfide	No	ug/L	5/11/2011	2/24/2017	26	1	3.85	0.05	1.6	0.31	0.31	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	5/11/2011	2/24/2017	26	26	100	--	--	185	782	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	5/11/2011	2/24/2017	26	15	57.69	1	1.0	0.25	0.46	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	5/11/2011	2/24/2017	25	25	100	--	--	5.7	41	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	8/13/2014	2/6/2015	3	1	33.33	2.1	2.1	0.38	0.38	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	5/11/2011	2/24/2017	24	24	100	--	--	81	200	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/11/2011	2/24/2017	25	25	100	--	--	4.6	37	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	5/11/2011	2/24/2017	26	13	50	12.8	40	19	330	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	5/11/2011	2/24/2017	26	7	26.92	0.84	4.0	1.5	12	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	5/11/2011	2/24/2017	26	1	3.85	0.27	1.6	0.33	0.33	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	2/6/2015	2/6/2015	1	1	100	--	--	1.5	1.5	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	5/11/2011	2/24/2017	26	13	50	0.5	67	2.0	41	1.6	13	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	5/11/2011	2/24/2017	24	24	100	--	--	13,800	24,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	5/11/2011	2/24/2017	24	9	37.5	19.7	131	66	4,010	94	8	DOE/RL-96-61 Rev.0, Table ES-1	3,300	1	40 CFR 141 - federal MCL
Silver	No	ug/L	5/11/2011	2/24/2017	26	2	7.69	0.2	6.0	1.8	4.5	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	5/11/2011	11/29/2016	23	23	100	--	--	209	362	323	8	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	5/11/2011	2/24/2017	26	1	3.85	0.366	1.9	0.92	0.92	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	5/11/2011	11/29/2016	23	23	100	--	--	14	54	0.83	23	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Total petroleum hydrocarbons - diesel range	No	ug/L	11/11/2011	11/29/2016	6	1	16.67	16	70	36	36	--	--	--	500	0	WAC 173-340-900,Table 720-1
Total petroleum hydrocarbons - gasoline range	No	ug/L	11/11/2011	11/29/2016	6	2	33.33	10	50	17	39	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Trichloroethene	No	ug/L	5/11/2011	2/24/2017	26	26	100	--	--	0.70	5.1	--	--	--	0.54	26	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	5/11/2011	2/24/2017	26	26	100	--	--	877	1,700	119	26	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	2/6/2015	11/29/2016	2	2	100	--	--	2.1	2.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	5/11/2011	2/24/2017	26	23	88.46	10	15	7.0	20	12	14	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	5/11/2011	2/24/2017	26	6	23.08	3.3	8.3	5.8	24	22	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-190																	
Acetone	No	ug/L	6/23/2011	11/13/2016	9	2	22.22	0.34	5.0	3.4	11	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Aluminum	No	ug/L	10/24/2011	11/13/2016	21	5	23.81	10	20	10	117	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/24/2011	11/13/2016	21	21	100	--	--	3.6	5.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	36	51	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/24/2011	11/13/2016	14	10	71.43	15	15	12	66	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/24/2011	11/13/2016	21	1	4.76	0.05	0.30	0.18	0.18	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	6/23/2011	11/13/2016	22	22	100	--	--	84	247	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	6/23/2011	11/13/2016	9	5	55.56	1	1.0	0.42	0.70	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	8.0	17	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/24/2011	11/13/2016	21	1	4.76	0.05	0.22	0.65	0.65	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/24/2011	11/13/2016	21	17	80.95	0.2	0.35	0.21	0.92	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	116	262	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	7.6	18	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/23/2011	11/13/2016	11	2	18.18	30	30	19	69	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/24/2011	11/13/2016	21	2	9.52	0.05	0.50	0.36	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	6/23/2011	11/13/2016	15	4	26.67	0.1	4.0	0.42	6.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	6/23/2011	11/13/2016	9	1	11.11	0.27	1.6	0.34	0.34	--	--	--	5.0	0	40 CFR 141 - federal MCL

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Molybdenum	No	ug/L	10/24/2011	11/13/2016	21	21	100	--	--	2.4	3.2	3.2	1	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/23/2011	11/13/2016	15	7	46.67	0.5	5.1	0.12	1.1	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	24,700	43,400	26,871	18	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	6/23/2011	11/13/2016	23	4	17.39	9.85	131	193	301	94	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/24/2011	11/13/2016	21	1	4.76	1	2.0	1.6	1.6	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	6/23/2011	11/13/2016	23	1	4.35	0.04	5.1	4.0	4.0	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	6/23/2011	11/13/2016	15	15	100	--	--	208	276	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	6/23/2011	11/13/2016	23	4	17.39	0.463	2.0	1.1	4.7	0.015	4	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	6/23/2011	11/13/2016	23	21	91.3	34.6	37	14	54	0.83	21	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/24/2011	11/13/2016	21	3	14.29	0.05	0.60	0.70	0.97	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	3	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/24/2011	11/13/2016	21	2	9.52	0.05	1.0	2.2	2.7	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	6/23/2011	11/13/2016	9	9	100	--	--	3.7	6.5	--	--	--	0.54	9	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	6/23/2011	11/13/2016	23	22	95.65	340	340	350	908	119	22	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	12/6/2013	11/13/2016	13	13	100	--	--	2.8	3.6	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/23/2011	11/13/2016	13	13	100	--	--	12	17	12	13	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-17. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-18. Groundwater Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	Yes	ug/L	10/24/2011	11/13/2016	22	4	18.18	5	20	10.7	22.3	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/24/2011	11/13/2016	25	25	100	--	--	2.9	5.29	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/24/2011	11/13/2016	25	1	4	0.05	0.34	0.13	0.13	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	2/24/2017	75	75	100	--	--	5.45	68	2.4	75	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/24/2011	11/13/2016	25	15	60	0.2	2.1	0.324	5.5	0.81	5	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	2/3/2010	2/24/2017	79	79	100	--	--	4.6	95	--	--	--	10.0	54	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/15/2010	2/24/2017	63	11	17.46	12.8	40	18	275	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/24/2011	11/13/2016	22	2	9.09	0.05	0.5	0.29	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/15/2010	2/24/2017	67	25	37.31	0.2	66.5	0.296	21.9	1.6	21	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/24/2011	11/13/2016	22	2	9.09	1	2	1.5	2.5	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/15/2010	2/24/2017	75	4	5.33	0.04	7	0.104	18	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	2	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/24/2017	67	30	44.78	3.3	8.3	3.97	500	21.8	3	DOE/RL-96-61 Rev.0, Table ES-1	91.0	1	WAC 173-201A - freshwater CCC
Anions																	
Chloride	No	ug/L	6/15/2010	2/24/2017	70	70	100	--	--	10,200	23,000	--	--	--	230,000	0	CWA - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-19. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-168																	
Arsenic	Yes	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	2.9	2.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	11/19/2014	11/19/2014	1	0	0	0.34	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/15/2010	2/13/2017	27	27	100	--	--	8.8	68	2.4	27	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/19/2014	11/19/2014	1	1	100	--	--	5.5	5.5	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	2/3/2010	2/13/2017	31	31	100	--	--	7.8	95	--	--	--	10	24	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/15/2010	2/13/2017	26	4	15.38	12.8	40	18	109	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	6/15/2010	2/13/2017	26	10	38.46	1.5	10	1.7	21	1.6	10	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	6/15/2010	2/13/2017	26	2	7.69	0.99	7.0	4.6	18	5.3	1	DOE/RL-96-61 Rev.0, Table ES-1	2.6	2	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/15/2010	2/13/2017	26	22	84.62	3.3	6.0	5.0	500	22	3	DOE/RL-96-61 Rev.0, Table ES-1	91	1	WAC 173-201A - freshwater CCC
199-K-184																	
Aluminum	Yes	ug/L	2/6/2015	2/6/2015	1	0	0	15	15	--	--	7.1	0	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	8/13/2014	2/6/2015	3	3	100	--	--	2.9	3.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	8/13/2014	2/6/2015	3	0	0	0.11	0.34	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	5/11/2011	2/24/2017	25	25	100	--	--	5.5	37	2.4	25	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	8/13/2014	2/6/2015	3	1	33.33	0.35	2.1	2.8	2.8	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	5/11/2011	2/24/2017	25	25	100	--	--	4.6	37	--	--	--	10	14	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	5/11/2011	2/24/2017	26	7	26.92	12.8	40	19	275	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-19. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Lead	Yes	ug/L	2/6/2015	2/6/2015	1	0	0	0.5	0.50	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	5/11/2011	2/24/2017	26	11	42.31	0.5	67	1.6	22	1.6	11	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	2/6/2015	2/6/2015	1	0	0	1.5	1.5	--	--	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	5/11/2011	2/24/2017	26	1	3.85	0.2	6.0	1.6	1.6	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	5/11/2011	2/24/2017	26	4	15.38	3.3	8.3	6.0	17	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-190																	
Aluminum	Yes	ug/L	10/24/2011	11/13/2016	21	4	19.05	5	20	11	22	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/24/2011	11/13/2016	21	21	100	--	--	3.7	5.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/24/2011	11/13/2016	21	1	4.76	0.05	0.30	0.13	0.13	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	7.6	18	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/24/2011	11/13/2016	21	13	61.9	0.2	0.45	0.32	2.7	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	6/23/2011	11/13/2016	23	23	100	--	--	7.6	18	--	--	--	10	16	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	6/23/2011	11/13/2016	11	0	0	19	30	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/24/2011	11/13/2016	21	2	9.52	0.05	0.50	0.29	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	6/23/2011	11/13/2016	15	4	26.67	0.2	5.1	0.30	0.98	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/24/2011	11/13/2016	21	2	9.52	1	2.0	1.5	2.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	6/23/2011	11/13/2016	23	1	4.35	0.04	5.1	0.10	0.10	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	6/23/2011	11/13/2016	15	4	26.67	3.5	8.3	4.0	6.0	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC

Table D-19. Individual Monitoring Well Summary Statistics for Wells Screened in the Lower Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-20. Groundwater Summary Statistics for Well 199-K-193 Screened in the Upper and Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Strontium-90	No	pCi/L	5/10/2011	11/14/2016	23	2	8.7	0.305	1.93	1.7	4.9	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	5/10/2011	11/14/2016	23	1	4.35	83.3	354	1,490	1,490	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Volatile Organic Compounds																	
2-Butanone	No	ug/L	5/10/2011	11/14/2016	23	2	8.7	0.47	3	1	1.2	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	5/10/2011	11/14/2016	23	1	4.35	0.34	5	6.3	6.3	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon disulfide	No	ug/L	5/10/2011	11/14/2016	23	1	4.35	0.05	1.6	3.3	3.3	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	ug/L	5/10/2011	11/14/2016	23	9	39.13	0.3	1	0.24	0.41	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Ethylbenzene	No	ug/L	5/10/2011	11/14/2016	23	1	4.35	0.09	1	2.5	2.5	--	--	--	4.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	5/10/2011	11/14/2016	23	1	4.35	0.07	1	0.6	0.6	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	5/10/2011	11/14/2016	23	1	4.35	0.2	1	2.8	2.8	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Aluminum	No	ug/L	9/28/2011	11/14/2016	21	16	76.19	10	20	13	80.4	7.1	16	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	9/28/2011	11/14/2016	21	3	14.29	0.6	1.7	0.14	0.16	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	9/28/2011	11/14/2016	21	20	95.24	1.7	1.7	3.2	9.9	7.9	1	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	5/10/2011	11/14/2016	23	23	100	--	--	19	35	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/28/2011	11/14/2016	14	12	85.71	6.4	7.2	6.4	20.7	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	9/28/2011	11/14/2016	21	2	9.52	0.099	0.11	0.11	0.12	0.92		DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL

Table D-20. Groundwater Summary Statistics for Well 199-K-193 Screened in the Upper and Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	No	ug/L	5/10/2011	11/14/2016	23	23	100	--	--	6.54	63.1	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	9/28/2011	11/14/2016	21	11	52.38	0.1	0.22	0.09	0.34	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	9/28/2011	11/14/2016	21	12	57.14	0.2	1.1	0.312	2.1	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/10/2011	11/14/2016	23	23	100	--	--	6.1	33.3	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	5/10/2011	11/14/2016	11	11	100	--	--	72	670	570	2	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	9/28/2011	11/14/2016	21	5	23.81	0.1	0.5	0.104	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	5/10/2011	11/14/2016	15	15	100	--	--	2.63	21	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	9/28/2011	11/14/2016	21	21	100	--	--	6.19	12	3.2	21	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	5/10/2011	11/14/2016	15	14	93.33	4.2	4.2	2.73	11	1.6	14	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Selenium	No	ug/L	9/28/2011	11/14/2016	21	19	90.48	1.6	2	0.85	4.74	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	5/10/2011	11/14/2016	15	15	100	--	--	230	387	323	7	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	9/28/2011	11/14/2016	21	1	4.76	0.014	0.55	2.3	2.3	1.7	1	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	9/28/2011	11/14/2016	21	3	14.29	0.1	1.3	0.101	3	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	11/22/2013	11/14/2016	13	13	100	--	--	3	4.8	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	5/10/2011	11/14/2016	13	12	92.31	8.1	8.1	9.9	15	11.5	8	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	5/10/2011	11/14/2016	15	15	100	--	--	25.9	111	21.8	15	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-20. Groundwater Summary Statistics for Well 199-K-193 Screened in the Upper and Lower Unconfined Aquifer (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Anions																	
Fluoride	No	ug/L	5/10/2011	11/14/2016	20	20	100	--	--	179	324	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	5/10/2011	11/14/2016	20	20	100	--	--	4380	16600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	5/10/2011	11/14/2016	20	4	20	9.85	131	159	291	93.7	4	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-21. Groundwater Summary Statistics for Well 199-K-193 Screened in the Upper and Lower Unconfined Aquifer (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	Yes	ug/L	9/28/2011	11/14/2016	21	4	19.05	10	20	15	61.7	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	9/28/2011	11/14/2016	21	20	95.24	1.7	1.7	2.5	10	7.9	1	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	5/10/2011	11/14/2016	23	23	100	--	--	14	36.1	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/28/2011	11/14/2016	21	6	28.57	0.2	1.1	0.232	0.932	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	9/28/2011	11/14/2016	21	4	19.05	10	20	15	61.7	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	5/10/2011	11/14/2016	23	23	100	--	--	6.1	33.3	--	--	--	10.0	21	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	5/10/2011	11/14/2016	11	9	81.82	20	30	18.4	180	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	9/28/2011	11/14/2016	21	5	23.81	0.1	0.5	0.17	0.44	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	5/10/2011	11/14/2016	15	12	80	4	4.2	0.8	9	1.6	11	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Selenium	Yes	ug/L	9/28/2011	11/14/2016	21	20	95.24	1.6	1.6	1.2	4.43	10.5		DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Zinc	Yes	ug/L	5/10/2011	11/14/2016	15	14	93.33	9.1	9.1	17.2	99	21.8	11	DOE/RL-96-61 Rev.0, Table ES-1	91.0	2	WAC 173-201A - freshwater CCC
Anions																	
Chloride	No	ug/L	5/10/2011	11/14/2016	20	20	100	--	--	4,800	25,000	--	--	--	230,000	0	CWA - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-22. Groundwater Summary Statistics for Wells Screened in the Ringold Upper Mud Formation (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Gross alpha	No	pCi/L	10/26/2012	7/22/2016	6	2	33.33	2	3.2	2.51	2.8	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/26/2012	7/22/2016	6	6	100	--	--	4.8	8.4	0.0081	6	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	12/8/2010	11/13/2016	26	2	7.69	0.456	3.2	1.2	3.8	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	12/8/2010	11/13/2016	26	1	3.85	5.6	35	20	20	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Volatile Organic Compounds																	
Acetone	No	ug/L	4/26/2011	11/13/2016	7	1	14.29	1	5	2.5	2.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons - gasoline range	No	ug/L	8/10/2015	7/22/2016	2	1	50	10	10	34	34	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Metals																	
Aluminum	No	ug/L	10/11/2011	11/13/2016	26	7	26.92	10	20	15	190	7.1	7	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/11/2011	11/13/2016	26	26	100	--	--	1.3	10.2	7.9	17	DOE/RL-96-61 Rev.0, Table ES-1	10.0	1	40 CFR 141 - federal MCL
Barium	No	ug/L	12/8/2010	11/13/2016	28	28	100	--	--	53	77.6	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/11/2011	11/13/2016	18	18	100	--	--	11.5	37.2	36.0	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/11/2011	11/13/2016	26	1	3.85	0.099	0.3	1.3	1.3	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	12/8/2010	11/13/2016	28	27	96.43	5	5	4.8	41	2.4	27	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/11/2011	11/13/2016	26	5	19.23	0.1	0.22	0.154	0.357	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/11/2011	11/13/2016	26	26	100	--	--	0.41	3.58	0.81	24	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-22. Groundwater Summary Statistics for Wells Screened in the Ringold Upper Mud Formation (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	12/8/2010	11/13/2016	28	26	92.86	2	8	2.9	9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/8/2010	11/13/2016	18	7	38.89	19	30	33.8	180	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/11/2011	11/13/2016	26	5	19.23	0.1	0.5	0.141	0.56	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/8/2010	11/13/2016	21	13	61.9	1	6	0.656	13	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/11/2011	11/13/2016	26	26	100	--	--	3.7	11.4	3.2	26	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	12/8/2010	11/13/2016	21	13	61.9	0.4	66.5	0.34	15	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Selenium	No	ug/L	10/11/2011	11/13/2016	26	11	42.31	1.5	2	1.7	4.3	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/8/2010	11/13/2016	28	3	10.71	0.04	7	0.04	0.112	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/8/2010	11/13/2016	21	21	100	--	--	412	522	323	21	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	10/11/2011	11/13/2016	26	1	3.85	0.014	0.6	1.3	1.3	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/11/2011	11/13/2016	26	3	11.54	0.1	1.1	0.132	3.1	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	12/4/2013	11/13/2016	16	16	100	--	--	3	3.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/8/2010	11/13/2016	19	17	89.47	4.4	17	4.17	27.3	11.5	13	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/11/2011	11/13/2016	26	7	26.92	10	20	15	190	7.1	7	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Fluoride	No	ug/L	12/8/2010	11/13/2016	28	28	100	--	--	198	450	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	12/8/2010	11/13/2016	28	28	100	--	--	6240	10700	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-22. Groundwater Summary Statistics for Wells Screened in the Ringold Upper Mud Formation (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	12/8/2010	11/13/2016	28	6	21.43	9.85	131	210	342	93.7	6	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-23. Individual Monitoring Well Summary Statistics for Wells Screened in the Ringold Upper Mud (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-32B																	
Aluminum	No	ug/L	10/11/2011	7/22/2016	5	3	60	10	20	15	190	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/11/2011	7/22/2016	5	5	100	--	--	1.3	1.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	53	64	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	10/11/2011	7/22/2016	4	4	100	--	--	21	35	36	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	10/11/2011	7/22/2016	5	1	20	0.099	0.10	1.3	1.3	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	14	41	2.4	6	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/11/2011	7/22/2016	5	2	40	0.1	0.22	0.15	0.32	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/11/2011	7/22/2016	5	5	100	--	--	0.41	1.1	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	198	290	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	11/7/2012	7/22/2016	3	1	33.33	2.7	3.2	2.5	2.5	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	11/7/2012	7/22/2016	3	3	100	--	--	4.9	8.4	0.0081	3	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	2.9	7.1	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	43	180	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/11/2011	7/22/2016	5	3	60	0.1	0.10	0.21	0.56	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	12/8/2010	7/22/2016	6	4	66.67	4	6.0	1.5	4.0	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/11/2011	7/22/2016	5	5	100	--	--	3.7	4.3	3.2	5	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-23. Individual Monitoring Well Summary Statistics for Wells Screened in the Ringold Upper Mud (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nickel	No	ug/L	12/8/2010	7/22/2016	6	5	83.33	66.5	67	4.0	15	1.6	5	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	10,200	10,700	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	12/8/2010	7/22/2016	6	1	16.67	118	131	210	210	94	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/11/2011	7/22/2016	5	3	60	1.6	2.0	1.8	2.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Silver	No	ug/L	12/8/2010	7/22/2016	6	3	50	0.1	7.0	0.040	0.11	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	412	461	323	6	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	12/8/2010	12/6/2013	4	1	25	1.1	1.6	1.2	1.2	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tin	No	ug/L	10/11/2011	7/22/2016	5	1	20	0.1	1.1	3.1	3.1	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total petroleum hydrocarbons - gasoline range	No	ug/L	8/10/2015	7/22/2016	2	1	50	10	10	34	34	--	--	--	1,000	0	WAC 173-340-900,Table 720-1
Uranium	No	ug/L	12/6/2013	7/22/2016	3	3	100	--	--	3.0	3.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	12/8/2010	7/22/2016	6	4	66.67	4.4	17	4.2	6.1	12	0	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
199-K-192																	
Acetone	No	ug/L	4/26/2011	11/13/2016	7	1	14.29	1	5.0	2.5	2.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/26/2011	11/13/2016	21	4	19.05	10	20	15	20	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	10/26/2011	11/13/2016	21	21	100	--	--	7.5	10	7.9	17	DOE/RL-96-61 Rev.0, Table ES-1	10	0	40 CFR 141 - federal MCL
Barium	No	ug/L	4/26/2011	11/13/2016	22	22	100	--	--	58	78	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL

Table D-23. Individual Monitoring Well Summary Statistics for Wells Screened in the Ringold Upper Mud (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Boron	No	ug/L	10/26/2011	11/13/2016	14	14	100	--	--	12	37	36	1	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	4/26/2011	11/13/2016	22	21	95.45	5	5.0	4.8	9.4	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/26/2011	11/13/2016	21	3	14.29	0.1	0.22	0.19	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/26/2011	11/13/2016	21	21	100	--	--	0.83	3.6	0.81	21	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	4/26/2011	11/13/2016	22	22	100	--	--	286	450	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/26/2012	11/12/2015	3	1	33.33	2	2.9	2.8	2.8	--	--	--	15	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/26/2012	11/12/2015	3	3	100	--	--	4.8	6.6	0.0081	3	Scott W. Petersen, Jan. 27,1998 Memo	4 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	4/26/2011	11/13/2016	22	20	90.91	2	8.0	2.9	9.0	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	4/26/2011	11/13/2016	12	1	8.33	19	30	34	34	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	10/26/2011	11/13/2016	21	2	9.52	0.1	0.50	0.14	0.26	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	4/26/2011	11/13/2016	15	9	60	1	4.0	0.66	13	39	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/26/2011	11/13/2016	21	21	100	--	--	7.4	11	3.2	21	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	4/26/2011	11/13/2016	15	8	53.33	0.4	5.0	0.34	4.9	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	4/26/2011	11/13/2016	22	22	100	--	--	6,240	7,970	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	4/26/2011	11/13/2016	22	5	22.73	9.85	131	214	342	94	5	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/26/2011	11/13/2016	21	8	38.1	1.5	2.0	1.7	4.3	11	0	DOE/RL-96-61 Rev.0, Table ES-1	50	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	4/26/2011	11/13/2016	15	15	100	--	--	449	522	323	15	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-23. Individual Monitoring Well Summary Statistics for Wells Screened in the Ringold Upper Mud (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Strontium-90	No	pCi/L	4/26/2011	11/13/2016	22	1	4.55	0.456	3.2	3.8	3.8	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	4/26/2011	11/13/2016	22	1	4.55	5.9	35	20	20	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	10/26/2011	11/13/2016	21	1	4.76	0.1	0.60	1.3	1.3	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	10/26/2011	11/13/2016	21	2	9.52	0.1	1.1	0.13	0.25	22	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	12/4/2013	11/13/2016	13	13	100	--	--	3.0	3.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	4/26/2011	11/13/2016	13	13	100	--	--	18	27	12	13	DOE/RL-96-61 Rev.0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	4/26/2011	11/13/2016	15	5	33.33	3.5	8.3	5.3	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-24. Groundwater Summary Statistics for Wells Screened in the Ringold Upper Mud Formation (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	Yes	ug/L	10/11/2011	11/13/2016	26	3	11.54	5	20	21	33.2	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/11/2011	11/13/2016	26	26	100	--	--	1.1	10.7	7.9	18	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/11/2011	11/13/2016	26	1	3.85	0.05	0.3	2.8	2.8	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	0.72	1	CWA - freshwater CCC
Chromium	Yes	ug/L	12/8/2010	11/13/2016	28	26	92.86	5	14	4.7	10.1	2.4	26	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/11/2011	11/13/2016	26	24	92.31	0.68	1.1	0.258	6.08	0.81	19	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	12/8/2010	11/13/2016	28	26	92.86	2	8	2.9	9	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/8/2010	11/13/2016	18	5	27.78	19	38	17.7	36	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/11/2011	11/13/2016	26	5	19.23	0.1	0.5	0.0524	2.9	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	1	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/8/2010	11/13/2016	21	10	47.62	0.5	13.3	0.232	4.7	1.6	4	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/11/2011	11/13/2016	26	9	34.62	1.5	2	1.46	2.9	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Zinc	Yes	ug/L	12/8/2010	11/13/2016	21	6	28.57	3.5	9.3	4.38	16	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	91.0	0	WAC 173-201A - freshwater CCC
Metals																	
Chloride	No	ug/L	12/8/2010	11/13/2016	28	28	100	--	--	3,180	4,610	--	--	--	230,000	0	CWA - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-25. Individual Monitoring Well Summary Statistics for Wells Screened in the Ringold Upper Mud (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
199-K-32B																	
Aluminum	Yes	ug/L	10/11/2011	7/22/2016	5	2	40	10	20	21	28	7.1	2	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/11/2011	7/22/2016	5	5	100	--	--	1.1	2.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/11/2011	7/22/2016	5	0	0	0.099	0.10	--	--	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	12/8/2010	7/22/2016	6	5	83.33	14	14	9.2	10	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/11/2011	7/22/2016	5	3	60	0.68	1.1	0.26	0.95	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	12/8/2010	7/22/2016	6	6	100	--	--	2.9	7.1	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	12/8/2010	7/22/2016	6	5	83.33	38	38	18	36	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/11/2011	7/22/2016	5	2	40	0.1	0.17	0.40	0.48	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	12/8/2010	7/22/2016	6	2	33.33	4	13	2.2	3.0	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/11/2011	7/22/2016	5	2	40	1.6	2.0	2.0	2.5	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	12/8/2010	7/22/2016	6	0	0	0.039	7.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	12/8/2010	7/22/2016	6	0	0	4	9.3	--	--	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC
199-K-192																	
Aluminum	Yes	ug/L	10/26/2011	11/13/2016	21	1	4.76	5	20	33	33	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/26/2011	11/13/2016	21	21	100	--	--	7.3	11	7.9	18	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	10/26/2011	11/13/2016	21	1	4.76	0.05	0.30	2.8	2.8	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	0.72	1	CWA - freshwater CCC
Chromium	Yes	ug/L	4/26/2011	11/13/2016	22	21	95.45	5	5.0	4.7	9.6	2.4	21	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC

Table D-25. Individual Monitoring Well Summary Statistics for Wells Screened in the Ringold Upper Mud (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Copper	Yes	ug/L	10/26/2011	11/13/2016	21	21	100	--	--	0.54	6.1	0.81	18	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	4/26/2011	11/13/2016	22	20	90.91	2	8.0	2.9	9.0	--	--	--	10	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	4/26/2011	11/13/2016	12	0	0	19	30	--	--	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	10/26/2011	11/13/2016	21	3	14.29	0.1	0.50	0.052	2.9	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	2.1	1	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	4/26/2011	11/13/2016	15	8	53.33	0.5	5.0	0.23	4.7	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/26/2011	11/13/2016	21	7	33.33	1.5	2.0	1.5	2.9	11	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
Silver	Yes	ug/L	4/26/2011	11/13/2016	22	0	0	0.04	5.0	--	--	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CMC
Zinc	Yes	ug/L	4/26/2011	11/13/2016	15	6	40	3.5	4.0	4.4	16	22	0	DOE/RL-96-61 Rev.0, Table ES-1	91	0	WAC 173-201A - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-26. Summary Statistics for Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Radionuclides																	
Carbon-14	No	pCi/L	8/13/2012	2/21/2017	175	87	49.71	3.0	56	5.2	416	--	--	--	2,000	0	40 CFR 141 - federal MCL
Gross alpha	No	pCi/L	9/24/2012	10/10/2016	38	7	18.42	1.00	3.7	1.5	8.6	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	9/24/2012	10/10/2016	38	26	68.42	1.8	3.6	1.2	55	0.0081	26	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	9/24/2012	2/21/2017	173	31	17.92	0.40	2.0	0.85	8.8	0.015	31	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	9/24/2012	10/10/2016	31	5	16.13	5.8	39	24	61	0.83	5	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	8/13/2012	2/21/2017	207	54	26.09	76	421	131	9,900	119	54	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Volatile Organic Compounds																	
1-Butanol	No	ug/L	8/13/2012	10/10/2016	63	2	3.17	12	100	16	120	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Butanone	No	ug/L	8/13/2012	2/21/2017	113	3	2.65	0.47	3.0	0.49	2.1	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	9/6/2016	2/21/2017	7	7	100	--	--	20	180	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	8/13/2012	2/21/2017	113	24	21.24	0.34	5.0	0.48	9.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	ug/L	8/13/2012	2/21/2017	113	3	2.65	0.13	1.0	1.6	2.2	--	--	--	0.63	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	ug/L	8/13/2012	2/21/2017	113	12	10.62	0.10	1.0	0.13	0.48	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	8/13/2012	2/21/2017	113	6	5.31	0.27	1.6	1.7	3.4	--	--	--	5.0	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	8/13/2012	2/21/2017	113	11	9.73	0.070	1.0	0.17	0.60	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	8/13/2012	2/21/2017	113	37	32.74	0.16	1.0	0.30	2.7	--	--	--	0.54	23	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	8/13/2012	2/21/2017	113	1	0.88	0.19	1.0	0.42	0.42	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-26. Summary Statistics for Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Semivolatile Organic Compounds																	
Naphthalene	No	ug/L	10/11/2012	10/11/2012	3	1	33.33	0.97	0.98	1.3	1.3	--	--	--	160	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Aluminum	No	ug/L	8/13/2012	10/10/2016	72	62	86.11	13	20	14	2,470	7.1	62	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	8/13/2012	2/21/2017	115	6	5.22	0.23	36	0.23	5.7	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	8/13/2012	2/21/2017	118	57	48.31	0.40	30	0.40	6.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	8/13/2012	2/21/2017	115	115	100	--	--	13	90	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	8/13/2012	10/10/2016	76	2	2.63	0.10	4.0	0.21	0.46	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/12/2013	10/10/2016	55	18	32.73	4.0	25	2.7	9.7	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	8/13/2012	2/21/2017	115	1	0.87	0.050	4.0	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	8/13/2012	2/21/2017	124	82	66.13	1.0	5.0	0.34	51	2.4	32	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	8/13/2012	2/21/2017	115	34	29.57	0.050	15	0.077	1.8	0.92	2	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	8/13/2012	2/21/2017	115	65	56.52	0.20	7.0	0.21	12	0.81	37	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/21/2012	2/21/2017	370	153	41.35	1.5	8.0	1.5	50	--	--	--	48.0	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	8/13/2012	2/21/2017	112	92	82.14	13	40	14	2,750	570	9	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	8/13/2012	10/10/2016	72	16	22.22	0.050	1.0	0.13	0.81	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	8/13/2012	2/21/2017	114	91	79.82	0.70	4.0	0.49	90	38.5	6	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	8/13/2012	10/10/2016	72	62	86.11	0.30	2.0	0.24	1.9	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-26. Summary Statistics for Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nickel	No	ug/L	8/13/2012	2/21/2017	114	26	22.81	0.20	10	0.10	6.3	1.6	7	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Selenium	No	ug/L	8/13/2012	10/10/2016	72	6	8.33	0.42	2.0	0.81	3.3	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Silver	No	ug/L	8/13/2012	2/21/2017	115	1	0.87	0.039	4.0	0.050	0.050	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	8/13/2012	10/10/2016	75	75	100	--	--	70	329	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	8/13/2012	10/10/2016	72	4	5.56	0.014	0.90	0.040	1.3	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	2	40 CFR 141 - federal MCLG
Tin	No	ug/L	8/13/2012	10/10/2016	72	13	18.06	0.050	1.2	0.078	5.9	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/12/2013	10/10/2016	56	54	96.43	0.23	0.23	0.087	12	9.9	1	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	8/13/2012	2/21/2017	111	90	81.08	4.4	15	1.6	34	11.5	26	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	8/13/2012	2/21/2017	114	22	19.3	2.0	9.3	3.6	56	21.8	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Fluoride	No	ug/L	8/13/2012	2/21/2017	237	219	92.41	46	50	47	1,040	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	8/13/2012	2/21/2017	237	227	95.78	35	177	155	32,100	26,871	5	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	8/13/2012	2/21/2017	237	35	14.77	9.9	250	129	480	93.7	35	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
14-D																	
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	125	270	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/9/2012	9/12/2016	5	1	20	1.2	3.0	3.7	3.7	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/9/2012	9/12/2016	5	5	100	--	--	20	55	0.0081	5	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	2.1	7.3	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	16,400	22,900	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	9/12/2016	5	1	20	125	131	294	294	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Technetium-99	No	pCi/L	10/9/2012	9/12/2016	5	4	80	39	39	45	61	0.83	4	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/9/2012	9/12/2016	5	5	100	--	--	3,680	7,100	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
17-D																	
2-Butanone	No	ug/L	9/16/2014	2/21/2017	7	1	14.29	0.47	3.0	2.1	2.1	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	9/8/2016	2/21/2017	2	2	100	--	--	48	97	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	9/16/2014	2/21/2017	7	4	57.14	0.55	3.0	0.64	6.7	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	9/24/2012	9/8/2016	5	4	80	13	13	25	140	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	9/24/2012	2/21/2017	9	2	22.22	0.60	3.5	0.27	0.94	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	9/24/2012	2/21/2017	9	5	55.56	4.0	5.0	1.9	2.8	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	9/24/2012	2/21/2017	9	9	100	--	--	33	74	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	9/24/2012	9/8/2016	5	1	20	0.20	0.35	0.21	0.21	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Boron	No	ug/L	9/12/2013	9/8/2016	4	2	50	6.4	7.2	4.5	8.3	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	9/24/2012	2/21/2017	9	8	88.89	55	55	24	113	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	9/24/2012	2/21/2017	9	7	77.78	4.0	4.0	0.50	2.9	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	9/24/2012	2/21/2017	9	2	22.22	0.10	15	0.13	0.26	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	9/24/2012	2/21/2017	9	4	44.44	1.1	7.0	0.56	1.6	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	9/24/2012	2/21/2017	9	9	100	--	--	92	220	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	9/24/2012	9/8/2016	5	2	40	1.1	2.0	3.8	8.6	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	9/24/2012	9/8/2016	5	4	80	3.4	3.4	2.8	5.4	0.0081	4	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	9/24/2012	2/21/2017	9	4	44.44	1.5	8.0	1.7	2.5	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/24/2012	2/21/2017	9	8	88.89	30	30	14	684	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	9/24/2012	9/8/2016	5	2	40	0.10	0.17	0.21	0.53	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	9/24/2012	2/21/2017	9	6	66.67	2.0	4.0	0.49	19	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	9/24/2012	9/8/2016	5	5	100	--	--	0.93	1.9	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/24/2012	2/21/2017	9	9	100	--	--	292	14,600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/24/2012	2/21/2017	9	2	22.22	20	131	177	480	93.7	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	9/24/2012	9/8/2016	5	5	100	--	--	130	253	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	9/24/2012	9/8/2016	5	2	40	0.014	0.55	0.14	1.3	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG
Tin	No	ug/L	9/24/2012	9/8/2016	5	1	20	0.10	1.1	4.6	4.6	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Toluene	No	ug/L	9/16/2014	2/21/2017	7	2	28.57	0.070	0.30	0.27	0.29	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	9/16/2014	2/21/2017	7	4	57.14	0.25	0.25	0.38	1.1	--	--	--	0.54	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/12/2013	9/8/2016	4	4	100	--	--	0.88	6.6	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/24/2012	2/21/2017	9	7	77.78	15	15	6.5	12	11.5	3	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Xylenes (total)	No	ug/L	9/16/2014	2/21/2017	7	1	14.29	0.19	0.30	0.42	0.42	--	--	--	1,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
17-M																	
2-Propanol	No	ug/L	2/21/2017	2/21/2017	1	1	100	--	--	86	86	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	9/1/2016	2/21/2017	4	1	25	0.55	0.55	4.1	4.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	32	58	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	9/1/2016	2/21/2017	4	4	100	--	--	30	358	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	9/1/2016	2/21/2017	4	2	50	0.10	0.10	0.13	0.13	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	9/1/2016	2/21/2017	4	2	50	4.0	4.0	2.1	3.6	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	72	180	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	150	642	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	7.7	27	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	487	27,400	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/1/2016	2/21/2017	4	1	25	125	125	187	187	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	9/1/2016	2/21/2017	4	1	25	0.14	0.14	0.24	0.24	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Trichloroethene	No	ug/L	9/1/2016	2/21/2017	4	2	50	0.25	0.25	1.1	1.1	--	--	--	0.54	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Vanadium	No	ug/L	9/1/2016	2/21/2017	4	2	50	15	15	4.3	5.8	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	9/1/2016	2/21/2017	4	1	25	3.0	6.0	4.1	4.1	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
18-S																	
1-Butanol	No	ug/L	12/11/2014	10/10/2016	3	1	33.33	12	12	16	16	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	12/11/2014	10/10/2016	3	1	33.33	0.34	0.34	0.64	0.64	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	25	119	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	No	ug/L	11/29/2012	10/10/2016	5	1	20	0.40	4.0	1.1	1.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	27	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/17/2013	10/10/2016	4	1	25	7.2	25	4.6	4.6	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	11/29/2012	10/10/2016	5	4	80	4.0	4.0	1.0	1.7	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	0.69	2.3	0.81	4	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	116	236	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	11/29/2012	10/10/2016	5	3	60	1.9	3.2	2.2	7.8	0.0081	3	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Iron	No	ug/L	11/29/2012	10/10/2016	4	3	75	30	30	30	176	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	11/29/2012	10/10/2016	5	4	80	4.0	4.0	1.1	2.9	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	11/29/2012	10/10/2016	5	4	80	2.0	2.0	1.3	1.6	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	664	2,060	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	11/29/2012	10/10/2016	5	1	20	125	131	221	221	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	11/29/2012	10/10/2016	5	1	20	0.60	2.0	3.0	3.0	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	91	138	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tin	No	ug/L	11/29/2012	10/10/2016	5	1	20	0.10	1.2	2.8	2.8	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	12/11/2014	10/10/2016	3	1	33.33	0.070	0.14	0.60	0.60	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/17/2013	10/10/2016	4	4	100	--	--	0.80	4.6	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	11/29/2012	10/10/2016	5	2	40	4.4	15	1.9	5.4	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
19-D																	
2-Butanone	No	ug/L	10/21/2014	9/7/2016	3	1	33.33	0.52	0.52	2.0	2.0	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	10/21/2014	9/7/2016	3	2	66.67	0.34	0.34	0.73	3.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	10/3/2012	9/7/2016	5	3	60	17	20	20	284	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	10/3/2012	9/7/2016	5	5	100	--	--	18	39	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/17/2013	9/7/2016	4	1	25	4.0	25	9.7	9.7	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	10/3/2012	9/7/2016	5	4	80	2.0	2.0	0.34	1.9	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/3/2012	9/7/2016	5	1	20	0.10	0.22	0.24	0.24	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/3/2012	9/7/2016	5	2	40	0.20	0.68	0.33	0.73	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Fluoride	No	ug/L	10/3/2012	9/7/2016	5	5	100	--	--	50	110	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	10/3/2012	9/7/2016	5	1	20	1.8	3.2	3.2	3.2	0.0081	1	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/3/2012	9/7/2016	5	1	20	1.5	2.0	3.6	3.6	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/21/2014	9/7/2016	3	1	33.33	13	30	353	353	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	9/17/2013	9/7/2016	4	4	100	--	--	1.1	13	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/3/2012	9/7/2016	5	3	60	1.0	1.0	0.27	0.44	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/3/2012	9/7/2016	5	4	80	177	177	159	257	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/3/2012	9/7/2016	5	1	20	20	131	132	132	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	9/17/2013	9/7/2016	4	4	100	--	--	92	221	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/17/2013	9/7/2016	4	3	75	0.23	0.23	0.16	0.36	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/17/2013	9/7/2016	4	3	75	15	15	1.6	5.1	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	9/17/2013	9/7/2016	4	3	75	9.3	9.3	4.4	56	21.8	1	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
19-M																	
Fluoride	No	ug/L	9/7/2016	9/7/2016	1	1	100	--	--	86	86	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/3/2012	9/7/2016	5	5	100	--	--	4.0	5.9	0.015	5	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	9/7/2016	9/7/2016	1	1	100	--	--	0.12	0.12	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
21-M																	
Fluoride	No	ug/L	10/8/2012	10/26/2016	5	4	80	46	46	72	110	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Hexavalent Chromium	No	ug/L	10/8/2012	10/26/2016	5	1	20	1.5	2.0	2.1	2.1	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/8/2012	10/26/2016	5	2	40	124	168	165	262	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	10/8/2012	10/26/2016	5	3	60	1.1	1.6	1.6	4.2	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
21-S																	
Hexavalent Chromium	No	ug/L	10/8/2012	9/8/2016	5	1	20	1.5	2.0	1.8	1.8	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
22-D																	
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	4	80	46	46	92	140	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	5.0	43	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	792	4,250	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	9/12/2016	5	1	20	20	131	192	192	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
22-M																	
Strontium-90	No	pCi/L	10/9/2012	9/12/2016	5	5	100	--	--	6.3	8.8	0.015	5	Scott W. Petersen, Jan. 27,1998 Memo	8.0	1	40 CFR 141 - federal MCL
23-M																	
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	56	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	270	345	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
25-D																	
Fluoride	No	ug/L	10/11/2012	9/20/2016	5	4	80	46	46	83	120	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/11/2012	9/20/2016	5	4	80	168	168	309	797	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/11/2012	9/20/2016	5	1	20	125	131	215	215	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
26-D																	
Fluoride	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	168	360	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/21/2012	9/20/2016	7	3	42.86	1.5	2.0	2.2	4.4	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	11,500	15,100	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/11/2012	9/20/2016	5	1	20	20	131	198	198	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/11/2012	9/20/2016	5	5	100	--	--	1,550	2,220	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
26-M																	
Hexavalent Chromium	No	ug/L	5/21/2012	9/20/2016	7	2	28.57	1.5	2.0	3.0	3.9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
AT-K-1-D																	
Acetone	No	ug/L	9/10/2014	11/29/2016	6	1	16.67	0.34	3.0	2.0	2.0	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	9/24/2012	9/6/2016	5	5	100	--	--	34	298	7.1	5	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	9/24/2012	11/29/2016	8	1	12.5	0.30	3.5	0.26	0.26	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	9/24/2012	11/29/2016	8	5	62.5	4.0	5.0	0.96	1.6	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	25	77	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Beryllium	No	ug/L	9/24/2012	9/6/2016	5	1	20	0.10	0.35	0.46	0.46	2.3	0	DOE/RL-96-61 Rev.0, Table ES-1	4.0	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/12/2013	9/6/2016	4	2	50	6.4	7.2	5.1	8.3	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	9/24/2012	11/29/2016	8	3	37.5	11	39	5.3	257	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	9/24/2012	12/12/2016	10	8	80	4.0	4.0	1.6	46	2.4	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Cobalt	No	ug/L	9/24/2012	11/29/2016	8	3	37.5	0.22	15	0.080	0.44	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	9/24/2012	11/29/2016	8	4	50	1.1	7.0	0.64	1.1	0.81	3	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	56	190	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	9/24/2012	9/6/2016	5	3	60	1.3	1.3	1.8	7.0	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	9/24/2012	9/6/2016	5	5	100	--	--	3.1	22	0.0081	5	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	9/24/2012	12/12/2016	9	3	33.33	1.5	8.0	1.5	29	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	27	554	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	9/24/2012	9/6/2016	5	2	40	0.16	0.17	0.14	0.15	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	1.2	19	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	9/24/2012	9/6/2016	5	3	60	1.0	1.0	0.35	0.46	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	9/24/2012	11/29/2016	8	4	50	0.80	10	0.40	5.9	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	252	11,900	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/24/2012	11/29/2016	8	1	12.5	20	131	238	238	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	9/24/2012	9/6/2016	5	1	20	1.0	2.0	0.81	0.81	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	9/24/2012	9/6/2016	5	5	100	--	--	150	329	323	1	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Technetium-99	No	pCi/L	9/24/2012	9/6/2016	5	1	20	6.9	9.9	24	24	0.83	1	DOE/RL-96-61 Rev.0, Table ES-1	900	0	40 CFR 141 - federal MCL
Thallium	No	ug/L	9/24/2012	9/6/2016	5	1	20	0.014	0.55	0.65	0.65	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	1	40 CFR 141 - federal MCLG

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Tin	No	ug/L	9/24/2012	9/6/2016	5	1	20	0.050	1.1	5.9	5.9	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	9/10/2014	11/29/2016	6	1	16.67	0.070	0.30	0.37	0.37	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	9/10/2014	11/29/2016	6	1	16.67	0.25	0.30	0.37	0.37	--	--	--	0.54	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/24/2012	11/29/2016	8	1	12.5	310	409	610	610	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Uranium	No	ug/L	9/12/2013	9/6/2016	4	4	100	--	--	1.4	12	9.9	1	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/24/2012	11/29/2016	8	7	87.5	15	15	4.5	7.8	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
AT-K-1-M																	
2-Butanone	No	ug/L	9/10/2014	11/29/2016	6	1	16.67	0.47	2.0	0.49	0.49	--	--	--	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	9/6/2016	9/6/2016	1	1	100	--	--	20	20	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	9/10/2014	11/29/2016	6	2	33.33	0.34	1.9	1.2	3.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	24	48	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	9/10/2014	11/29/2016	6	1	16.67	9.7	24	5.2	5.2	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/24/2016	12/12/2016	5	1	20	1.1	4.0	2.7	2.7	2.4	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	99	120	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	140	580	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	4.8	11	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	168	434	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/24/2016	11/29/2016	3	2	66.67	15	15	4.2	5.5	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Zinc	No	ug/L	6/24/2016	11/29/2016	3	1	33.33	3.0	6.0	5.6	5.6	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
AT-K-1-S																	
2-Propanol	No	ug/L	9/6/2016	9/6/2016	1	1	100	--	--	26	26	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	ug/L	9/10/2014	11/29/2016	6	1	16.67	0.34	3.0	1.5	1.5	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	44	90	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	6/24/2016	12/12/2016	5	4	80	4.0	4.0	1.5	26	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	6/24/2016	11/29/2016	3	1	33.33	1.0	15	1.8	1.8	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	6/24/2016	11/29/2016	3	2	66.67	7.0	7.0	4.5	7.1	0.81	2	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	83	100	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	973	2,750	570	3	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	40	90	38.5	3	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	6/24/2016	11/29/2016	3	2	66.67	10	10	1.5	3.1	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	208	620	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	9/10/2014	11/29/2016	6	2	33.33	0.46	1.6	1.0	2.4	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	6/24/2016	11/29/2016	3	2	66.67	15	15	3.9	7.0	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	6/24/2016	11/29/2016	3	2	66.67	6.0	6.0	5.6	9.7	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
AT-K-2-D																	
Aluminum	No	ug/L	10/10/2012	9/8/2016	5	4	80	15	15	15	32	7.1	4	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	10/10/2012	9/8/2016	5	3	60	1.7	1.7	0.44	1.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/10/2012	9/8/2016	5	5	100	--	--	16	25	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/10/2012	9/8/2016	5	3	60	3.0	28	15	134	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/10/2012	9/8/2016	5	2	40	2.0	3.0	1.5	1.6	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	10/10/2012	9/8/2016	5	1	20	0.10	0.10	0.16	0.16	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	10/10/2012	9/8/2016	5	4	80	0.35	0.35	0.33	0.64	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/10/2012	9/8/2016	5	4	80	46	46	71	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	10/10/2012	9/8/2016	5	2	40	1.9	3.5	1.2	3.3	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	10/10/2012	9/8/2016	5	1	20	1.5	8.0	2.2	2.2	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/10/2012	9/8/2016	5	2	40	30	30	49	120	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/10/2012	9/8/2016	5	3	60	1.0	1.0	1.4	6.6	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	10/10/2012	9/8/2016	5	5	100	--	--	0.38	0.89	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/10/2012	9/8/2016	5	2	40	0.50	4.0	0.22	0.92	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/10/2012	9/8/2016	5	4	80	177	177	155	522	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/10/2012	9/8/2016	5	1	20	125	250	144	144	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	10/10/2012	9/8/2016	5	1	20	1.5	2.0	3.3	3.3	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/10/2012	9/8/2016	5	5	100	--	--	94	144	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Uranium	No	ug/L	9/17/2013	9/8/2016	4	4	100	--	--	0.15	0.47	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/10/2012	9/8/2016	5	4	80	5.0	5.0	2.7	4.2	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/10/2012	9/8/2016	5	1	20	3.5	5.0	8.8	8.8	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
AT-K-3-D																	
Arsenic	No	ug/L	9/19/2013	9/7/2016	4	1	25	1.8	30	2.7	2.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	28	36	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/4/2012	9/7/2016	5	2	40	17	46	14	16	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	23	51	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	10/4/2012	9/7/2016	5	1	20	2.1	5.0	3.4	3.4	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	85	230	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	4	4	100	--	--	29	31	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/4/2012	9/7/2016	5	4	80	30	30	122	487	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/4/2012	9/7/2016	5	4	80	2.5	2.5	14	40	38.5	1	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	10/4/2012	9/7/2016	5	2	40	4.0	10	3.9	6.3	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	11,100	12,000	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/4/2012	9/7/2016	5	1	20	20	131	173	173	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/4/2012	10/4/2012	1	1	100	--	--	176	176	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/4/2012	9/7/2016	5	5	100	--	--	5,530	7,800	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Vanadium	No	ug/L	10/4/2012	9/7/2016	5	3	60	10	15	4.4	11	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	10/4/2012	9/7/2016	5	1	20	5.0	8.3	6.2	6.2	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
AT-K-3-M																	
Fluoride	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	76	190	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	30	50	--	--	--	48.0	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	11,400	15,100	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
AT-K-3-S																	
Fluoride	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	82	210	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	8.4	25	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	4,870	8,770	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
AT-K-4-D																	
Nitrate	No	ug/L	10/9/2012	10/9/2012	1	1	100	--	--	364	364	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	10/9/2012	1	1	100	--	--	161	161	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
AT-K-4-M																	
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	54	152	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	1	20	1.5	8.0	2.7	2.7	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	344	624	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
AT-K-5-D																	
Arsenic	No	ug/L	10/9/2012	9/12/2016	5	4	80	1.7	1.7	3.3	4.9	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	106	270	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	4	80	8.0	8.0	3.1	8.8	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	1,240	1,910	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	9/12/2016	5	1	20	125	250	188	188	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
AT-K-5-M																	
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	136	300	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	4	80	8.0	8.0	1.9	2.8	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	410	1,140	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	9/12/2016	5	1	20	20	131	137	137	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium-90	No	pCi/L	10/9/2012	9/12/2016	5	3	60	0.51	0.87	0.85	2.9	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
AT-K-5-S																	
Fluoride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	67	150	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	1	20	1.5	8.0	1.6	1.6	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	326	930	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	9/12/2016	5	1	20	125	250	209	209	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
AT-K-6-M																	
Fluoride	No	ug/L	10/11/2012	9/20/2016	5	4	80	46	46	66	120	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/11/2012	9/20/2016	5	3	60	35	168	219	575	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	10/11/2012	9/20/2016	5	1	20	20	131	160	160	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
C6236																	
Arsenic	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	3.9	4.0	4.1	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	41	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	9/1/2016	11/29/2016	3	3	100	--	--	108	137	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	0.16	0.22	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	4.5	7.1	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	220	230	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	9/24/2012	11/29/2016	7	7	100	--	--	2.7	5.3	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	85	430	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	5.5	13	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	24,300	26,100	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	125	125	197	197	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	0.14	0.14	0.25	0.25	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	1.7	2.1	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/1/2016	11/29/2016	3	3	100	--	--	2,190	2,370	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/1/2016	11/29/2016	3	2	66.67	15	15	12	12	11.5	2	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	3.0	6.0	3.9	3.9	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6237																	
Barium	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	37	42	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	9/1/2016	11/29/2016	3	3	100	--	--	81	120	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	0.30	0.30	0.21	0.21	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chromium	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	4.8	6.6	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	220	230	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	3.5	7.5	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	30	30	332	332	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	2.0	2.0	4.0	4.0	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	24,800	27,000	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	125	125	207	207	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	2.4	2.7	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/1/2016	11/29/2016	3	3	100	--	--	2,010	2,230	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/1/2016	11/29/2016	3	2	66.67	15	15	11	11	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6238																	
Barium	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	37	43	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	9/24/2012	11/29/2016	8	8	100	--	--	45	249	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	0.19	0.20	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	4.7	6.6	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Copper	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	1.9	7.0	2.4	2.4	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	115	260	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	3.8	6.7	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	9/1/2016	11/29/2016	3	2	66.67	16	16	19	53	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	9/1/2016	11/29/2016	3	1	33.33	0.70	4.0	1.4	1.4	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	24,000	27,000	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/24/2012	11/29/2016	8	1	12.5	20	131	283	283	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Trichloroethene	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	2.0	2.5	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/24/2012	11/29/2016	8	8	100	--	--	1,400	2,610	119	8	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	9/1/2016	11/29/2016	3	2	66.67	15	15	11	12	11.5	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6239																	
Acetone	No	ug/L	10/20/2014	9/13/2016	3	1	33.33	0.34	0.55	0.69	0.69	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	10/20/2014	9/13/2016	3	1	33.33	0.070	0.070	0.18	0.18	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6240																	
Acetone	No	ug/L	10/22/2014	9/13/2016	3	3	100	--	--	1.1	9.1	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	10/22/2014	9/13/2016	3	1	33.33	3.8	9.8	7.9	7.9	--	--	--	2,000	0	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	9/24/2012	9/13/2016	5	1	20	1.5	2.0	2.0	2.0	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6241																	
2-Propanol	No	ug/L	9/13/2016	9/13/2016	1	1	100	--	--	75	75	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	9/16/2013	9/13/2016	4	4	100	--	--	73	153	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chloroform	No	ug/L	10/22/2014	9/13/2016	3	3	100	--	--	0.24	0.48	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	9/16/2013	9/13/2016	4	4	100	--	--	128	182	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/21/2012	9/13/2016	7	5	71.43	1.5	2.0	2.9	5.8	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	9/16/2013	9/13/2016	4	4	100	--	--	14,000	32,100	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Toluene	No	ug/L	10/22/2014	9/13/2016	3	1	33.33	0.30	0.30	0.17	0.17	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	10/22/2014	9/13/2016	3	1	33.33	0.16	0.30	0.39	0.39	--	--	--	0.54	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	9/16/2013	9/13/2016	4	2	50	298	310	131	210	119	2	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
C6242																	
Hexavalent Chromium	No	ug/L	9/24/2012	9/14/2016	5	2	40	1.5	2.0	2.2	2.7	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6243																	
Hexavalent Chromium	No	ug/L	9/24/2012	9/14/2016	5	1	20	1.5	2.0	2.4	2.4	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	9/24/2012	9/14/2016	5	1	20	1.1	1.9	3.0	3.0	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
C6244																	
Carbon-14	No	pCi/L	9/24/2012	9/14/2016	5	1	20	3.9	52	6.4	6.4	--	--	--	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	9/24/2012	9/14/2016	5	5	100	--	--	75	190	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	9/24/2012	9/14/2016	5	1	20	1.5	2.0	2.7	2.7	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrate	No	ug/L	9/24/2012	9/14/2016	5	5	100	--	--	381	1,570	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	9/24/2012	9/14/2016	5	1	20	20	131	130	130	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	9/24/2012	9/14/2016	5	1	20	270	403	414	414	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
C6245																	
Hexavalent Chromium	No	ug/L	10/3/2012	9/14/2016	5	3	60	1.5	1.5	3.7	10	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/3/2012	9/14/2016	5	1	20	1.2	1.9	2.0	2.0	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
C6246																	
Hexavalent Chromium	No	ug/L	10/3/2012	9/14/2016	5	4	80	1.5	1.5	1.5	12	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6247																	
Carbon-14	No	pCi/L	10/3/2012	9/14/2016	5	4	80	9.4	9.4	26	416	--	--	--	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	10/3/2012	9/14/2016	5	4	80	46	46	91	150	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/3/2012	9/14/2016	5	3	60	1.5	1.5	9.0	11	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/3/2012	9/14/2016	5	5	100	--	--	443	31,000	26,871	1	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/3/2012	9/14/2016	5	3	60	308	407	316	710	119	3	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
C6248																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/14/2016	5	3	60	1.5	1.5	2.5	3.0	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6249																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/14/2016	5	5	100	--	--	1.7	6.4	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6250																	
Carbon-14	No	pCi/L	10/4/2012	9/14/2016	5	3	60	18	46	10	23	--	--	--	2,000	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Fluoride	No	ug/L	10/4/2012	9/14/2016	5	3	60	46	50	93	110	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	5/21/2012	9/14/2016	7	5	71.43	1.5	2.0	2.2	5.6	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/4/2012	9/14/2016	5	5	100	--	--	10,600	13,300	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/4/2012	9/14/2016	5	1	20	20	131	148	148	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/4/2012	9/14/2016	5	5	100	--	--	2,970	9,900	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
C6251																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/19/2016	4	2	50	1.5	1.5	2.0	3.9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6252																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/19/2016	5	5	100	--	--	3.5	13	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6253																	
Carbon-14	No	pCi/L	10/4/2012	9/19/2016	5	2	40	18	46	17	24	--	--	--	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	10/4/2012	9/19/2016	5	4	80	46	46	85	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/4/2012	9/19/2016	4	2	50	1.5	1.5	7.6	12	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/4/2012	9/19/2016	5	5	100	--	--	11,600	14,200	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/4/2012	9/19/2016	5	5	100	--	--	1,670	5,800	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
C6254																	
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	5	1	20	1.5	2.0	4.6	4.6	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/8/2012	9/19/2016	5	4	80	1.3	1.3	0.92	1.2	0.015	4	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6255																	
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	5.6	9.4	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6256																	
Carbon-14	No	pCi/L	10/8/2012	9/19/2016	5	3	60	17	53	11	12	--	--	--	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	53	160	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	4	4	100	--	--	12	17	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	930	1,140	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/8/2012	9/19/2016	5	1	20	20	131	144	144	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/8/2012	9/19/2016	5	1	20	303	357	298	298	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
C6257																	
Strontium-90	No	pCi/L	10/8/2012	10/26/2016	5	3	60	1.1	1.5	2.2	3.8	0.015	3	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
C6259																	
Fluoride	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	70	150	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	354	797	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/8/2012	9/19/2016	5	1	20	125	131	215	215	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
C6260																	
Fluoride	No	ug/L	10/9/2012	9/20/2016	5	5	100	--	--	47	120	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/20/2016	5	2	40	1.5	2.0	1.7	2.3	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/20/2016	5	5	100	--	--	289	549	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6261																	
Fluoride	No	ug/L	10/9/2012	9/20/2016	5	4	80	46	46	67	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/9/2012	9/20/2016	5	4	80	2.0	2.0	1.6	3.7	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/9/2012	9/20/2016	5	5	100	--	--	810	1,590	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/9/2012	9/20/2016	5	1	20	125	131	129	129	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
C6263																	
Barium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	26	26	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	674	674	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	3	60	1.5	1.5	2.0	3.9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	97	97	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	14	14	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Naphthalene	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	1.3	1.3	--	--	--	160	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	12,700	12,700	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	145	145	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	124	124	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/11/2012	10/11/2012	1	1	100	--	--	1,800	1,800	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	19	19	11.5	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6264																	
Barium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	15	15	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	945	945	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	3	60	1.5	1.5	1.7	3.5	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	59	59	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	8.8	8.8	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	12,900	12,900	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	182	182	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	85	85	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/11/2012	10/11/2012	1	1	100	--	--	3.3	3.3	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tritium	No	pCi/L	10/11/2012	10/11/2012	1	1	100	--	--	1,900	1,900	119	1	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	34	34	11.5	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C6265																	
Barium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	13	13	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Carbon-14	No	pCi/L	10/11/2012	9/20/2016	5	5	100	--	--	42	55	--	--	--	2,000	0	40 CFR 141 - federal MCL
Fluoride	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	870	1,040	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	4	80	1.5	1.5	1.9	4.9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	12,000	14,600	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	10/11/2012	9/20/2016	5	1	20	20	131	154	154	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	82	82	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tritium	No	pCi/L	10/11/2012	9/20/2016	5	5	100	--	--	1,600	2,200	119	5	DOE/RL-96-61 Rev.0, Table ES-1	20,000	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	30	30	11.5	1	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C7641																	
Aluminum	No	ug/L	8/13/2012	9/14/2016	16	16	100	--	--	23	2,470	7.1	16	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	8/13/2012	11/29/2016	19	1	5.26	0.30	3.5	5.7	5.7	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	8/13/2012	11/29/2016	19	8	42.11	1.2	5.0	0.40	6.3	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	8/13/2012	11/29/2016	19	19	100	--	--	13	52	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/16/2013	9/14/2016	12	3	25	4.0	15	4.2	8.6	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	ug/L	8/13/2012	11/29/2016	19	1	5.26	0.13	1.0	1.7	1.7	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	8/13/2012	11/29/2016	19	1	5.26	3.3	56	22	22	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	8/13/2012	11/29/2016	20	11	55	1.0	3.0	0.55	5.1	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	8/13/2012	11/29/2016	19	12	63.16	0.10	1.0	0.11	1.3	0.92	1	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	8/13/2012	11/29/2016	19	16	84.21	3.0	3.0	0.29	8.1	0.81	10	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	8/13/2012	11/29/2016	18	15	83.33	46	46	63	130	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	10/20/2014	9/14/2016	3	2	66.67	2.5	2.5	2.1	3.0	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	8/13/2012	10/26/2016	19	3	15.79	1.5	8.0	1.7	2.9	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Iron	No	ug/L	8/13/2012	11/29/2016	19	18	94.74	40	40	30	2,540	570	2	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	8/13/2012	9/14/2016	16	6	37.5	0.10	0.50	0.14	0.81	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	8/13/2012	11/29/2016	19	17	89.47	1.0	2.0	1.5	61	38.5	2	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	8/13/2012	11/29/2016	19	4	21.05	0.27	1.6	1.7	3.4	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	8/13/2012	9/14/2016	16	14	87.5	0.30	1.0	0.24	0.53	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	8/13/2012	11/29/2016	19	7	36.84	0.20	5.0	0.35	2.7	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	8/13/2012	11/29/2016	18	18	100	--	--	241	2,370	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	8/13/2012	11/29/2016	18	1	5.56	9.9	131	159	159	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	8/13/2012	9/14/2016	16	16	100	--	--	70	156	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/20/2014	11/29/2016	6	1	16.67	0.89	1.4	3.9	3.9	0.015	1	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tin	No	ug/L	8/13/2012	9/14/2016	16	3	18.75	0.10	1.0	0.13	3.2	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	8/13/2012	11/29/2016	19	1	5.26	0.070	1.0	0.37	0.37	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/16/2013	9/14/2016	12	11	91.67	0.23	0.23	0.087	0.50	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	8/13/2012	11/29/2016	18	14	77.78	5.0	10	4.3	8.9	11.5	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	8/13/2012	11/29/2016	19	6	31.58	3.3	8.3	3.6	10	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C7642																	
1-Butanol	No	ug/L	8/13/2012	9/14/2016	16	1	6.25	12	100	120	120	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
2-Propanol	No	ug/L	9/14/2016	9/14/2016	1	1	100	--	--	180	180	--	--	--	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Acetone	No	ug/L	8/13/2012	11/29/2016	19	6	31.58	0.34	5.0	0.48	3.4	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	8/13/2012	7/29/2016	15	10	66.67	15	20	14	412	7.1	10	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	ug/L	8/13/2012	11/29/2016	18	2	11.11	0.30	5.4	0.23	1.7	55.1	0	DOE/RL-96-61 Rev.0, Table ES-1	6.0	0	40 CFR 141 - federal MCL
Arsenic	No	ug/L	8/13/2012	11/29/2016	18	15	83.33	3.9	5.0	1.3	3.2	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	8/13/2012	11/29/2016	18	18	100	--	--	18	51	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/16/2013	7/29/2016	11	5	45.45	6.4	7.2	3.9	7.2	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cadmium	No	ug/L	8/13/2012	11/29/2016	18	1	5.56	0.050	1.0	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	40 CFR 141 - federal MCL
Carbon tetrachloride	No	ug/L	8/13/2012	11/29/2016	19	1	5.26	0.13	1.0	1.6	1.6	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	8/13/2012	11/29/2016	19	18	94.74	40	40	10	128	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	8/13/2012	11/29/2016	19	13	68.42	1.0	3.0	1.0	2.7	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	8/13/2012	11/29/2016	18	4	22.22	0.050	1.0	0.24	0.50	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	8/13/2012	11/29/2016	18	10	55.56	0.35	3.0	0.21	1.0	0.81	6	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	8/13/2012	11/29/2016	18	16	88.89	46	46	52	180	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross alpha	No	pCi/L	10/20/2014	10/6/2015	2	1	50	1.3	1.3	1.5	1.5	--	--	--	15.0	0	40 CFR 141 - federal MCL
Gross beta	No	pCi/L	10/20/2014	10/6/2015	2	2	100	--	--	4.3	5.9	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	8/13/2012	10/26/2016	18	6	33.33	1.5	8.0	1.7	9.2	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	8/13/2012	11/29/2016	18	12	66.67	13	40	15	293	570	0	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	8/13/2012	7/29/2016	15	4	26.67	0.050	0.50	0.13	0.36	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Manganese	No	ug/L	8/13/2012	11/29/2016	18	14	77.78	0.70	4.0	0.91	29	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	ug/L	8/13/2012	7/29/2016	15	12	80	1.0	1.0	0.68	1.2	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	8/13/2012	11/29/2016	18	2	11.11	0.20	5.0	0.22	0.76	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	8/13/2012	11/29/2016	18	18	100	--	--	261	5,440	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	8/13/2012	11/29/2016	18	2	11.11	9.9	131	252	378	93.7	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Selenium	No	ug/L	8/13/2012	7/29/2016	15	3	20	0.66	2.0	1.9	2.4	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	50.0	0	40 CFR 141 - federal MCL
Strontium	No	ug/L	8/13/2012	7/29/2016	15	15	100	--	--	132	318	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	ug/L	8/13/2012	7/29/2016	15	1	6.67	0.050	0.55	0.040	0.040	1.7	0	DOE/RL-96-61 Rev.0, Table ES-1	0.50	0	40 CFR 141 - federal MCLG
Tin	No	ug/L	8/13/2012	7/29/2016	15	5	33.33	0.050	1.1	0.11	3.0	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	ug/L	8/13/2012	11/29/2016	19	2	10.53	0.070	1.0	0.18	0.26	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	8/13/2012	11/29/2016	19	14	73.68	0.25	1.0	0.32	0.97	--	--	--	0.54	7	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/16/2013	7/29/2016	11	11	100	--	--	1.1	6.2	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	8/13/2012	11/29/2016	17	17	100	--	--	9.5	19	11.5	11	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	8/13/2012	11/29/2016	18	2	11.11	3.0	9.3	3.7	15	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
C7643																	
Acetone	No	ug/L	8/13/2012	11/29/2016	19	2	10.53	1.0	5.0	3.5	3.7	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Aluminum	No	ug/L	8/13/2012	9/14/2016	16	15	93.75	15	15	31	418	7.1	15	DOE/RL-96-61 Rev.0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Arsenic	No	ug/L	8/13/2012	11/29/2016	19	14	73.68	1.7	5.0	1.1	4.1	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	10.0	0	40 CFR 141 - federal MCL
Barium	No	ug/L	8/13/2012	11/29/2016	19	19	100	--	--	20	51	105	0	DOE/RL-96-61 Rev.0, Table ES-1	2,000	0	40 CFR 141 - federal MCL
Boron	No	ug/L	9/16/2013	9/14/2016	12	4	33.33	4.0	15	2.7	4.7	36.0	0	DOE/RL-96-61 Rev.0, Table ES-1	3,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	ug/L	8/13/2012	11/29/2016	19	1	5.26	0.30	1.0	2.2	2.2	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon-14	No	pCi/L	8/13/2012	11/29/2016	19	10	52.63	3.3	56	6.3	100	--	--	--	2,000	0	40 CFR 141 - federal MCL
Chromium	No	ug/L	8/13/2012	11/29/2016	20	12	60	1.0	3.0	1.0	3.5	2.4	4	DOE/RL-96-61 Rev.0, Table ES-1	100	0	40 CFR 141 - federal MCL
Cobalt	No	ug/L	8/13/2012	11/29/2016	19	10	52.63	0.050	1.0	0.077	0.77	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	4.8	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	ug/L	8/13/2012	11/29/2016	19	16	84.21	3.0	3.0	0.23	12	0.81	7	DOE/RL-96-61 Rev.0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	ug/L	8/13/2012	11/29/2016	19	17	89.47	46	46	56	151	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Gross beta	No	pCi/L	10/20/2014	9/14/2016	3	2	66.67	3.6	3.6	2.9	3.9	0.0081	2	Scott W. Petersen, Jan. 27,1998 Memo	4.0 mrem/yr	--	40 CFR 141 - federal MCL
Hexavalent Chromium	No	ug/L	8/13/2012	10/26/2016	19	3	15.79	1.5	8.0	3.0	9.0	--	--	--	48.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	ug/L	8/13/2012	11/29/2016	19	18	94.74	16	16	22	590	570	1	DOE/RL-96-61 Rev.0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	ug/L	8/13/2012	9/14/2016	16	2	12.5	0.050	0.50	0.14	0.32	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	15.0	0	40 CFR 141 - federal MCL
Manganese	No	ug/L	8/13/2012	11/29/2016	19	14	73.68	0.74	4.0	1.5	37	38.5	0	DOE/RL-96-61 Rev.0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	ug/L	8/13/2012	11/29/2016	19	2	10.53	1.0	1.6	2.4	2.6	--	--	--	5.0	0	40 CFR 141 - federal MCL
Molybdenum	No	ug/L	8/13/2012	9/14/2016	16	16	100	--	--	0.48	1.6	3.2	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	ug/L	8/13/2012	11/29/2016	19	7	36.84	0.50	5.0	0.10	0.68	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	100	0	WAC 246-290-310
Nitrate	No	ug/L	8/13/2012	11/29/2016	19	19	100	--	--	487	3,490	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL

Table D-27. Summary Statistics for Individual Aquifer Tubes adjacent to 100-KR-4 Groundwater OU (Comparison to Human Health Drinking Water Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Nitrite	No	ug/L	8/13/2012	11/29/2016	19	2	10.53	125	131	264	298	93.7	2	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL
Silver	No	ug/L	8/13/2012	11/29/2016	19	1	5.26	0.050	1.0	0.050	0.050	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	ug/L	8/13/2012	9/14/2016	16	16	100	--	--	94	224	323	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium-90	No	pCi/L	10/20/2014	11/29/2016	6	2	33.33	0.94	1.9	0.96	4.2	0.015	2	Scott W. Petersen, Jan. 27,1998 Memo	8.0	0	40 CFR 141 - federal MCL
Tin	No	ug/L	8/13/2012	9/14/2016	16	2	12.5	0.050	1.0	0.078	0.98	21.6	0	DOE/RL-96-61 Rev.0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	ug/L	8/13/2012	11/29/2016	19	6	31.58	0.30	1.0	0.30	0.74	--	--	--	0.54	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	ug/L	9/16/2013	9/14/2016	12	12	100	--	--	0.28	3.5	9.9	0	DOE/RL-96-61 Rev.0, Table ES-1	30.0	0	40 CFR 141 - federal MCL
Vanadium	No	ug/L	8/13/2012	11/29/2016	18	18	100	--	--	9.0	13	11.5	6	DOE/RL-96-61 Rev.0, Table ES-1	80.0	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	ug/L	8/13/2012	11/29/2016	19	4	21.05	2.0	5.0	3.8	9.5	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
DK-04-2																	
Fluoride	No	ug/L	10/30/2012	10/23/2014	3	3	100	--	--	101	162	1,047	0	DOE/RL-96-61 Rev.0, Table ES-1	960	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	ug/L	10/30/2012	10/23/2014	3	2	66.67	168	168	379	380	26,871	0	DOE/RL-96-61 Rev.0, Table ES-1	45,000	0	40 CFR 141 - federal MCL
Nitrite	No	ug/L	10/30/2012	10/23/2014	3	1	33.33	125	131	145	145	93.7	1	DOE/RL-96-61 Rev.0, Table ES-1	3,300	0	40 CFR 141 - federal MCL

Sources:

40 CFR 141, "National Primary Drinking Water Regulations."

DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

Table D-28. Summary Statistics for Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Surface Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Metals																	
Aluminum	Yes	ug/L	8/13/2012	10/10/2016	72	9	12.5	10	20	12	69	7.1	9	DOE/RL-96-61 Rev.0, Table ES-1	87	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	8/13/2012	2/21/2017	118	62	52.54	0.40	30	0.40	6.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Cadmium	Yes	ug/L	8/13/2012	2/21/2017	115	1	0.87	0.099	4.0	0.12	0.12	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	0.72	0	CWA - freshwater CCC
Chromium	Yes	ug/L	8/13/2012	2/21/2017	124	74	59.68	1.0	5.0	0.31	51	2.4	23	DOE/RL-96-61 Rev.0, Table ES-1	74	0	CWA - freshwater CCC
Copper	Yes	ug/L	8/13/2012	2/21/2017	115	47	40.87	0.20	7.0	0.24	4.1	0.81	15	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	5/21/2012	2/21/2017	370	153	41.35	1.5	8.0	1.5	50	--	--	--	10	25	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	8/13/2012	2/21/2017	112	15	13.39	13	40	21	595	570	1	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	8/13/2012	10/10/2016	72	2	2.78	0.10	1.0	0.17	0.48	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	8/13/2012	2/21/2017	114	17	14.91	0.20	10	0.20	10	1.6	6	DOE/RL-96-61 Rev.0, Table ES-1	52	0	CWA - freshwater CCC
Silver	Yes	ug/L	8/13/2012	2/21/2017	115	1	0.87	0.039	4	0.05	0.05	5.3	0	DOE/RL-96-61 Rev.0, Table ES-1	2.6	0	WAC 173-201A - freshwater CCC
Selenium	Yes	ug/L	8/13/2012	10/10/2016	72	4	5.56	0.60	2.0	1.7	3.5	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5	0	WAC 173-201A - freshwater CCC
Zinc	Yes	ug/L	8/13/2012	2/21/2017	114	8	7.02	3.0	9.3	3.6	7.8	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	91.0	0	WAC 173-201A - freshwater CCC
Anions																	
Chloride	No	ug/L	8/13/2012	2/21/2017	237	237	100	--	--	277	17,900	--	--	--	230,000	0	CWA - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
14-D																	
Chloride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	9,200	9,700	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	2.1	7.3	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
17-D																	
Aluminum	Yes	ug/L	9/24/2012	9/8/2016	5	1	20	10	20	30	30	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	9/24/2012	2/21/2017	9	6	66.67	4.0	5.0	1.6	6.5	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	9/24/2012	2/21/2017	9	9	100	--	--	1,040	5,100	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/24/2012	2/21/2017	9	7	77.78	4.0	4.0	0.55	2.8	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	9/24/2012	2/21/2017	9	3	33.33	0.68	7.0	0.76	1.8	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	9/24/2012	2/21/2017	9	4	44.44	1.5	8.0	1.7	2.5	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	9/24/2012	2/21/2017	9	1	11.11	13	30	93	93	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	9/24/2012	2/21/2017	9	1	11.11	0.20	10	7.6	7.6	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
17-M																	
Arsenic	Yes	ug/L	9/1/2016	2/21/2017	4	1	25	3.9	4.0	4.0	4.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	1,000	9,200	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/1/2016	2/21/2017	4	2	50	4.0	4.0	2.0	2.4	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Iron	Yes	ug/L	9/1/2016	2/21/2017	4	4	100	--	--	170	595	570	1	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
18-S																	
Aluminum	Yes	ug/L	11/29/2012	10/10/2016	5	1	20	10	20	69	69	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	11/29/2012	10/10/2016	5	1	20	0.40	4.0	1.0	1.0	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	408	2,080	--	--	--	230,000	0	CWA - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	11/29/2012	10/10/2016	5	4	80	4.0	4.0	1.0	1.7	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	11/29/2012	10/10/2016	5	5	100	--	--	0.69	2.0	0.81	4	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	11/29/2012	10/10/2016	4	1	25	13	30	56	56	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Selenium	Yes	ug/L	11/29/2012	10/10/2016	5	1	20	0.60	2.0	2.3	2.3	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
19-D																	
Aluminum	Yes	ug/L	10/3/2012	9/7/2016	5	1	20	10	20	35	35	7.1	1	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	10/3/2012	9/7/2016	5	1	20	0.40	1.7	0.40	0.40	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	10/3/2012	9/7/2016	5	5	100	--	--	546	1,600	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/3/2012	9/7/2016	5	3	60	1.0	2.0	0.31	1.3	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/3/2012	9/7/2016	5	1	20	0.20	0.68	0.48	0.48	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/3/2012	9/7/2016	5	1	20	1.5	2.0	3.6	3.6	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
19-M																	
Chloride	No	ug/L	9/7/2016	9/7/2016	1	1	100	--	--	500	500	--	--	--	230,000	0	CWA - freshwater CCC
21-M																	
Chloride	No	ug/L	10/8/2012	10/26/2016	5	5	100	--	--	790	1,600	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/8/2012	10/26/2016	5	1	20	1.5	2.0	2.1	2.1	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
21-S																	
Hexavalent Chromium	No	ug/L	10/8/2012	9/8/2016	5	1	20	1.5	2.0	1.8	1.8	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
22-D																	
Chloride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	1,180	3,300	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	5.0	43	--	--	--	10.0	3	WAC 173-201A - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
23-M																	
Chloride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	720	951	--	--	--	230,000	0	CWA - freshwater CCC
25-D																	
Chloride	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	678	910	--	--	--	230,000	0	CWA - freshwater CCC
26-D																	
Chloride	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	12,300	16,000	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	5/21/2012	9/20/2016	7	3	42.86	1.5	2.0	2.2	4.4	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
26-M																	
Hexavalent Chromium	No	ug/L	5/21/2012	9/20/2016	7	2	28.57	1.5	2.0	3.0	3.9	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-1-D																	
Aluminum	Yes	ug/L	9/24/2012	9/6/2016	5	3	60	17	20	12	27	7.1	3	DOE/RL-96-61 Rev.0, Table ES-1	87.0	0	CWA - freshwater CCC
Arsenic	Yes	ug/L	9/24/2012	11/29/2016	8	5	62.5	4.0	5.0	0.87	1.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	530	6,610	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/24/2012	12/12/2016	10	6	60	1.1	4.0	1.6	37	2.4	2	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	9/24/2012	11/29/2016	8	3	37.5	0.45	7.0	0.43	0.76	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	9/24/2012	12/12/2016	9	3	33.33	1.5	8.0	1.5	29	--	--	--	10.0	1	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	9/24/2012	11/29/2016	8	2	25	13	30	23	53	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Lead	Yes	ug/L	9/24/2012	9/6/2016	5	1	20	0.10	0.17	0.17	0.17	0.92	0	DOE/RL-96-61 Rev.0, Table ES-1	2.1	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	9/24/2012	11/29/2016	8	1	12.5	0.20	10	7.6	7.6	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Zinc	Yes	ug/L	9/24/2012	11/29/2016	8	1	12.5	3.3	9.3	5.4	5.4	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	91.0	0	WAC 173-201A - freshwater CCC
AT-K-1-M																	
Chloride	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	420	770	--	--	--	230,000	0	CWA - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chromium	Yes	ug/L	6/24/2016	12/12/2016	5	2	40	3.0	4.0	1.6	2.2	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Iron	Yes	ug/L	6/24/2016	11/29/2016	3	1	33.33	16	16	36	36	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
AT-K-1-S																	
Chloride	No	ug/L	6/24/2016	11/29/2016	3	3	100	--	--	330	720	--	--	--	230,000	0	CWA - freshwater CCC
AT-K-2-D																	
Arsenic	Yes	ug/L	10/10/2012	9/8/2016	5	3	60	1.7	1.7	0.40	1.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	10/10/2012	9/8/2016	5	5	100	--	--	277	1,570	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/10/2012	9/8/2016	5	2	40	2.0	3.0	1.1	1.4	2.4	0	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/10/2012	9/8/2016	5	4	80	0.35	0.35	0.35	0.72	0.81	0	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/10/2012	9/8/2016	5	1	20	1.5	8.0	2.2	2.2	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/10/2012	9/8/2016	5	1	20	20	30	21	21	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Nickel	Yes	ug/L	10/10/2012	9/8/2016	5	1	20	0.20	4.0	0.94	0.94	1.6	0	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
Selenium	Yes	ug/L	10/10/2012	9/8/2016	5	1	20	1.5	2.0	3.5	3.5	10.5	0	DOE/RL-96-61 Rev.0, Table ES-1	5.0	0	WAC 173-201A - freshwater CCC
AT-K-3-D																	
Arsenic	Yes	ug/L	9/19/2013	9/7/2016	4	2	50	1.8	30	3.5	4.4	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	9,310	14,300	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	25	51	2.4	5	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	10/4/2012	9/7/2016	5	1	20	2.1	5.0	2.2	2.2	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	4	4	100	--	--	29	31	--	--	--	10.0	4	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	10/4/2012	9/7/2016	5	2	40	4.0	10	2.8	4.7	1.6	2	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
AT-K-3-M																	
Chloride	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	8,030	12,000	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	30	50	--	--	--	10.0	5	WAC 173-201A - freshwater CCC
AT-K-3-S																	
Chloride	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	2,800	6,700	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	5	5	100	--	--	8.4	25.4	--	--	--	10.0	3	WAC 173-201A - freshwater CCC
AT-K-4-S																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/7/2016	5	0	0	1.5	8	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-5-D																	
Arsenic	Yes	ug/L	10/9/2012	9/12/2016	5	4	80	1.7	1.7	3.32	5.93	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	1,300	2,050	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	4	80	8	8	3.1	8.8	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-5-M																	
Chloride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	1,000	1,220	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	4	80	8	8	1.9	2.8	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-5-S																	
Chloride	No	ug/L	10/9/2012	9/12/2016	5	5	100	--	--	925	1,310	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/12/2016	5	1	20	1.5	8	1.6	1.6	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-6-D																	
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	0	0	1.5	8	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-6-M																	
Chloride	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	491	1,100	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	0	0	1.5	8	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
AT-K-6-S																	
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	0	0	1.5	8	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6236																	

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
Chloride	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	11,000	12,000	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	4	7.8	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	9/24/2012	11/29/2016	7	7	100	--	--	2.7	5.3	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Nickel	Yes	ug/L	9/1/2016	11/29/2016	3	1	33.33	1.6	10	2.3	2.3	1.6	1	DOE/RL-96-61 Rev.0, Table ES-1	52.0	0	CWA - freshwater CCC
C6237																	
Chloride	No	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	11,000	12,000	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	5	6.6	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Copper	Yes	ug/L	9/1/2016	11/29/2016	3	1	33.33	3	7	3.73	3.73	0.81	1	DOE/RL-96-61 Rev.0, Table ES-1	9.9	0	WAC 173-201A - freshwater CCC
Hexavalent Chromium	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	3.5	7.5	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	9/1/2016	11/29/2016	3	1	33.33	30	30	48.4	48.4	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
Zinc	Yes	ug/L	9/1/2016	11/29/2016	3	1	33.33	3.3	6	3.55	3.55	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	91.0	0	WAC 173-201A - freshwater CCC
C6238																	
Arsenic	Yes	ug/L	9/1/2016	11/29/2016	3	1	33.33	3.9	4	4.7	4.7	7.9	0	DOE/RL-96-61 Rev.0, Table ES-1	150	0	CWA - freshwater CCC
Chloride	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	10,100	12,000	--	--	--	230,000	0	CWA - freshwater CCC
Chromium	Yes	ug/L	9/1/2016	11/29/2016	3	3	100	--	--	4.3	6.5	2.4	3	DOE/RL-96-61 Rev.0, Table ES-1	74.0	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	9/24/2012	11/29/2016	8	8	100	--	--	3.8	6.7	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Zinc	Yes	ug/L	9/1/2016	11/29/2016	3	1	33.33	3	6	4.1	4.1	21.8	0	DOE/RL-96-61 Rev.0, Table ES-1	91.0	0	WAC 173-201A - freshwater CCC
C6239																	
Hexavalent Chromium	No	ug/L	9/24/2012	10/7/2015	4	0	0	1.5	8	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6240																	
Hexavalent Chromium	No	ug/L	9/24/2012	9/13/2016	5	1	20	1.5	2	2	2	--	--	--	10.0	0	WAC 173-201A - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6241																	
Chloride	No	ug/L	9/16/2013	9/13/2016	4	4	100	--	--	4,700	9,940	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	5/21/2012	9/13/2016	7	5	71.43	1.5	2	2.9	5.8	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6242																	
Hexavalent Chromium	No	ug/L	9/24/2012	9/14/2016	5	2	40	1.5	2	2.2	2.7	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6243																	
Hexavalent Chromium	No	ug/L	9/24/2012	9/14/2016	5	1	20	1.5	2	2.4	2.4	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6244																	
Chloride	No	ug/L	9/24/2012	9/14/2016	5	5	100	--	--	690	1,400	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	9/24/2012	9/14/2016	5	1	20	1.5	2	2.7	2.7	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6245																	
Hexavalent Chromium	No	ug/L	10/3/2012	9/14/2016	5	3	60	1.5	1.5	3.7	10	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6246																	
Hexavalent Chromium	No	ug/L	10/3/2012	9/14/2016	5	4	80	1.5	1.5	1.5	12	--	--	--	10.0	1	WAC 173-201A - freshwater CCC
C6247																	
Chloride	No	ug/L	10/3/2012	9/14/2016	5	5	100	--	--	570	6,000	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/3/2012	9/14/2016	5	3	60	1.5	1.5	9	11.1	--	--	--	10.0	2	WAC 173-201A - freshwater CCC
C6248																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/14/2016	5	3	60	1.5	1.5	2.5	3	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6249																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/14/2016	5	5	100	--	--	1.7	6.4	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6250																	
Chloride	No	ug/L	10/4/2012	9/14/2016	5	5	100	--	--	13,000	16,100	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	5/21/2012	9/14/2016	7	5	71.43	1.5	2	2.2	5.6	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6251																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/19/2016	4	2	50	1.5	1.5	2	3.9	--	--	--	10.0	0	WAC 173-201A - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6252																	
Hexavalent Chromium	No	ug/L	10/4/2012	9/19/2016	5	5	100	--	--	3.5	12.5	--	--	--	10.0	1	WAC 173-201A - freshwater CCC
C6253																	
Chloride	No	ug/L	10/4/2012	9/19/2016	5	5	100	--	--	15,000	17,900	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/4/2012	9/19/2016	4	2	50	1.5	1.5	7.6	12.2	--	--	--	10.0	1	WAC 173-201A - freshwater CCC
C6254																	
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	5	1	20	1.5	2	4.6	4.6	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6255																	
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	5.6	9.4	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6256																	
Chloride	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	1,200	1,300	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	4	4	100	--	--	12.1	17.2	--	--	--	10.0	4	WAC 173-201A - freshwater CCC
C6257																	
Hexavalent Chromium	No	ug/L	10/8/2012	10/26/2016	5	0	0	1.5	2	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6259																	
Chloride	No	ug/L	10/8/2012	9/19/2016	5	5	100	--	--	846	988	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/8/2012	9/19/2016	5	0	0	1.5	2	--	--	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6260																	
Chloride	No	ug/L	10/9/2012	9/20/2016	5	5	100	--	--	720	980	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/20/2016	5	2	40	1.5	2	1.7	2.3	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6261																	
Chloride	No	ug/L	10/9/2012	9/20/2016	5	5	100	--	--	751	856	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/9/2012	9/20/2016	5	4	80	2	2	1.6	3.7	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C6263																	
Chloride	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	16,400	16,400	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	3	60	1.5	1.5	2	3.9	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	21.1	21.1	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC

Table D-29. Summary Statistics for Individual Aquifer Tubes Adjacent to the 100-KR-4 Groundwater OU (Comparison to Surface Water Quality Standards and Criteria)

Analyte	Filtered?	Units	First Sample Date	Last Sample Date	No. of Results	No. of Detects	Frequency of Detects (%)	Minimum Nondetect	Maximum Nondetect	Minimum Detect	Maximum Detect	Groundwater Background 90th Percentile	No. of Detects > Groundwater Background	Groundwater Background Level Basis	Action Level	No. of Detects > Action Level	Action Level Basis
C6264																	
Chloride	No	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	16,600	16,600	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	3	60	1.5	1.5	1.7	3.5	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
Iron	Yes	ug/L	10/11/2012	10/11/2012	1	1	100	--	--	22.1	22.1	570	0	DOE/RL-96-61 Rev.0, Table ES-1	1,000	0	CWA - freshwater CCC
C6265																	
Chloride	No	ug/L	10/11/2012	9/20/2016	5	5	100	--	--	13,800	16,400	--	--	--	230,000	0	CWA - freshwater CCC
Hexavalent Chromium	No	ug/L	10/11/2012	9/20/2016	5	4	80	1.5	1.5	1.9	4.9	--	--	--	10.0	0	WAC 173-201A - freshwater CCC
C7641																	
Chloride	No	ug/L	8/13/2012	11/29/2016	18	18	100	--	--	389	2,100	--	--	--	230,000	0	CWA - freshwater CCC
C7642																	
Chloride	No	ug/L	8/13/2012	11/29/2016	18	18	100	--	--	550	4,820	--	--	--	230,000	0	CWA - freshwater CCC
C7643																	
Chloride	No	ug/L	8/13/2012	11/29/2016	19	19	100	--	--	653	4,720	--	--	--	230,000	0	CWA - freshwater CCC
DK-04-2																	
Chloride	No	ug/L	10/30/2012	10/23/2014	3	3	100	--	--	880	1,060	--	--	--	230,000	0	CWA - freshwater CCC

Note: 40 CFR 131, "Water Quality Standards"; EPA, 2009, *National Recommended Water Quality Criteria*; and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," only apply in locations where groundwater has the potential to discharge to the Columbia River.

Sources:

40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CMC = criteria maximum concentration
CWA = *Clean Water Act of 1977*

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Table D-30. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)
Monitoring Wells Screened Across Top of the Unconfined Aquifer	
199-K-106A	Carbon-14, Nitrate, TCE, Tritium
199-K-107A	Strontium-90, TCE
199-K-108A	TCE, Nitrate[a]
199-K-110A	Total chromium[c]
199-K-111A	Tritium, Cr(VI)[b], Total Chromium[c], Dissolved Total Chromium[e]
199-K-132	Carbon-14, Cr(VI)[d], Nitrate, TCE
199-K-139	Strontium-90, Cr(VI)[d], TCE
199-K-140	Cr(VI)[d], TCE
199-K-18	None
199-K-19	Strontium-90
199-K-200	Strontium-90
199-K-201	Strontium-90, Cr(VI)[d]
199-K-22	Cr(VI)[d]
199-K-23	Cr(VI)[b], Total Chromium[c], Dissolved Total Chromium[e], Nitrate[a]
199-K-29*	Carbon-14[f], Nitrate[f]
199-K-30*	Carbon-14[f]
199-K-32A	Cr(VI)[d], Nitrate[a]
199-K-34	Strontium-90
199-K-36	Cr(VI)[b]
699-73-61	None
Extraction Well Screened Across Top of the Unconfined Aquifer	
199-K-137	Cr(VI)[b], TCE
Monitoring Wells Screened Across Upper Unconfined Aquifer	
199-K-11	TCE
199-K-117A	None
199-K-125A	None
199-K-138	TCE

Table D-30. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)
199-K-142	Cr(VI)[d]
199-K-173	Cr(VI)[b], Dissolved Total Chromium[e], TCE
199-K-183	TCE
199-K-186	Cr(VI)[d]
199-K-187	None
199-K-188	Cr(VI)[d]
199-K-191	None
199-K-194	None
199-K-20	Strontium-90
199-K-204	Carbon-14, TCE
199-K-21	Strontium-90, Cr(VI)[d]
199-K-221	Strontium-90, Tritium, Cr(VI)[d]
199-K-222	Strontium-90, Cr(VI)[d]
199-K-31	TCE
199-K-37	Cr(VI)[d]
699-72-73	None
Combined Wells Screened Across Upper Confined Aquifer (199-K-205 is an operating KW extraction well)	
199-K-35*, K-195*, K-205	Cr(VI)[b], Dissolved Total Chromium[e], Total Chromium[c], TCE
Extraction Wells Screened Across Upper Unconfined Aquifer	
199-K-113A	None
199-K-114A	None
199-K-141	Strontium-90, Cr(VI)[d]
199-K-144	Cr(VI)[d]
199-K-146	None
199-K-147	Cr(VI)[d]
199-K-148	None
199-K-161	Strontium-90
199-K-178	Cr(VI)[d]

Table D-30. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)
Monitoring Wells Screened Across Entire Aquifer	
199-K-151	None
199-K-157	None
199-K-185	Carbon-14, Nitrate, TCE
199-K-189	Carbon-14, Tritium, Cr(VI)[d]
199-K-202	Carbon-14, Tritium, Cr(VI)[d]
199-K-203	Cr(VI)[d]
199-K-207	Tritium, Cr(VI)[b], Dissolved Total Chromium[e], Nitrate
199-K-209	None
199-K-223	Cr(VI)[d], TCE
Extraction Wells Screened Across Entire Aquifer	
199-K-116A	None
199-K-120A	None
199-K-145	None
199-K-152	Cr(VI)[d]
199-K-153	Cr(VI)[d]
199-K-154	Cr(VI)[d]
199-K-163	None
199-K-165	Cr(VI)[d], TCE
199-K-166	Cr(VI)[d], TCE
199-K-171	Cr(VI)[d]
199-K-182	Cr(VI)[d]
199-K-208	None
199-K-210	Cr(VI)[d]
199-K-224	Cr(VI)[b], Total Chromium[c], Total Dissolved Chromium[e], TCE
Monitoring Wells Screened Across Lower Unconfined Aquifer	
199-K-168	TCE
199-K-184	TCE

Table D-30. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)
199-K-190	TCE
Extraction Well Screened Across Upper and Lower Unconfined Aquifer	
199-K-193	Cr(VI)[d]
Monitoring Wells Screened Across Ringold Upper Mud	
199-K-192	None
199-K-32B	None
Aquifer Tubes	
14-D	None
17-D	None
17-M	None
18-S	None
19-D	None
19-M	None
21-M	None
21-S	None
22-D	Cr(VI)[d]
22-M	Strontium-90
23-M	None
25-D	None
26-D	None
26-M	None
AT-K-1-D	None
AT-K-1-M	None
AT-K-1-S	None
AT-K-2-D	None
AT-K-3-D	Cr(VI)[d]
AT-K-3-M	Cr(VI)[d]
AT-K-3-S	None

Table D-30. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)
AT-K-4-D	None
AT-K-4-M	None
AT-K-4-S	None
AT-K-5-D	None
AT-K-5-M	None
AT-K-5-S	None
AT-K-6-D	None
AT-K-6-M	None
AT-K-6-S	None
C6236	None
C6237	None
C6238	None
C6239	None
C6240	None
C6241	None
C6242	None
C6243	None
C6244	None
C6245	None
C6246	None
C6247	None
C6248	None
C6249	None
C6250	None
C6251	None
C6252	None
C6253	None
C6254	None

Table D-30. Summary of Groundwater COPCs for the 100-KR-4 Groundwater OU

Well Name	Individual Groundwater Evaluation Results (Comparison to Groundwater and Surface Water Action Levels)
C6255	None
C6256	Cr(VI)[d]
C6257	None
C6259	None
C6260	None
C6261	None
C6263	None
C6264	None
C6265	None
C7641	None
C7642	None
C7643	None
DK-04-2	None

* Well is currently decommissioned.

a. Concentrations have recently increased above the DWS in 2017.

b. Cr(VI) concentrations are greater than WAC 173-201A standard of 10 µg/L and the MTCA (WAC 173-340-720) groundwater cleanup level of 48 µg/L.

c. Total chromium concentrations are greater than the the DWS of 100 µg/L.

d. Cr(VI) concentrations are greater than WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," of 10 µg/L.

e. Dissolved total chromium concentrations are greater than the AWQC of 74 µg/L.

f. Exceeded DWS prior to decommissioning.

COPC = contaminant of potential concern

Cr(VI) = hexavalent chromium

TCE = trichloroethene

Appendix E

Waste Site Table

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Contents

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E2 References E-1

Table

Table E-1. Waste Site Table E-11

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E1 Introduction

This appendix is composed of Table E-1, which lists the waste sites identified at 100-K as of April 30, 2017. The table provides the following summary information for each site:

- Site Code – The Waste Information Data System (WIDS) identifier assigned to a given site.
- Site Type – The WIDS category assigned to a given site.
- Operable Unit – The operable unit to which the site has been assigned.
- Lateral Site Dimensions – Approximate lateral footprint size of a site.
- Site History – Known operations that may have impacted a site.
- Known or Suspected Contaminants – Those contaminants that are believed to be present at a site based on its operational history or previous sampling data that may pose an unacceptable risk to human health or the environment.
- Classification/Reclassification Status – The classification or reclassification (if applicable) status of the site, as identified in WIDS.
- Waste Site Reclassification Documentation – The waste site reclassification form number and document number for any supporting verification package document.
- Interim Remedial Action Start Date – Month and year in which active field remediation began at a given site.
- Interim Remedial Action End Date – Month and year in which active field remediation was completed at a given site.
- Contaminated Waste tonnage to the Environmental Restoration Disposal Facility (ERDF) – The mass of contaminated soil and waste removed from a given site and disposed in ERDF.
- Maximum Depth of Remedial Action – The maximum final depth below normal grade reached by the excavation during remedial action.

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Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-1	French Drain	100-KR-2	0.5-m (1.5-ft) diameter	This site is a french drain that received liquid discharges from the 119-KW Building, including heat exchanger cooling water from sample equipment, wastewater from a swamp cooler, and effluent from a building floor drain.	Cs-137, Co-60, Eu-152, Eu-154, and Sr-90	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-2	Burial Ground	None	11,980 m^2 (128,900 ft^2)	This site was identified as a possible sludge burial ground on sketch drawings. Former employees identified that sludge from the 100-K Area was hauled to the 200 Area for disposal and direct intrusive investigation of the site found no evidence of sludge disposal or other hazardous/radioactive waste.	N/A	Rejected	WSRF 2010-077	N/A	N/A	N/A	N/A
100-K-3	Valve Pit	100-KR-2	36 m^2 (390 ft^2) pit area; 2,380 m (7,800 ft) of associated pipeline run	This site consisted of recirculation piping and a heat exchange pit used to supply effluent water to 1706-KE Wet Fish Studies Laboratory. The site was excavated and the features were removed under interim remedial actions in conjunction with collocated sites on the western side of the 105-KE Reactor.	Ag, Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Cl^-, NO_3^-, NO_2^-, SO_4^{2-}, Am-241, C-14, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238	Interim Closed Out	WSRF 2012-089; DOE/RL-2012-40; DOE/RL-2012-46	January 2010	May 2012	11,513 metric tons (2,989 tons)	12 m (39 ft)
100-K-4	Pond	100-KR-2	680 m^2 (7,300 ft^2)	This site consisted of two circular ponds and a valve pit used to support the 1706-KE Wet Fish Studies Laboratory. The site was excavated and the features were removed under interim remedial actions.	Cs-137, Co-60, Eu152, Eu-154, Eu-155, Pu-238, Pu-239/240, Sr-90, U-234, U-235, Cd, Cr, Cr(VI), Pb, and Hg	Interim Closed Out	WSRF 2010-041; DOE/RL-2010-43	January 2010	February 2010	2,712 metric tons (2,989 tons)	5.4 m (17.6 ft)
100-K-5	French Drain	100-KR-2	3.0 m^2 (32 ft^2)	This site is a french drain that received effluent from floor drains and overflows at the 1705-KE Experimental Water Treatment Basin.	Cr(VI), Pb, and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-6	Process Unit/Plant	100-KR-2	5.3 m^2 (57 ft^2)	This site was a cyclone separator within a pit that received radiologically contaminated exhaust from the decontamination solution pit within the 105-KE Reactor Building. The site was excavated and the features were removed under interim remedial actions in conjunction with collocated sites on the eastern side of the 105-KE Reactor.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Sr-90, H-3, Cr, Cr(VI), Cu, Pb, Hg, Ni, Zn, Cl^-, NO_3^-, and NO_2^-	Interim Closed Out	WSRF 2012-063; DOE/RL-2012-38	August 2011	September 2011	34,200 metric tons (37,700 tons) total from the 100-K-6, 100-K-46, 100-K-62, and 132-KE-1 waste sites	6.1 m (20 ft)
100-K-7	Storage Tank	None	118 m^2 (1,270 ft^2)	This site was the location of two underground carbon steel ethylene glycol storage tanks. The tanks were excavated and removed in 1994; inspection and soil sampling did not indicate any releases to soil occurred.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-8	Storage Tank	None	150 m^2 (1,650 ft^2)	This site was the location of two underground carbon steel ethylene glycol storage tanks. The tanks were excavated and removed in 1993; inspection and soil sampling did not indicate any releases to soil occurred.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-9	French Drain	None	0.6-m (2-ft) diameter	This site was one of two french drains that received moisture infiltration from the 118-KE-2 Rod Storage Cave. The drain was removed during remediation of the 118-KE-2 site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-10	French Drain	None	0.6-m (2-ft) diameter	This site was one of two french drains that received moisture infiltration from the 118-KE-2 Rod Storage Cave. The drain was removed during remediation of the 118-KE-2 site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-11	French Drain	None	0.6-m (2-ft) diameter	This site was one of two french drains that received moisture infiltration from the 118-KW-2 Rod Storage Cave. The drain was removed during remediation of the 118-KW-2 site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-12	French Drain	None	0.6-m (2-ft) diameter	This site was one of two french drains that received moisture infiltration from the 118-KW-2 Rod Storage Cave. The drain was removed during remediation of the 118-KW-2 site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-13	French Drain	100-KR-2	13 m^2 (140 ft^2)	This site is a french drain that received sump drainage from the 166-KW Oil Storage Tank pump room (130-KW-2 waste site).	PAHs, PCBs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-14	French Drain	100-KR-2	5.3 m^2 (57 ft^2)	This site was a french drain for an acid storage tank at the 183.1-KE Water Treatment Plant Headhouse. The site was excavated and the drain was removed under interim remedial actions in conjunction with other waste sites in the headhouse vicinity.	Cr, Cr(VI), Hg, Cl^-, NO_3^-, and SO_4^{2-}	Interim Closed Out	WSRF 2017-002; DOE/RL-2017-20	December 2015	December 2015	848 metric tons (935 tons)	4.6 m (15 ft)
100-K-15	Storage Tank	None	120 m^2 (1,290 ft^2)	This site was an above-ground alum storage tank at the 183.1-KW Water Treatment Plant Headhouse. The tank has been removed.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-16	Storage Tank	None	120 m^2 (1,290 ft^2)	This site was an aboveground alum storage tank at the 183.1-KW Water Treatment Plant Headhouse. The tank has been removed.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-18	Sump	100-KR-2	4.8 m^2 (51 ft^2)	This site was a neutralization pit for sodium hydroxide waste from the 183-KW Water Treatment Plant. The pit and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the 183.1-KW Headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2012-017; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)
100-K-19	Foundation	100-KR-2	51 m^2 (550 ft^2)	This site was an aboveground sodium hydroxide storage tank at the 183.1-KW Water Treatment Plant Headhouse. The tank and underlying soil were removed under interim remedial actions in conjunction with other waste sites near the headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2012-018; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)
100-K-20	Foundation	None	23 m^2 (250 ft^2)	This site addresses a former above-grade sodium silicate near the 183.1-KW Water Treatment Plant Headhouse. The tank was removed in 1964 or 1965.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-21	Foundation	None	70 m^2 (760 ft^2)	This site addresses a former above-grade sodium silicate near the 183.1-KW Water Treatment Plant Headhouse. The tank was removed in 1964 or 1965.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-22	Foundation	None	46 m^2 (500 ft^2)	This site addresses a former above-grade sodium silicate near the 183.1-KE Water Treatment Plant Headhouse. The tank was removed in 1964 or 1965.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-23	Foundation	None	70 m^2 (760 ft^2)	This site addresses a former above-grade sodium silicate near the 183.1-KE Water Treatment Plant Headhouse. The tank was removed in 1964 or 1965.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-24	Storage Tank	None	23 m^2 (250 ft^2)	This site addresses a former above-grade bauxite storage silo near the 183.1-KW Water Treatment Plant Headhouse. The silo was removed after production operations ceased in 1971.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-25	Sump	100-KR-2	4.3 m^2 (46 ft^2)	This site is a former neutralization pit for caustic waste from the 183-KE Water Treatment Plant. Effluent from the pit was discharged to the process sewer system.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-27	Foundation	100-KR-2	50 m^2 (540 ft^2)	This site is the footprint of a former aboveground caustic soda storage tank adjacent to the 183.1-KE Water Treatment Plant Headhouse. The tank was removed at an unknown date, but the concrete foundation remains.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-28	Storage Tank	None	24 m^2 (250 ft^2)	This site addresses a former above-grade bauxite storage silo near the 183.1-KE Water Treatment Plant Headhouse. The silo was removed after production operations ceased in 1971.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-29	Dumping Area	100-KR-2	700 m^2 (7,500 ft^2)	This site is an area where steel components from the 183-KE Water Treatment Plant were sandblasted prior to being sold as scrap. The spent sandblasting media was excavated and removed under interim remedial actions.	Cr, Cr(VI), Pb, and Aroclor-1254	Interim Closed Out	WSRF 2004-040	December 2003	December 2003	187 metric tons (206 tons)	0.05 m (0.2 ft)
100-K-30	Storage Tank	100-KR-2	38 m^2 (410 ft^2)	This site was the remaining concrete supports of a former above-grade external sulfuric acid tank at the 183.1-KE Water Treatment Plant Headhouse. The tank was previously removed at an undocumented date. The supports and surrounding soil were excavated and removed under interim remedial actions. Additional soil excavation and removal was also incidentally performed under later interim remedial action efforts for collocated sites at the headhouse.	As, Ba, Cd, Cr, Cr(VI), Pb, Hg, Se, Ag, and SO_4^{2-}	Interim Closed Out	WSRF 2003-036	January 2004	January 2004	Not documented	1 m (3 ft)
100-K-31	Storage Tank	100-KR-2	38 m^2 (410 ft^2)	This site was the remaining concrete supports of a former above-grade external sulfuric acid tank at the 183.1-KE Water Treatment Plant Headhouse. The tank was previously removed at an undocumented date. The supports and surrounding soil were excavated and removed under interim remedial actions. Additional soil excavation and removal was also incidentally performed under later interim remedial action efforts for collocated sites at the headhouse.	As, Ba, Cd, Cr, Cr(VI), Pb, Hg, Se, Ag, and SO_4^{2-}	Interim Closed Out	WSRF 2004-038	December 2003	December 2003	Not documented	0.6 m (2 ft)
100-K-32	Storage Tank	100-KR-2	38 m^2 (410 ft^2)	This site was the remaining concrete supports of a former above-grade external sulfuric acid tank at the 183.1-KW Water Treatment Plant Headhouse. The tank was previously removed at an undocumented date. The supports and surrounding soil were excavated and removed under interim remedial actions. Additional soil excavation and removal was also incidentally performed under later interim remedial action efforts for collocated sites at the headhouse.	As, Ba, Cd, Cr, Cr(VI), Pb, Hg, Se, Ag, and SO_4^{2-}	Interim Closed Out	WSRF 2004-039	December 2003	December 2003	Not documented	0.6 m (2 ft)

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-33	Storage Tank	100-KR-2	38 m^2 (410 ft^2)	This site was the remaining concrete supports of a former above-grade external sulfuric acid tank at the 183.1-KW Water Treatment Plant Headhouse. The tank was previously removed at an undocumented date. The supports and surrounding soil were excavated and removed under interim remedial actions. Additional soil excavation and removal was also incidentally performed under later interim remedial action efforts for collocated sites at the headhouse.	As, Ba, Cd, Cr, Cr(VI), Pb, Hg, Se, Ag, and SO_4^{2-}	Interim Closed Out	WSRF 2004-041	December 2003	December 2003	Not documented	0.6 m (2 ft)
100-K-34	Sump	100-KR-2	4.1 m^2 (44 ft^2)	This site is a former neutralization pit for acid waste from the 183-KW Water Treatment Plant. The pit drained directly to a french drain. The site was excavated and the pit and surrounding soil were removed under interim remedial actions in conjunction with collocated sites near the 183.1-KW Headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2012-023; DOE/RL-2012-28	April 2010	January 2012	31,750 metric tons (35,000 tons) total from the 100-K-34, 100-K-102, and 1607-K3 waste sites	9.8 m (32.2 ft)
100-K-35	Sump	100-KR-2	5.7 m^2 (61 ft^2)	This site is a former neutralization pit for acid waste from the 183-KE Water Treatment Plant. The pit drained directly to a french drain.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-36	French Drain	100-KR-2	0.46-m (18-in.) diameter	This site was a drywell at the 1706-KE Water Studies Semi Works Building that received acidic and caustic overflow and rinsate from a chemical storage facility. The drain and surrounding soil were excavated and removed under interim actions in conjunction with demolition of the 1706-KE facility.	Ag, Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Cl^-, NO_3^-, NO_2^-, SO_4^{2-}, Am-241, C-14, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, H-3, Ni-63, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238	Interim Closed Out	WSRF 2012-083; DOE/RL-2012-40	December 2010	September 2011	Not documented	8 m (26 ft)
100-K-37	Storage Tank	100-KR-2	3.6 m^2 (38 ft^2)	This site is a former above-grade sulfuric acid storage tank for the demineralizer plant at the 1706-KE facility. The tank was removed under interim actions; the underlying slab and soil were subsequently excavated and removed as part of interim remedial actions for other waste sites in the vicinity.	N/A	Interim Closed Out	WSRF 2010-038; DOE/RL-2010-44	November 2009	November 2009	Not documented	N/A
100-K-38	Unplanned Release	100-KR-2	3.6 m^2 (38 ft^2)	This site is a former above-grade sodium hydroxide storage tank for the demineralizer plant at the 1706-KE facility. The tank was removed under interim actions; the underlying slab and soil were subsequently excavated and removed as part of interim remedial actions for other waste sites in the vicinity.	N/A	Interim Closed Out	WSRF 2010-039; DOE/RL-2010-44	November 2009	November 2009	Not documented	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-39	Crib	None	825 m^2 (88,80 ft^2)	This site was identified as a crib in the original remedial investigation/feasibility study work plan for the 100-KR-1 Operable Unit. The area depicted is identical to the electrical distribution intertie yard between 100-K East and West, and no other evidence of a crib at the location has been identified.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-42	Storage	100-KR-2	2,100 m^2 (22,600 ft^2)	This site is the former fuel storage basin for the 105-KE Reactor Building. After reactor operations were terminated, the basin continued to be used for storage of irradiated fuel from the 105-N Reactor. Sludge and debris was removed from the basin by 2007, and the basin structure was demolished and remediated from 2008 to 2009.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-43	Storage	100-KR-2	2,140 m^2 (23,000 ft^2)	This site is the fuel storage basin for the 105-KW Reactor Building. After reactor operations were terminated, the basin continued to be used for storage of irradiated fuel from the 105-N Reactor.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-44	Unplanned Release	None	Not defined	This site was identified to address the portions of the 100-K exclusion area that were not part of another waste site. There is no specific known contamination or release for these areas; where contamination and/or suspect releases have been identified, they have been designated as a separate waste site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-46	French Drain	100-KR-2	Not documented	This site was a drywell and connecting pipeline that received floor drainage from the 119-KE Exhaust Air Sample Building. The site was excavated and the features were removed under interim remedial actions in conjunction with collocated sites on the eastern side of the 105-KE Reactor.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Sr-90, H-3, Cr, Cr(VI), Cu, Pb, Hg, Ni, Zn, Cl^-, NO_3^-, and NO_2^-	Interim Closed Out	WSRF 2012-064; DOE/RL-2012-38	January 2009	February 2009	34,200 metric tons (37,700 tons) total from the 100-K-6, 100-K-46, 100-K-62, and 132-KE-1 waste sites	6.1 m (20 ft)
100-K-47	Process Sewer	100-KR-2	4,000 m (13,100 ft) of pipeline run	This site consists of the nonradioactive process sewers for the 105-KE, 105-KW, 165-KE, 190-KE, and 1706-KE facilities. These sewers were used to discharge treated and untreated liquid waste effluents to the 100-K-56 sewer system. A portion of the pipelines in this waste site were excavated and removed with collocated sites on the northwestern side of the 105-KE Reactor under interim remedial actions.	Cs-137, Co-60, Eu-152, Eu-154, Sr-90, Sb, As, Cr(VI) Pb, Hg, PAHs, PCBs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-48	Unplanned Release	100-KR-2	210 m^2 (2,300 ft^2)	This site is three areas of suspect fuel oil contamination in soil on the northern and western side of the 166-KE Oil Storage Tank (130-KE-2 waste site).	Pb, PAHs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-49	Unplanned Release	100-KR-2	750 m^2 (8,000 ft^2)	This site is multiple areas of suspect fuel oil contamination in soil in 100-K West, likely associated with releases from railroad car unloading.	Pb, PAHs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-50	Storage Tank	100-KR-2	28.5 m^2 (310 ft^2)	This site was a sanitary sewage holding tank for the 1725-K and 1726-K mobile office buildings. The site was excavated and the tank was removed under interim remedial actions in conjunction with other waste sites near the 183.1-KE Water Treatment Plant Headhouse.	Cr, Cr(VI), Hg, Cl^-, NO_3^-, SO_4^{2-}, PAHs, PCBs, and TPH	Interim Closed Out	WSRF 2017-003; DOE/RL-2017-20	October 2015	October 2015	1,408 metric tons (1,553 tons)	4.6 m (15 ft)
100-K-51	Storage Pad (	None	10.9 m^2 (117 ft^2)	This site is a portable steel building used as a 90-day waste accumulation area.	N/A	Rejected	WSRF 2000-017	N/A	N/A	N/A	N/A
100-K-52	Storage	None	Not documented	This site was a wet fish studies laboratory located at the 1706-KE facility, consisting of a laboratory area and three external ponds. These features were removed with demolition of the 1706-KE facility.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-53	Product Piping	100-KR-2	291 m (953 ft) of pipeline run	This site was the underground pipelines formerly used to transfer ethylene glycol solutions from the 150-KE Heat Recovery Station to the 165-KE Powerhouse.	Ethylene glycol	Interim Closed Out	WSRF 2012-055; DOE/RL-2012-37	May 2010	July 2011	20,176 metric tons (22,240 tons)	6.1 m (20 ft)
100-K-54	Product Piping	100-KR-2	560 m (1,850 ft) of pipeline run	This site is the underground pipelines formerly used to transfer ethylene glycol solutions from the 150-KW Heat Recovery Station to the 165-KW Powerhouse.	Ethylene glycol	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-55:1	Radioactive Process Sewer	100-KR-2	Not documented	This site was portions of the effluent sewer pipelines from the 105-KW Reactor outside of the security fence. These pipelines were part of the sewer system that conveyed effluent from the reactor to the 107-KW Retention Basins, 1904-K Outfall, 116-K-1 Crib, and 116-K-2 Trench. The pipelines outside of the security fence and surrounding soil were excavated and removed under interim remedial actions.	Cs-137, Eu-152, Eu-154	Interim Closed Out	CVP-2005-00006	December 2002	April 2005	86,551 metric tons (95,406 tons) total from the 100-K-55:1, 100-K-56:1, 116-KE-5, and 116-KW-4 sites	8.8 m (29 ft)

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-55:2	Radioactive Process Sewer	100-KR-2	Not documented	This site is portions of the effluent sewer pipelines from the 105-KW Reactor inside of the security fence. These pipelines were part of the sewer system that conveyed effluent from the reactor to the 107-KW Retention Basins, 1904-K Outfall, 116-K-1 Crib, and 116-K-2 Trench.	Cs-137, Co-60, Sr-90, Eu-152, Eu-154, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-56:1	Radioactive Process Sewer	100-KR-2	Not documented	This site was portions of the effluent sewer pipelines from the 105-KE Reactor outside of the security fence. These pipelines were part of the sewer system that conveyed effluent from the reactor to the 107-KE Retention Basins, 1904-K Outfall, 116-K-1 Crib, and 116-K-2 Trench. The pipelines outside of the security fence and surrounding soil were excavated and removed under interim remedial actions.	Cs-137, Eu-152, Eu-154	Interim Closed Out	CVP-2005-00006	December 2002	April 2005	86,551 metric tons (95,406 tons) total from the 100-K-55:1, 100-K-56:1, 116-KE-5, and 116-KW-4 sites	8.8 m (29 ft)
100-K-56:2	Radioactive Process Sewer	100-KR-2	Not documented	This site is portions of the effluent sewer pipelines from the 105-KE Reactor inside of the security fence. These pipelines were part of the sewer system that conveyed effluent from the reactor to the 107-KE Retention Basins, 1904-K Outfall, 116-K-1 Crib, and 116-K-2 Trench. A portion of the pipelines in this site were excavated and removed with collocated sites on the northwestern side of the 105-KE Reactor under interim remedial actions.	Cs-137, Co-60, Sr-90, Eu-152, Eu-154, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-56:3	Radioactive Process Sewer	100-KR-2	Not documented	This site is portions of the effluent sewer pipeline system near the 1904-K Outfall. These pipelines were part of the connections to the 100-K-47 and 100-K-55 sewer systems that conveyed effluent to the outfall structure.	Cs-137, Co-60, Sr-90, Eu-152, Eu-154, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-57	Ditch	100-KR-1	530 m (1,750 ft) combined ditch run length	This site addresses a shallow collection ditch system used to channel effluent leakage and runoff from the 107-KE Retention Basin area to the river. The site is located within the 100-K-64 site.	Cs-137, Co-60, Eu-152, Eu-154, Sr-90, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-58	Product Piping	None	Not documented	This site consists of the service water pipelines that supplied raw and sanitary water to facilities in 100-K East.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-59	Product Piping	None	Not documented	This site consists of the service water pipelines that supplied raw and sanitary water to facilities in 100-K West.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-60	Process Sewer	100-KR-2	412 m (1,352 ft) of pipeline run	This site consists of the nonradioactive process sewer for the 165-KW Powerhouse. This sewer connects to the larger 100-K-47 process sewer system, and was used for discharge of wastewater from the Powerhouse.	Pb, Hg, Cr(VI), PAHs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-61	Process Unit/Plant	100-KR-2	317 m^2 (3,410 ft^2)	This site is associated with the 117-KW Filter Building. The facility is outside the scope of waste site definitions, and demolition and removal are planned to be performed as a removal action associated with the facility code.	N/A	Rejected	WSRF 2015-085	N/A	N/A	N/A	N/A
100-K-62	Process Unit/Plant	100-KR-2	320 m^2 (3,400 ft^2)	This site addresses the 117-KE Filter Building. The building was demolished and removed and underlying soil excavated and disposed under interim remedial actions in conjunction with collocated sites on the eastern side of the 105-KE Reactor.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Sr-90, H-3, Cr, Cr(VI), Cu, Pb, Hg, Ni, Zn, Cl^-, NO_3^-, and NO_2^-	Interim Closed Out	WSRF 2012-065; DOE/RL-2012-38	August 2010	May 2011	34,200 metric tons (37,700 tons) total from the 100-K-6, 100-K-46, 100-K-62, and 132-KE-1 waste sites	10.6 m (34.8 ft)
100-K-63	Unplanned Release	100-KR-1	80,000 m^2 (870,000 ft^2)	This site addresses the shoreline embankment and floodplain area adjacent to the former 107-KW Retention Basins. Contaminated effluent leakage from the retention basin area flowed through this area towards the river. Portions of the site were excavated and disposed under interim remedial actions.	Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Sr-90, and Cr(VI)	Interim Closed Out	WSRF 2012-013; DOE/RL-2012-25	July 2010	November 2010	77,501 metric tons (85,431 tons)	4.1 m (13.3 ft)
100-K-64	Unplanned Release	100-KR-1	74,000 m^2 (800,000 ft^2)	This site addresses the shoreline embankment and floodplain area adjacent to the former 107-KE Retention Basins. Contaminated effluent leakage from the retention basin area flowed through this area towards the river. A collection ditch system within this area is addressed as the separate 100-K-57 site.	Cs-137, Co-60, Eu-152, Eu-154, Sr-90, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-66	Control Structure	100-KR-2	2,520 m^2 (27,100 ft^2)	This site is associated with the 165-KW Filter Building. The facility is outside the scope of waste site definitions, and demolition and removal are planned to be performed as a removal action associated with the facility code.	N/A	Rejected	WSRF 2015-086	N/A	N/A	N/A	N/A
100-K-67	Control Structure	100-KR-2	2,580 m^2 (27,800 ft^2)	This site is associated with the 165-KE Filter Building. The facility is outside the scope of waste site definitions, and demolition and removal are planned to be performed as a removal action associated with the facility code.	N/A	Rejected	WSRF 2015-087	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-68	Catch Tank	100-KR-2	5 m^2 (54 ft^2)	This site was a below-grade catch tank that received overflow from the 105-KE Reactor fuel storage basin and diverted it to the 116-KE-3 crib. The tank and surrounding soil were excavated and removed under interim remedial actions in conjunction with collocated sites on the northwestern side of the 105-KE Reactor.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Am-241, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238	Interim Closed Out	WSRF 2012-090; DOE/RL-2012-46	April 2010	May 2012	11,920 metric tons (13,139 tons) total from the 100-K-68, 100-K-69, and 100-K-70 waste sites	12 m (39 ft)
100-K-69	Sump	100-KR-2	3.2 m^2 (35 ft^2)	This site was a below-grade concrete sump that received water from the 105-KE Reactor fuel storage basin floor drains. The sump and surrounding soil were excavated and removed under interim remedial actions in conjunction with collocated sites on the northwestern side of the 105-KE Reactor.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Am-241, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238	Interim Closed Out	WSRF 2012-091; DOE/RL-2012-46	April 2010	May 2012	11,920 metric tons (13,139 tons) total from the 100-K-68, 100-K-69, and 100-K-70 waste sites	12 m (39 ft)
100-K-70	Storage Tank	100-KR-2	35 m^2 (375 ft^2)	This site was an at-grade storage tank covered by an earthen berm, installed to receive wastewater from the 105-KE Reactor fuel storage basin. The tank was removed during demolition of the fuel storage basin and underlying soil was excavated and removed under interim remedial actions in conjunction with collocated sites on the northwestern side of the reactor.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Am-241, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238	Interim Closed Out	WSRF 2012-092; DOE/RL-2012-46	April 2010	May 2012	11,920 metric tons (13,139 tons) total from the 100-K-68, 100-K-69, and 100-K-70 waste sites	12 m (39 ft)
100-K-71	Diversion Box	100-KR-2	11 m^2 (120 ft^2)	This site was a below-grade concrete collection box for the process sewer system at the 105-KE Reactor fuel storage basin. The box and surrounding soil were excavated and removed under interim remedial actions in conjunction with collocated sites on the northwestern side of the 105-KE Reactor.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Am-241, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, Sr-90, U-233/234, U-235, and U-238	Interim Closed Out	WSRF 2012-093; DOE/RL-2012-46	March 2010	May 2012	5,868 metric tons (6,457 tons)	12 m (39 ft)
100-K-72	Catch Tank	100-KR-2	5 m^2 (54 ft^2)	This site is a below-grade catch tank that received overflow from the 105-KW Reactor fuel storage basin and diverted it to the 116-KW-2 crib.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-73	Diversion Box	100-KR-2	11 m^2 (120 ft^2)	This site is a below-grade concrete collection box for the process sewer lines at the 105-KW Reactor.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-74	Storage Tank	100-KR-2	35 m^2 (375 ft^2)	This site is an at-grade storage tank covered by an earthen berm, installed to receive wastewater from the 105-KW Reactor fuel storage basin.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-75	Sump	100-KR-2	3.2 m^2 (35 ft^2)	This site is a below-grade concrete sump that received water from the 105-KW Reactor fuel storage basin floor drains.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-76	Unplanned Release	None	Not documented	This site is a duplicate entry for the 130-KW-1 site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
100-K-77	Dumping Area	100-KR-2	9.4 m^2 (101 ft^2)	This site was the location of a small pit with timber sidewalls and bracing; railroad ties were present at the bottom of the pit. The purpose or use of the feature is not known. The location was temporarily backfilled; debris and soil were later excavated and removed under interim remedial actions.	Cs-137, Co-60, Eu-152, Eu-154, Eu-155, As, Cr, Cr(VI), Cu, Pb, Zn, PAHs, phenol, and cresols	Interim Closed Out	WSRF 2011-098; DOE/RL-2011-105	June 2011	July 2011	4,219 metric tons (4,651 tons)	3 m (10 ft)
100-K-78	Unplanned Release	100-KR-1	250 m^2 (2,700 ft^2)	This site addresses a legacy radiological posting near the 116-K-1 Crib. The origin of the posting is not known, but may have been related to identification of contamination from releases at the 116-K-1 Crib or 116-K-2 Trench or an earlier remediation or drilling work control posting that was inadvertently not downposted. Surveys and confirmatory soil sampling did not identify any significant contamination present.	C-14, Cs-137, Co-60, Eu-152, Ni-63, Sr-90, and Cr(VI)	Interim No Action	WSRF 2011-004	N/A	N/A	N/A	N/A
100-K-79:1	Product Piping	100-KR-2	Not documented	This site addresses the sodium dichromate product pipelines near the 183.1-KW Water Treatment Plant Headhouse. These lines were used to transfer sodium dichromate from the railroad offloading area to storage tanks and from the storage tanks to the headhouse. The pipelines and underlying soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Cr and Cr(VI)	Interim Closed Out	WSRF 2012-019; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)
100-K-79:2	Product Piping	100-KR-2	Not documented	This site addresses the sulfuric acid product pipelines near the 183.1-KW Water Treatment Plant Headhouse. These lines were used to transfer sulfuric from the railroad offloading area to storage tanks and from the storage tanks to the headhouse. The pipelines and underlying soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Pb and Hg	Interim Closed Out	WSRF 2012-019; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)

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Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-79:3	Product Piping	100-KR-2	Not documented	This site addresses the sodium dichromate product pipelines near the 183.1-KE Water Treatment Plant Headhouse. These lines were used to transfer sodium dichromate from the railroad offloading area to storage tanks and from the storage tanks to the headhouse.	Cr and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-79:4	Product Piping	100-KR-2	Not documented	This site addresses the sulfuric acid product pipelines near the 183.1-KE Water Treatment Plant Headhouse. These lines were used to transfer sulfuric from the railroad offloading area to storage tanks and from the storage tanks to the headhouse.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-79:5	Product Piping	100-KR-2	Not documented	This site addresses the conditioned water pipelines between the 165-KW Powerhouse and 105-KW Reactor.	Cr and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-79:6	Product Piping	100-KR-2	Not documented	This site addresses the conditioned water pipelines between the 165-KE Powerhouse and 105-KE Reactor.	Cr and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-79:7	Product Piping	100-KR-2	Not documented	This site addresses the conditioned water cross-tie lines between the 105-KE and 105-KW Reactors. A portion of the pipelines in this site were excavated and removed with collocated sites on the southwestern side of the 105-KE Reactor under interim remedial actions.	Cr and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-79:8	Product Piping	100-KR-2	Not documented	This site addresses the cross-tie line between the 183.4-KE and 183.4-KW Water Treatment Plant Clearwells.	Cr and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-79:9	Product Piping	100-KR-2	Not documented	This site addresses a segment of a conditioned water cross-tie line between the 105-KE and 105-KW Reactors.	Cr and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-80	Radioactive Process Sewer	100-KR-1	161 m (528 ft) pipeline length	This site addresses a portion of one of the outfall pipelines extending from the 1904-K Outfall structure to the Columbia River. These pipelines were used as the primary discharge for cooling water effluent and other liquid waste streams from the process sewer collection system.	Cs-137, Eu-152, and Sr-90	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-81	Unplanned Release	100-KR-1	29 m^2 (311 ft^2)	This site addresses a large metallic cylinder staged by the 1904-K Outfall, including an associated soil contamination area. The cylinder was formerly used as a plug within the outfall structure.	Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A

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Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-82	Unplanned Release	100-KR-2	Not documented	This site addresses contaminated vadose zone soil resulting from contaminated water leakage beneath the 105-KW Reactor fuel storage basin. The volume of water leaked is unknown.	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-83	Outfall	100-KR-1	680 m^2 (7,300 ft^2)	This site is the former emergency overflow spillway for the 1904-K Outfall, designed to provide an alternate discharge channel if effluent could not be completely discharged through the river effluent pipelines. The spillway is a concrete flume extending from the outfall structure, transitioning to an earthen channel. The concrete flume and a portion of the earthen channel were covered with soil to grade level sometime after the end of operations.	Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-84	Unplanned Release	100-KR-2	1,170 m^2 (12,560 ft^2)	This site consisted of five areas of red-stained soil near the 118-K-1 Burial Ground. Affected soil was excavated and removed under interim remedial actions.	Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, and Zn	Interim Closed Out	WSRF 2013-058	November 2012	March 2013	4,156 metric tons (4,582 tons)	0.9 m (3 ft)
100-K-85	Trench	100-KR-2	595 m^2 (6,410 ft^2)	This site was a large pit near temporary construction facilities. The use of the pit is unknown, and it was backfilled at an unknown date. Confirmatory excavation within the footprint did not identify any anomalous materials, and constituents detected in soil samples from the site were below background levels.	N/A	Interim No Action	WSRF 2011-013	N/A	N/A	N/A	N/A
100-K-86	Unplanned Release	100-KR-2	258 m^2 (2,770 ft^2)	This site was four small areas of debris and associated soil-staining located outside of the 100-K fence. Soil and debris were excavated and removed under interim remedial actions	Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, PAHs, PCBs, and TPH	Interim Closed Out	WSRF 2013-059	November 2012	January 2013	527 metric tons (581 tons)	1.5 m (5 ft)
100-K-87	Unplanned Release	100-KR-2	N/A	This site was an area of suspect asbestos-containing pipe lagging material disposed at the surface. Debris and underlying soil were excavated and removed under interim remedial actions.	N/A	Interim Closed Out	WSRF 2013-060	February 2013	April 2013	111 metric tons (122 tons)	0.9 m (3 ft)
100-K-88	Unplanned Release	100-KR-2	20 m^2 (220 ft^2)	This site is an area of bare soil with scattered yellow and white granular material, located outside of the 100-K Area fence. Confirmatory sampling of the site demonstrated that no interim remedial action was required.	Sb, As, Ba, Be, Cd, Cr, Cr(VI), Co, Cu, Pb, Hg, Ni, Se, Ag, V, Zn, and PCBs	Interim No Action	WSRF 2010-099	N/A	N/A	N/A	N/A

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Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-89	Burn Pit	100-KR-2	92 m^2 (990 ft^2)	This site was a surface-level burning area for construction-type debris associated with the former 100-K construction camp and laydown area. Burned material and underlying soil was excavated and removed in conjunction with interim remedial actions at the adjacent 600-29 waste site.	PAHs and TPH	Interim Closed Out	WSRF 2012-052	September 2011	April 2012	16,800 metric tons (18,500 tons) total from both the 600-29 and 100-K-89 waste sites	Not documented
100-K-90	Unplanned Release	100-KR-2	3 m^2 (30 ft^2)	This site is an area of with scattered white granular material visible at the surface, located outside of the 100-K Area fence. Confirmatory sampling of the site demonstrated that no interim remedial action was required.	Sb, As, Ba, Be, Cd, Cr, Cr(VI), Co, Cu, Pb, Hg, Ni, Se, Ag, V, and Zn	Interim No Action	WSRF 2010-100	N/A	N/A	N/A	N/A
100-K-91	Unplanned Release	100-KR-2	N/A	This site was a single vehicle battery outside of the fence that was likely the result of random littering. The battery and underlying soil was excavated and removed under interim remedial actions.	Cd, Cr, Cu, Pb, and Ni	Interim Closed Out	WSRF 2013-061	November 2012	November 2012	<1 metric ton (<1 ton)	1.2 m (4 ft)
100-K-92	Unplanned Release	100-KR-2	5.8 m^2 (62 ft^2)	This site was two areas of red-hued crusted soil outside of the fence. Impacted soil was excavated and removed under interim remedial actions	Sb, As, Cd, Cr, Cr(VI), Cu, Pb, Hg, Ni, Zn, PCBs, SVOCs, and TPH	Interim Closed Out	WSRF 2013-062	November 2012	December 2012	49 metric tons (54 tons)	0.6 m (2 ft)
100-K-93	Unplanned Release	None	1.6 m^2 (17 ft^2)	This site was a small quantity of solidified gray/black tar-like substance next to a remnant of a 208-L (55-gal) drum in the 100-K floodplain area. The drum, tar substance, and immediately underlying soil were excavated by hand and removed under interim remedial actions. The 100-K-93 site footprint was then consolidated into the surrounding 100-K-111 site.	N/A	Consolidated	WSRF 2013-063	November 2012	November 2012	Not documented	0.2 m (0.5 ft)
100-K-94	French Drain	100-KR-1	Two 0.8-m (30-in.) diameter drywells	This site consists of two separate french drains: one associated with the 1702-KE Guardhouse, and one associated with the 1702-KW Guardhouse. These drains received effluent from drinking water fountains at the guardhouses, but are located within an underground radiological material area.	Cs-137, Eu-152, and Sr-90	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-95	Unplanned Release	100-KR-2	15,040 m^2 (161,900 ft^2)	This site was an area of scattered residual tar, likely related to historic construction activities. Impacted soil was excavated and removed under interim remedial actions.	PAHs and TPH	Interim Closed Out	WSRF 2013-064	January 2013	June 2013	6,200 metric tons (6,835 tons)	1.5 m (5 ft)

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100-K-96	Radioactive Process Sewer	100-KR-1	286 m (940 ft) pipeline length	This site addresses a portion of one of the outfall pipelines extending from the 1904-K Outfall structure to the Columbia River. These pipelines were used as the primary discharge for cooling water effluent and other liquid waste streams from the process sewer collection system.	Cs-137, Eu-152, Sr-90	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-97	French Drain	100-KR-2	0.2 m^2 (2 ft^2)	This site was a french drain that received collected drainage from sodium dichromate unloading near the 183.1-KW Water Treatment Plant Headhouse. The drain and underlying soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2012-020; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)
100-K-98	French Drain	100-KR-2	0.2 m^2 (2 ft^2)	This site is a french drain that received collected drainage from sodium dichromate and sulfuric acid unloading near the 183.1-KE Water Treatment Plant Headhouse.	Cr(VI), Pb, and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-99	Unplanned Release	100-KR-2	3,450 m^2 (37,200 ft^2)	This site addresses an area of potential soil contamination on the southern side of the former 107-KE Retention Basins.	Cs-137, Co-60, Sr-90, Eu-152, and Eu-154	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-100	Unplanned Release	100-KR-2	3,600 m^2 (38,700 ft^2)	This site was identified as an analog of the 100-K-99 waste site to address an area of potential soil contamination on the southern side of the former 107-KE Retention Basins. No contaminated material was identified in this area.	N/A	Rejected	WSRF 2017-017	N/A	N/A	N/A	N/A
100-K-101	French Drain	100-KR-2	9,200 m^2 (99,100 ft^2)	This site consists of french drains and sulfate-stained soils along the southern side of the former 183.2-KE Water Treatment Plant Flocculation Basins. Confirmatory soil sampling of the soils identified mercury contamination.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-102	French Drain	100-KR-2	8,900 m^2 (95,700 ft^2)	This site consists of french drains and sulfate-stained soils along the southern side of the former 183.2-KW Water Treatment Plant Flocculation Basins. The drains, piping, and surrounding soil were excavated and removed under interim remedial actions in conjunction with collocated sites near the 183.1-KW Headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2012-023; DOE/RL-2012-28	April 2010	January 2012	31,750 metric tons (35,000 tons) total from the 100-K-34, 100-K-102, and 1607-K3 waste sites	9.8 m (32.2 ft)
100-K-103	Settling Tank	100-KR-2	4,700 m^2 (50,600 ft^2)	This site addresses components of the 1607-K4 septic system that were not included in the 1607-K4 waste site.	NO_3^- and PAHs	Accepted	N/A	N/A	N/A	N/A	N/A

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100-K-104	French Drain	100-KR-2	13 m^2 (140 ft^2)	This site is a french drain that received sump drainage from the 166-KE Oil Storage Tank pump room (130-KE-2 waste site).	PAHs, PCBs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-105	Depression/Pit (nonspecific)	100-KR-2	117 m^2 (1,260 ft^2)	This site was a pit identified in the southeastern corner of the 100-K Area on a 1955 aerial photograph. The purpose or use of this pit is not known, and the area appears to have been backfilled in later photographs from the operational era. Confirmatory excavation within the footprint did not identify any anomalous materials, and no interim remedial action was warranted based on soil samples collected.	N/A	Interim No Action	WSRF 2016-013	N/A	N/A	N/A	N/A
100-K-106	Crib	100-KR-2	37 m^2 (400 ft^2)	This site was a shallow crib for floor drainage at the 182-K Emergency Water Pump House. The crib and underlying soil were excavated and removed in conjunction with demolition and removal of below-grade portions of the pump house.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, SO_4^{2-}, ethylene glycol, and TPH	Interim Closed Out	WSRF 2012-121; DOE/RL-2012-50	March 2012	June 2012	7,324 metric tons (8,073 tons)	Not documented
100-K-107	Drain/Tile Field	100-KR-2	140 m^2 (1,500 ft^2)	This site addresses a suspected location of an abandoned drain field for the 1706-KER Recirculation Test Facility. This drain field potentially received sanitary waste and floor drainage from the facility. A portion of the site may have been removed by earlier interim remedial actions in the vicinity.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Sr-90, NO_3^-, and PAHs	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-108	Septic Tank	100-KR-2	Not documented	This site is a septic tank, leaching crib, and associated sewer piping that received sanitary waste and floor drainage from the 1706-KER Recirculation Test Facility.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Sr-90, NO_3^-, and PAHs	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-109	Unplanned Release	100-KR-2	1,040 m^2 (11,200 ft^2)	This site was identified to address an area of soil affected by spills and releases during railcar unloading at the 183.1-KW Water Treatment Plant Headhouse. Chemical handling in this area included sodium dichromate, sulfuric acid, alum, chlorine, sodium silicate, and sodium chloride. Contaminated soil was excavated and removed in conjunction with remediation of other waste sites near the headhouse under interim remedial actions.	Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2011-112; DOE/RL-2011-114	August 2010	September 2011	7,189 metric tons (7,925 tons)	7.8 m (25.7 ft)

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-110	Unplanned Release	100-KR-2	32,700 m^2 (352,400 ft^2)	This site is the footprint of the former 183.2-KW Flocculation and Sedimentation Basins, 183.3-KW Sand Filter Basins, and 183.7-KW Pipe Tunnel. The facilities were demolished between 2009 and 2010. Based on sample results for underlying soil, no remediation was warranted under interim remedial actions.	Cd, Cr, Cr(VI), Pb, Hg, Se, V, and SO_4^{2-}	Interim No Action	WSRF 2017-008	N/A	N/A	N/A	N/A
100-K-111	Contamination Migration	100-KR-1	Not documented	This site addresses an area of the floodplain that may have been impacted by effluent from the 116-K-2 Trench.	Cs-137, Co-60, Eu-152, Eu-154, Sr-90, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-112	Unplanned Release	None	83 m^2 (890 ft^2)	This site addressed a contaminated area posting established within a radioactive material area when soil contamination was identified and could not be promptly removed. Surface soil was later excavated and the contaminated area posting was removed.	N/A	Rejected	WSRF 2012-118	N/A	N/A	N/A	N/A
100-K-113	Radioactive Process Sewer	100-KR-1	249 m (817 ft) pipeline length	This site addresses a portion of one of the outfall pipelines extending from the 1904-K Outfall structure to the Columbia River. These pipelines were used as the primary discharge for cooling water effluent and other liquid waste streams from the process sewer collection system.	Cs-137, Eu-152, and Sr-90	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-114	Radioactive Process Sewer	100-KR-1	249 m (817 ft) pipeline length	This site addresses a portion of one of the outfall pipelines extending from the 1904-K Outfall structure to the Columbia River. These pipelines were used as the primary discharge for cooling water effluent and other liquid waste streams from the process sewer collection system.	Cs-137, Eu-152, and Sr-90	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-115	Dumping Area	100-KR-2	1,040 m^2 (11,200 ft^2)	This site addresses potential residual asbestos-containing material following demolition of the 1717-K Maintenance Shop.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-116	Dumping Area	100-KR-2	700 m^2 (7,500 ft^2)	This site addresses potential residual asbestos-containing material following demolition of the 1720-K Patrol House.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-117	Foundation	None	330 m^2 (3,550 ft^2)	This site addresses the footprint of the 183-KW Chlorine Vault. No potential hazardous soil contamination is associated with this feature.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A

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Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
100-K-118	Foundation	100-KR-2	Not documented	This site was identified to address potential residual asbestos-containing material following demolition of the 183.1-KW Water Treatment Plant Headhouse. No suspect asbestos-containing or other hazardous material was identified in a subsequent site field inspection.	N/A	Rejected	WSRF 2016-009	N/A	N/A	N/A	N/A
100-K-119	Dumping Area	100-KR-2	7,640 m^2 (82,260 ft^2)	This site addresses potential residual asbestos-containing material following demolition of the 182-K Reservoir and headhouse.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-120	Dumping Area	100-KR-2	104 m^2 (1,110 ft^2)	This site addresses potential residual asbestos-containing material following demolition of the 110-KW Gas Storage Facility.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-121	Dumping Area	100-KR-2	Not documented	This site was identified to address potential residual asbestos-containing material following demolition of the 115-KE Gas Recirculation Building. No suspect asbestos-containing material was identified in a subsequent site field inspection.	N/A	Rejected	WSRF 2016-010	N/A	N/A	N/A	N/A
100-K-122	Dumping Area	100-KR-2	Not documented	This site was identified to address potential residual asbestos-containing material following demolition of the 1706-KE, 1706-KEL, and 1706-KER facilities. No suspect asbestos-containing material was identified in a subsequent site field inspection.	N/A	Rejected	WSRF 2016-011	N/A	N/A	N/A	N/A
100-K-123	Dumping Area	100-KR-2	Not documented	This site was identified to address potential residual asbestos-containing material following demolition of the 183.1-KE Water Treatment Plant Headhouse.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-124	Dumping Area	100-KR-2	80 m^2 (860 ft^2)	This site was identified to address potential residual asbestos-containing material following demolition of the 183.5-KE Water Treatment Plant Lime Feeder.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-125	Dumping Area	100-KR-2	80 m^2 (860 ft^2)	This site was identified to address potential residual asbestos-containing material following demolition of the 183.6-KE Water Treatment Plant Lime Feeder.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A

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100-K-126	Dumping Area	100-KR-2	Not documented	This site was identified to address potential residual asbestos-containing material following demolition of the 183.5-KW Water Treatment Plant Lime Feeder.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-127	Dumping Area	100-KR-2	206 m^2 (2,220 ft^2)	This site was identified to address potential residual asbestos-containing material following demolition of the 183.6-KW Water Treatment Plant Lime Feeder.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-128	Dumping Area	100-KR-2	2,350 m^2 (25,300 ft^2)	This site was identified to address potential residual asbestos-containing material following demolition of the 190-KE Pump House.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-129	Dumping Area	100-KR-2	2,370 m^2 (25,500 ft^2)	This site was identified to address potential residual asbestos-containing material following demolition of the 190-KW Pump House.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-130	Dumping Area	100-KR-2	Not documented	This site was identified to address potential residual asbestos-containing material following demolition of the 181-KE River Pump House. No suspect asbestos-containing material was identified in a subsequent site field inspection.	N/A	Rejected	WSRF 2016-012	N/A	N/A	N/A	N/A
100-K-131	Dumping Area	100-KR-2	15 m^2 (160 ft^2)	This site was identified to address potential residual asbestos-containing material following demolition of the 1908-KE Water Monitoring Station.	N/A	Accepted	N/A	N/A	N/A	N/A	N/A
100-K-132	Unplanned Release	100-KR-2	Not defined	This site was identified to address residual tritium contamination in deep vadose zone soil beneath the former 118-K-1 Burial Ground. Following remediation of the burial ground, test pit characterization beneath the remedial excavations identified elevated tritium contamination in the footprints of the former disposal trenches N and O. Slightly elevated tritium was detected at the base of excavation at the footprint of the former disposal trench K, but was not significantly detected in deeper characterization at that trench.	H-3	Accepted	N/A	N/A	N/A	N/A	N/A

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116-K-1	Crib	100-KR-1	22,800 m^2 (246,000 ft^2)	This site was a large crib intended for disposal of diverted contaminated cooling water. Part of the crib washed out shortly after initial start-up, and repairs were made in the area. The crib was abandoned once the 116-K-2 trench was completed, but continued to receive some contaminated effluent from valve leaks in the sewer piping system. The crib and surrounding soil were excavated and removed under interim remedial actions.	Cs-137, Co-60, Eu-152, Eu-154, Sr-90, Cr, and Cr(VI)	Interim Closed Out	CVP-2003-00024	September 2003	November 2003	101,396 metric tons (111,536 tons)	11 m (36 ft)
116-K-2	Trench	100-KR-1	21,500 m^2 (232,000 ft^2)	This site was a large earthen trench used for disposal of diverted liquid waste from the reactor effluent sewer system, primarily consisting of cooling water contaminated by fuel cladding failures. The trench also received a semi-regular flow of normal process water effluent due to valve leakage in the effluent sewer system. Contaminated soil at the site was excavated and disposed under interim remedial actions.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Ni-63, Pu-239/240, Sr-90, and Cr(VI)	Interim Closed Out	CVP-2006-00001	February 2004	October 2005	410,000 metric tons (451,900 tons)	7.6 m (25 ft)
116-K-3	Outfall	100-KR-1	110 m^2 (1,170 ft^2)	This site is the 1904-K Outfall Structure. This structure was designed to channel effluent from the river outfall pipelines to an emergency spillway if necessary.	Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
116-KE-1	Crib	100-KR-2	28 m^2 (300 ft^2)	This site was a crib for the 115-KE Gas Recirculation Facility, and primarily received condensate from the reactor gas purification system. The crib and associated sewer pipeline were excavated and removed in 2004 under interim remedial actions, but residual contamination in underlying soil did not achieve cleanup criteria. Additional soil was excavated and removed in conjunction with remediation of collocated waste sites on the eastern side of the 105-KE Reactor. Elevated residual radionuclide contamination, particularly carbon-14, was detected at the base of remediation in the footprint of the former crib, but additional remediation could not be performed at the time due to the proximity of the reactor building.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Sr-90, H-3 and NO_3^-	Accepted	N/A	N/A	N/A	N/A	N/A

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116-KE-2	Crib	100-KR-2	9 m^2 (100 ft^2) crib; 114 m (376 ft) sewer pipeline run length	This site is a former crib for the 1706-KER Recirculation Test Facility, used for disposal of contaminated cooling water and resin. A portion of the influent sewers to the crib were removed in 2009 during demolition of the 1706-KER facility and remediation of collocated waste sites on the southwestern side of the 105-KE Reactor.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Sr-90, and H-3	Accepted	N/A	N/A	N/A	N/A	N/A
116-KE-3	Injection/Reverse Well	100-KR-2	160 m^2 (1,720 ft^2)	This site was a crib and reverse well formerly used for disposal of sub-basin drainage effluent from the 105-KE Reactor fuel storage basin. The crib consisted of a drainfield over a gravel bed; the reverse well was located within the crib, extending from the drainfield to below the water table. The crib and a portion of the reverse well were excavated and removed under interim remedial actions; additional remediation was not performed due to the proximity of the 105-KE Reactor.	Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, H-3, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
116-KE-4	Retention Basin	100-KR-1	34,900 m^2 (375,600 ft^2)	This site was the 107-KE Retention Basins. Three open-topped steel tanks were used for temporary holding of process water effluent from the 105-KE Reactor to allow for thermal cooling and decay of short-lived radionuclides. Water was then routed to the river outfall pipeline system, the 116-K-1 Crib, or the 116-K-2 Trench. The walls of the tanks were removed in 1995. The remaining foundations and surrounding contaminated soil were excavated and removed as part of interim remedial actions.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239/240, Sr-90, U-233/234	Interim Closed Out	CVP-2005-00002	October 2003	March 2005	167,634 metric tons (184,785 tons)	4.3 m (14.1 ft)
116-KE-5	Process Unit/Plant	100-KR-2	1,470 m^2 (15,800 ft^2)	This site was the former 150-KE Heat Recovery Station. This was a system of heat exchangers and pumps that used an ethylene glycol solution to transfer heat from the reactor effluent sewers to the 165-KE Powerhouse. After the end of operations, components from the system were salvaged and used in other facilities. Remaining components and underlying soil were excavated and removed with collocated portions of the 100-K-56 effluent sewers under interim remedial actions.	As, Ba, Cd, Cr, Cr(VI), Pb, Hg, and ethylene glycol	Interim Closed Out	CVP-2005-00006	December 2002	April 2005	86,551 metric tons (95,406 tons) total from the 100-K-55:1, 100-K-56:1, 116-KE-5, and 116-KW-4 sites	3 m (10 ft)

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116-KE-6A	Storage Tank	100-KR-2	N/A	This site was a 363-L (96-gal) condensate collection tank within the 1706-KER Recirculation Test Facility. This tank was also a component of the 1706-KE Waste Treatment System TSD unit, used in 1986 and 1987 to treat mixed waste from the laboratories in the 1706-KE and 1706-KER facilities. The tank was removed and disposed in 2009 under a combined corrective action and remedial action. The 1706-KE and 1706-KER facilities were subsequently demolished as part of removal actions.	N/A	Interim Closed Out	WSRF 2010-029; DOE/RL-2010-42	June 2009	July 2009	Not documented	N/A
116-KE-6B	Storage Tank	100-KR-2	N/A	This site was a 114-L (30-gal) evaporation tank within the 1706-KER Recirculation Test Facility. This tank was also a component of the 1706-KE Waste Treatment System TSD unit, used in 1986 and 1987 to treat mixed waste from the laboratories in the 1706-KE and 1706-KER facilities. The tank was removed and disposed in 2009 under a combined corrective action and remedial action. The 1706-KE and 1706-KER facilities were subsequently demolished as part of removal actions.	N/A	Interim Closed Out	WSRF 2010-030; DOE/RL-2010-42	June 2009	July 2009	Not documented	N/A
116-KE-6C	Storage Tank	100-KR-2	N/A	This site was a 2,082-L (550-gal) waste accumulation tank within the 1706-KER Recirculation Test Facility. This tank was also a component of the 1706-KE Waste Treatment System TSD unit, used in 1986 and 1987 to treat mixed waste from the laboratories in the 1706-KE and 1706-KER facilities. The tank was removed and disposed in 2009 under a combined corrective action and remedial action. The 1706-KE and 1706-KER facilities were subsequently demolished as part of removal actions.	N/A	Interim Closed Out	WSRF 2010-031; DOE/RL-2010-42	June 2009	July 2009	Not documented	N/A

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116-KE-6D	Process Unit/Plant	100-KR-2	N/A	This site was an ion exchange column within the 1706-KER Recirculation Test Facility. This column was also a component of the 1706-KE Waste Treatment System TSD unit, used in 1986 and 1987 to treat mixed waste from the laboratories in the 1706-KE and 1706-KER facilities. The column was removed and disposed from 1994 to 1996; other components of the waste treatment system were removed and disposed under a combined corrective action and remedial action in 2009. The 1706-KE and 1706-KER facilities were subsequently demolished as part of removal actions.	N/A	Interim Closed Out	WSRF 2010-032; DOE/RL-2010-42	N/A	N/A	N/A	N/A
116-KW-1	Crib	100-KR-2	28 m^2 (300 ft^2)	This site was a crib for the 115-KW Gas Recirculation Facility, and primarily received condensate from the reactor gas purification system. The crib and associated sewer pipeline were excavated and removed in 2004 under interim remedial actions, but residual contamination, particularly carbon-14, in underlying soil did not achieve cleanup criteria. Additional remediation could not be performed at the time due to the proximity of the reactor building.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Sr-90, H-3 and NO_3^-	Accepted	N/A	N/A	N/A	N/A	N/A
116-KW-2	Injection/Reverse Well	100-KR-2	160 m^2 (1,720 ft^2)	This site is a crib and reverse well formerly used for disposal of sub-basin drainage effluent from the 105-KW Reactor fuel storage basin. The crib consists of a drainfield over a gravel bed; the reverse well is located within the crib, extending from the drainfield to below the water table.	Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, H-3, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
116-KW-3	Retention Basin	100-KR-1	34,400 m^2 (370,500 ft^2)	This site was the 107-KW Retention Basins. Three open-topped steel tanks were used for temporary holding of process water effluent from the 105-KW Reactor to allow for thermal cooling and decay of short-lived radionuclides. Water was then routed to the river outfall pipeline system, the 116-K-1 Crib, or the 116-K-2 Trench. The walls of the tanks were removed in 1994 and 1995. The remaining foundations and surrounding contaminated soil were excavated and removed as part of interim remedial actions.	Cs-137, Co-60, Eu-152, Eu-154, Pu-239/240, Sr-90, U-233/234, U-235, Cr(VI)	Interim Closed Out	CVP-2004-00001	December 2002	October 2003	169,893 metric tons (167,209 tons)	6.1 m (20 ft)

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116-KW-4	Process Unit/Plant	100-KR-2	1,470 m^2 (15,800 ft^2)	This site was the former 150-KW Heat Recovery Station. This was a system of heat exchangers and pumps that used an ethylene glycol solution to transfer heat from the reactor effluent sewers to the 165-KW Powerhouse. After the end of operations, components from the system were salvaged and used in other facilities. Remaining components and underlying soil were excavated and removed with collocated portions of the 100-K-55 effluent sewers under interim remedial actions.	As, Ba, Cd, Cr, Cr(VI), Pb, Hg, and ethylene glycol	Interim Closed Out	CVP-2005-00006	December 2002	April 2005	86,551 metric tons (95,406 tons) total from the 100-K-55:1, 100-K-56:1, 116-KE-5, and 116-KW-4 sites	3 m (10 ft)
118-K-1	Burial Ground	100-KR-2	33,300 m^2 (358,000 ft^2)	This site was the primary burial ground for radioactive solid waste at the 100-K Area, and received waste from the 100-N Area. The burial ground consisted of multiple disposal trenches, pits, and silos. Debris and contaminated soil was excavated and removed from the site under interim remedial actions.	Am-241, C-14, Co-60, Cm-244, Cs-137, Eu-152, Eu-154, H-3, Ni-63, Pu-238, Pu-239/240, Sr-90, Tc-99, U-235, U-238, Sb, Cd, Pb, Hg, anions, SVOCs, VOCs, pesticides, TPH, and PCBs	Interim Closed Out	CVP-2013-00002	May 2006	March 2012	268,600 metric tons (296,100 tons)	15.6 m (51 ft)
118-KE-1	Reactor	100-KR-2	3,270 m^2 (35,200 ft^2)	This site is the 105-KE Reactor Building structure, excluding the fuel storage basin. This site does not include any contaminated soil.	N/A	Rejected	WSRF 2015-011	N/A	N/A	N/A	N/A
118-KE-2	Storage	100-KR-2	176 m^2 (1,900 ft^2)	This site was a concrete and earthen bunker used to store horizontal control rods from the 105-KE Reactor pending further dispositioning. The feature was demolished and removed under interim remedial actions.	Cs-137, Sr-90, Pu-239/240	Interim Closed Out	WSRF 2010-042; DOE/RL-2010-50	September 2009	September 2009	Not documented	Surface
118-KW-1	Reactor	100-KR-2	3,270 m^2 (35,200 ft^2)	This site is the 105-KW Reactor Building structure, excluding the fuel storage basin. This site does not include any contaminated soil.	N/A	Rejected	WSRF 2015-012	N/A	N/A	N/A	N/A
118-KW-2	Storage	100-KR-2	183 m^2 (1,970 ft^2)	This site was a concrete and earthen bunker used to store horizontal control rods from the 105-KW Reactor pending further dispositioning. The feature was demolished and removed under interim remedial actions.	Cs-137, Sr-90, Pu-239/240	Interim Closed Out	WSRF 2011-026; DOE/RL-2011-35	November 2010	November 2010	Not documented	Surface
120-KE-1	Sump	100-KR-2	4.8 m^2 (52 ft^2)	This site is an acid neutralization pit at the 183.1-KW Water Treatment Plant Headhouse	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KE-2	French Drain	100-KR-2	0.9-m (3-ft) diameter	This site is a french drain that received waste acid and sludge from the sulfuric acid tanks near the 183.1-KE Water Treatment Plant Headhouse.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A

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120-KE-3	Trench	100-KR-2	67 m^2 (720 ft^2)	This site is a sand-lined trench that received sludge-water slurries from the sulfuric acid tanks near the 183.1-KE Water Treatment Plant Headhouse.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KE-4	Storage Tank	100-KR-2	15 m^2 (165 ft^2)	This site is a sulfuric acid storage tank near the 183.1-KE Water Treatment Plant Headhouse. After operations, the tank was taken out of service and the contents were drained and neutralized.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KE-5	Storage Tank	100-KR-2	17 m^2 (189 ft^2)	This site is a sulfuric acid storage tank near the 183.1-KE Water Treatment Plant Headhouse. After operations, the tank was taken out of service and the contents were drained and neutralized.	Pb and Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KE-6	Foundation	100-KR-2	30 m^2 (330 ft^2)	This site addresses the footprint of a former above-grade sodium dichromate storage tank at the 183.1-KE Water Treatment Plant Headhouse.	Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A
120-KE-8	Sump	100-KR-2	33 m^2 (350 ft^2)	This site is a below-grade brine mixing pit for the 165-KE Powerhouse. The brine was used for water softener regeneration.	Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KE-9	Sump	100-KR-2	29 m^2 (310 ft^2)	This site is a below-grade brine mixing pit for the 183-KE Water Treatment Plant. The brine was used for water softener regeneration.	Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KW-1	Sump	100-KR-2	5.0 m^2 (54 ft^2)	This site was an acid neutralization pit at the 183.1-KW Water Treatment Plant Headhouse. The structure and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Cl^-, and SO_4^{2-}	Interim Closed Out	WSRF 2011-108; DOE/RL-2011-113	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	14.2 m (46.6)
120-KW-2	French Drain	100-KR-2	0.9-m (3-ft) diameter	This site was a french drain that received waste acid and sludge from the sulfuric acid tanks near the 183.1-KW Water Treatment Plant Headhouse. The drain and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Cl^-, and SO_4^{2-}	Interim Closed Out	WSRF 2011-109; DOE/RL-2011-113	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	14.2 m (46.6)

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
120-KW-3	Storage Tank	100-KR-2	17 m^2 (186 ft^2)	This site was a sulfuric acid storage tank near the 183.1-KW Water Treatment Plant Headhouse. After operations, the tank was taken out of service and the contents were drained and neutralized. The tank was removed in 2003 or 2004. The remaining foundation pad and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Cl^-, and SO_4^{2-}	Interim Closed Out	WSRF 2011-110; DOE/RL-2011-113	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	14.2 m (46.6)
120-KW-4	Storage Tank	100-KR-2	17 m^2 (186 ft^2)	This site was a sulfuric acid storage tank near the 183.1-KW Water Treatment Plant Headhouse. After operations, the tank was taken out of service and the contents were drained and neutralized. The tank was removed in 2003 or 2004. The remaining foundation pad and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Ba, Cd, Cr, Cr(VI), Cu, Hg, Pb, Se, V, Zn, Cl^-, and SO_4^{2-}	Interim Closed Out	WSRF 2011-111; DOE/RL-2011-113	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	14.2 m (46.6)
120-KW-5	Foundation	100-KR-2	29 m^2 (310 ft^2)	This site was an aboveground sodium dichromate storage tank at the 183.1-KW Water Treatment Plant Headhouse. The tank was emptied and removed in 1971. The foundation and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Cr and Cr(VI)	Interim Closed Out	WSRF 2012-021; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)
120-KW-6	Sump	100-KR-2	14 m^2 (150 ft^2)	This site is a below-grade concrete brine pit that was used as part of water softener regeneration at the 165-KW Powerhouse.	Hg	Accepted	N/A	N/A	N/A	N/A	N/A
120-KW-7	Sump	100-KR-2	29 m^2 (310 ft^2)	This site was the salt dissolving pits and brine pump pit at the 183.1-KW Water Treatment Plant Headhouse, used as part of water softener regeneration. The features and surrounding soil were excavated and removed under interim remedial actions in conjunction with other waste sites near the headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, and SO_4^{2-}	Interim Closed Out	WSRF 2012-022; DOE/RL-2012-27	May 2010	June 2011	64,008 metric tons (70,557 tons) combined from the 100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5, and 120-KW-7 waste sites	11.0 m (36.0 ft)
126-K-1	Inert/ Demolition Landfill	None	11,740 m^2 (126,400 ft^2)	This site is a former gravel borrow pit used during 100-K Area construction in the 1950s. Inert debris materials were placed in a portion of the pit in the 1970s and 1980s.	N/A	Rejected	WSRF-2009-001	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
126-KE-2	Storage Tank	100-KR-2	120 m^2 (1,300 ft^2)	This site was an aboveground alum storage tank. The tank was removed and underlying soil were removed under interim remedial actions in conjunction with other waste sites near the 183.1-KE Water Treatment Plant Headhouse.	Cr, Cr(VI), Hg, Cl^-, NO_3^-, and SO_4^{2-}	Interim Closed Out	WSRF 2017-004; DOE/RL-2017-20	December 2015	December 2015	1,662 metric tons (1,832 tons)	4.6 m (15 ft)
126-KE-3	Storage Tank	None	118 m^2 (1,270 ft^2)	This site was an aboveground alum storage tank at the 183.1-KE Water Treatment Plant Headhouse. The tank has been removed.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
128-K-1	Burn Pit	100-KR-2	12,400 m^2 (133,600 ft^2)	This site was a shallow depression used for surface dumping of miscellaneous non-radioactive debris and burning of combustible non-radioactive wastes. Suspect hazardous debris items were removed and soil and burning residuals were excavated and removed under interim remedial actions.	Pb, PAHs, and TPH	Interim Closed Out	WSRF 2004-042	May 2003	December 2003	146 metric tons (161 tons)	0.5 m (1.6 ft)
128-K-2	Burn Pit	100-KR-2	18,900 m^2 (203,400 ft^2)	This site was a construction dump and burn pit. Soil and debris at the site was excavated and removed under interim remedial actions.	Cr, Cr(VI), Hg, PAHs, SVOCs, PAHs, PCBs, and TPH	Interim Closed Out	WSRF 2012-069	December 2011	May 2012	25,650 metric tons (28,280 tons)	6.5 m (21 ft)
130-K-1	Storage Tank	None	6.3 m^2 (68 ft^2)	This site was the location of an underground gasoline storage tank. The tank was emptied and rinsed in 1971 and was excavated and removed in 1989. Inspection and soil sampling did not indicate any releases to soil occurred.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A
130-K-2	Storage Tank	100-KR-2	2.7 m^2 (29 ft^2)	This site addresses a former underground waste oil storage tank at the 1717-K Maintenance Building. The tank was excavated in 1989 and low concentrations of petroleum hydrocarbons were detected in remaining soil.	PAHs, PCBs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
130-K-3	Storage Tank	None	120 m^2 (1,310 ft^2)	This site addresses two former underground emergency diesel supply tanks for the 182-K Emergency Water Pumphouse. The tanks were pumped and abandoned in approximately 1970 and removed in 1993. Visual inspection and soil sampling did not identify any evidence of a significant release at the site.	N/A	Not Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
130-KE-1	Storage Tank	100-KR-2	Not documented	This site addresses the footprint of two former underground emergency diesel supply tanks for the 105-KE Reactor Building. The tanks were removed in 1992, and no evidence of a significant release to soil was identified. Further excavation and soil removal was later performed at the location during the remediation of other waste sites on the eastern side of the 105-KE Reactor.	TPH	Interim Closed Out	WSRF 2010-040; DOE/RL-2010-45	N/A	N/A	N/A	N/A
130-KE-2	Storage Tank	100-KR-2	1,160 m^2 (12,500 ft^2)	This site addresses the 166-KE Oil Storage Tank. This is an underground concrete bunker formerly used to store fuel oil for the boilers at the 165-KE Powerhouse.	PAHs, PCBs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
130-KW-1	Storage Tank	100-KR-2	Not documented	This site addresses the footprint of two former underground emergency diesel supply tanks for the 105-KW Reactor Building. The tanks were removed in 1992, and radiological contamination was identified on the exterior of the tanks and adjacent soil. No further removal was performed for contaminated soil.	Cs-137, Co-60, Eu-152, Eu-154, Sr-90, PAHs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
130-KW-2	Storage Tank	100-KR-2	1,140 m^2 (12,300 ft^2)	This site addresses the 166-KW Oil Storage Tank. This is an underground concrete bunker formerly used to store fuel oil for the boilers at the 165-KW Powerhouse.	PAHs, PCBs, and TPH	Accepted	N/A	N/A	N/A	N/A	N/A
132-KE-1	Stack	100-KR-2	30 m^2 (320 ft^2)	This site is the 116-KE Reactor Exhaust Stack. The upper portion of the stack was demolished from 1980 to 1981, and the debris placed in the lower portion. The remaining stack and foundation were demolished and removed in 2010 and 2011 under interim remedial actions in conjunction with collocated sites on the eastern side of the 105-KE Reactor.	C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Sr-90, H-3, Cr, Cr(VI), Cu, Pb, Hg, Ni, Zn, Cl^-, NO_3^-, and NO_2^-	Interim Closed Out	WSRF 2012-066; DOE/RL-2012-38	July 2010	September 2011	34,200 metric tons (37,700 tons) total from the 100-K-6, 100-K-46, 100-K-62, and 132-KE-1 waste sites	6.1 m (20 ft)
132-KW-1	Stack	100-KR-2	30 m^2 (320 ft^2)	This site addresses the 116-KW Exhaust Stack. The upper 38 m (125 ft) of the original stack was demolished in 1980 and 1981; debris was placed in the below-grade portion of the stack. Demolition and removal of the remaining features is addressed as the 116-KW facility under a non-time critical removal action decision.	N/A	Rejected	WSRF 2015-088	N/A	N/A	N/A	N/A
1607-K1	Septic Tank	100-KR-2	140 m^2 (1,520 ft^2) septic tank and drainfield area and 76 m (250 ft) influent sewer pipeline run length	This site is a former septic system that serviced the 1701-K Badge House and 1720-K Offices.	NO_3^- and PAHs	Accepted	N/A	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
1607-K2	Septic Tank	100-KR-2	125 m^2 (1,340 ft^2)	This site was an underground septic tank and associated leaching trench for the 183.1-KE Water Treatment Plant Headhouse. The area was excavated and the tank and piping were removed under interim remedial actions in conjunction with other waste sites near the headhouse.	Cr, Cr(VI), Hg, Cl^-, NO_3^-, SO_4^{2-}, PAHs, PCBs, and TPH	Interim Closed Out	WSRF 2017-005; DOE/RL-2017-20	November 2015	December 2015	1,070 metric tons (1,180 tons)	4.6 m (15 ft)
1607-K3	Septic Tank	100-KR-2	370 m^2 (4,020 ft^2)	This site consisted of the former septic system for the 183-KW Water Treatment Plant. The site was excavated and the septic system features were removed under interim remedial actions in conjunction with collocated sites near the 183.1-KW Headhouse.	As, Ba, Cd, Cr, Cr(VI), Cu, Pb, Hg, Se, Ag, V, Zn, Cl^-, NO_3^-, NO_2^-, SO_4^{2-}, PAHs, PCBs, and TPH	Interim Closed Out	WSRF 2012-024; DOE/RL-2012-28	April 2010	January 2012	31,750 metric tons (35,000 tons) total from the 100-K-34, 100-K-102, and 1607-K3 waste sites	9.8 m (32.2 ft)
1607-K4	Septic Tank	100-KR-2	370 m^2 (4,020 ft^2)	This site is a former septic system that serviced the 1704-K Office and 1717-K Maintenance Shop. The tank was abandoned in 1999 in accordance with applicable Washington Administrative Code requirements.	N/A	Closed Out	WSRF 99-103	N/A	N/A	N/A	N/A
1607-K5	Septic Tank	100-KR-2	430 m^2 (4,620 ft^2)	This site is a former septic system that serviced the 105-KE Reactor Building, 115-KE Gas Recirculation Building, 165-KE Powerhouse, and 1706-K Water Treatment Laboratory.	Cs-137, Co-60, Eu-152, Eu-154, NO_3^-, and PAHs	Accepted	N/A	N/A	N/A	N/A	N/A
1607-K6	Septic Tank	100-KR-2	420 m^2 (4,520 ft^2) septic tank and drainfield area and 270 m (890 ft) influent sewer pipeline run length	This site is an active septic system and associated influent sewers servicing the 105-KW Reactor Building, 115-KW Gas Recirculation Building, and 165-KW Powerhouse.	Cs-137, Co-60, Eu-152, Eu-154, NO_3^-, and PAHs	Accepted	N/A	N/A	N/A	N/A	N/A
600-29	Dumping Area	100-KR-2	7.1 km^2 (2.7 mi^2)	This site is the footprint of the former construction camp and laydown area for the 100-K Area. Soil and debris were excavated and removed from portions of the area under interim remedial actions where interim remedial action goals were exceeded.	As, Pb, Ni, V, and TPH	Interim Closed Out	WSRF-2012-051	September 2011	April 2012	16,800 metric tons (18,500 tons) total from both the 600-29 and 100-K-89 waste sites	3 m (10 ft)
600-4	Dumping Area	None	0.25 km^2 (0.1 mi^2)	This site addresses miscellaneous non-hazardous debris around a former military encampment.	N/A	Rejected	WSRF 97-012	N/A	N/A	N/A	N/A
600-55	Dumping Area	None	1,790 m^2 (19,250 ft^2)	This site consists of asphalt paving and miscellaneous non-hazardous debris at the location of a former pre-Hanford general store and post office	N/A	Rejected	WSRF 97-007	N/A	N/A	N/A	N/A

Table E-1. Waste Site Table

Site Code	Site Type	Operable Unit	Lateral Site Dimensions	Site History	Known or Suspected Contaminants	Classification/ Reclassification Status	Waste Site Reclassification Documentation	Interim Remedial Action Start Date	Interim Remedial Action End Date	Contaminated Waste Tonnage to ERDF	Maximum Depth of Remedial Action
UPR-100-K-1	Unplanned Release	100-KR-2	Not documented	This site addresses contaminated vadose zone soil resulting from contaminated water leakage beneath the 105-KE fuel storage basin. The volume of water leaked is unknown but could be as much as 100 million L (26 million gal).	Am-241, Cs-137, Co-60, Eu-152, Eu-154, Pu-238, Pu-239/240, Sr-90, U-233/234, U-238, and Cr(VI)	Accepted	N/A	N/A	N/A	N/A	N/A

Note: Full reference citations are provided in Chapter E2.

Cr(VI) = hexavalent chromium
CVP = cleanup verification package
ERDF = Environmental Restoration Disposal Facility
N/A = not applicable
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound
TPH = total petroleum hydrocarbons
TSD = treatment, storage, and disposal
VOC = volatile organic compound
WSRF = waste site reclassification form

Appendix F

Fate and Transport Modeling Documentation

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Contents

F1 Introduction **F-1**

F2 References **F-4**

Supporting Information

The following supporting information is contained on the removable media.

Environmental Calculations

ECF-100KR1-11-0008, Rev. 1	*Computation of Exposure Point Concentrations for the 100-KR-1 and 100-KR-2 Source Operable Units*
ECF-100KR2-16-0127, Rev. 0	*Evaluation of Strontium-90 Leaching Characteristics from Borehole Sediment Samples Collected at UPR-100-K-1 and 116-KE-3 Crib within the 100-K Area of the Hanford Site*.
ECF-100KR1-17-0087, Rev. 0	*STOMP 1-D Modeling for Determination of Unit-Length Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Unit*
ECF-100KR1-17-0092, Rev. 0	*Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations*
ECF-100KR4-17-0240, Rev. 0	*Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels and Preliminary Remediation Goals Protective of Groundwater and Surface Water*
ECF-HANFORD-12-0023, Rev. 4	*Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*
ECF-HANFORD-15-0019, Rev. 0	*Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models*

Model Package Reports

CP-61711, Rev. 0	*Model Package Report: 100-K Scale-Appropriate Fate and Transport Model, Version 1.0*
SGW-50776, Rev. 3	*Model Package Report: Vadose Zone Model for the River Corridor*

Terms

ECF	environmental calculation file
PRG	preliminary remediation goal
SSL	soil screening level

F1 Introduction

This appendix describes the calculations that are summarized in the remedial investigation Chapter 5 (Contaminant Fate and Transport). Table F-1 is organized by general topic and provides a list and links to the supporting files.

Table F-1. 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units Contaminant Fate and Transport Supporting Information

Environmental Calculations
ECF-100-KR1-11-0008, 2018, *Computation of Exposure Point Concentrations for the 100-KR-1 and 100-KR-2 Source Operable Units*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064816H.
ECF-100KR1-17-0087, 2018, *Determination of Unit-Length Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Units*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064795H.
ECF-100KR1-17-0092, 2018, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064814H.
ECF-100KR2-16-0127, 2016, *Evaluation of Strontium-90 Leaching Characteristics from Borehole Sediment Samples Collected at UPR-100-K-1 and 116-KE-3 Crib within the 100-K Area of the Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0071362H.
ECF-100KR4-17-0240, 2018, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels and Preliminary Remediation Goals Protective of Groundwater and Surface Water*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/pdf.cfm?accession=0064794H.
ECF-200MW1-10-0080, 2010, *200-MW-1 Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2008-38 Decisional Draft*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093646.
ECF-Hanford-11-0165, 2012, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087250.
ECF-HANFORD-12-0023, 2017, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 4, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065283H.
ECF-HANFORD-13-0020, 2015, *Process for Constructing a Three-dimensional Geological Framework Model of the Hanford Site 100 Area*, Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079495H.
ECF-HANFORD-15-0019, 2016, *Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064817H.

Table F-1. 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units Contaminant Fate and Transport Supporting Information

Model Package Reports
CP-61711, Rev. 0, *100-K Scale-Appropriate Fate and Transport Model* Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064797H.
SGW-50776, 2014, *Model Package Report: Vadose Zone Model for the River Corridor*, Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1408280371.
Other
SGW-51818, 2012, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0088667.
DOE/RL-2014-32, 2014, *Hanford Site Groundwater Monitoring Report for 2013*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084842.
DOE/RL-2016-09, 2016, *Hanford Site Groundwater Monitoring Report for 2015*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0075314H.
DOE/RL-2016-67, 2017, *Hanford Site Groundwater Monitoring Report for 2016*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0068229H.
SGW-44022, 2010, *Geohydrologic Data Package in Support of 100-BC-5 Modeling*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1003100446.
SGW-59365, 2016, *Model Package Report: 100-BC Scale-Appropriate Fate and Transport Model*, Version 1.0, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0073923H.

Section 5.4 describes the development of modeling performed to evaluate waste site residual contamination for protection of groundwater and surface water in the future. The key calculation is provided in ECF-100KR1-17-0087, *STOMP 1-D Modeling for Determination of Unit-Length Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-K Source Operable Unit*, which uses the vadose zone flow and transport model described in model package report SGW-50776, *Model Package Report: Vadose Zone Model for the River Corridor*, to determine unit-length soil screening levels (SSLs) and preliminary remediation goals (PRGs) for 100-KR-1 and 100-KR-2 source operable units. Additionally, several environmental calculation files (ECFs) are cited for key information for the SSL and PRG calculations. However, these are not included in the removable media, as they are accessible to public at Hanford Administrative Record website (https://pdw.hanford.gov/arpir/) and at the links listed below. These calculations include the following:

- ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*, Rev. 1. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0086677.

- ECF-HANFORD-12-0023, *Groundwater and Surface Water Cleanup Levels and Distribution Coefficients for Nonradiological and Radiological Analytes in the 100 Areas and 300 Area*, Rev. 4. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065283H.

- ECF-200MW1-10-0080, *200-MW-1 Contaminant Fate and Transport Model to Evaluate Impacts to Groundwater in Support of DOE/RL-2008-38 Decisional Draft*, Rev. 0. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0093646.

Other key supporting information is provided in report SGW-51818, *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone*.

Section 5.5 evaluates the exposure point concentrations for waste sites against the SSL and PRG values in ECF-100KR4-17-0240, *Comparison of 100-KR-1 and 100-KR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels and Preliminary Remediation Goals Protective of Groundwater and Surface Water*. These comparisons require representative dimensions for waste site decision units in the general direction of groundwater flow so that the unit-length values can be scaled to provide evaluation values for each waste site. These dimensions are provided in the supporting calculation ECF-100KR1-17-0092, *Determination of Representative Lineal Dimensions for 100-K Waste Sites for Use in Soil Screening Level and Preliminary Remedial Goal Comparisons to Exposure Point Concentrations*.

Section 5.6 describes the development of modeling performed to evaluate future migration of groundwater contaminants of potential concern in the unconfined aquifer (saturated zone) of the 100-KR-4 Operable Unit under no-action conditions. The basis and development of the scale-appropriate fate and transport model for this purpose is described in model package report CP-61711, *100-K Scale-Appropriate Fate and Transport Model*. The basis of this model relied on key information provided in the following documents.

- ECF-HANFORD-13-0020, *Process for Constructing a Three-dimensional Geological Framework Model of the Hanford Site 100 Area*, provides the geologic framework on which the saturated zone model was developed

- ECF-HANFORD-15-0019, *Hanford Site-Wide Natural Recharge Boundary Condition for Groundwater Models*, provides estimated natural groundwater recharge both spatially and temporally through a Recharge Estimation Tool

- ECF-100KR2-16-0127, *Evaluation of Strontium-90 Leaching Characteristics from Borehole Sediment Samples Collected at UPR-100-K-1 and 116-KE-3 Crib within the 100-K Area of the Hanford Site*, provides a basis for selecting site specific soil:water distribution coefficient for strontium-90

The following documents were cited in Chapter 5 but are not part of deliverables for the remedial investigation. However, these documents are available at the Hanford Administrative Record website (https://pdw.hanford.gov/arpir/) and are included in the references with direct links.

- DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*, provides basis for initial concentrations for the contaminant fate and transport models

- DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*, provides basis for initial concentrations for the contaminant fate and transport models

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Human Health Risk Assessment Supporting Documentation

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Supporting Information

The following information is contained on the removable media.

Environmental Calculations

ECF-100KR1-11-0007. Rev. 1 *Waste Site Evaluation Process for the 100-KR-1 and 100-KR-2 Source Operable Units*

ECF-100KR1-11-0008, Rev. 1 *Computation of Exposure Point Concentrations for the 100-KR-1 and 100-KR-2 Source Operable Units*

ECF-100KR1-11-0009, Rev. 1 *Human Health Risk Evaluation for the 100-KR-1 and 100-KR-2 Source Operable Units*

ECF-100KR4-17-0081, Rev. 0 *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit*

ECF-100KR4-17-0082, Rev. 0 *Well-Specific Tap Water Risk Assessment for the 100-KR-4 Groundwater Operable Unit*

ECF-100KR4-17-0083, Rev. 0 *Native American Risk Assessments for the 100-KR-4 Groundwater Operable Unit*

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Terms

bgs	below ground surface
COPC	contaminant of potential concern
Cr(VI)	hexavalent chromium
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CVP	cleanup verification package
DOE	U.S. Department of Energy
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
FS	feasibility study
HI	hazard index
HQ	hazard quotient
LFI	limited field investigation
MTCA	“Model Toxics Control Act—Cleanup” (WAC 173-340)
OU	operable unit
PRG	preliminary remediation goal
RBSL	risk based screening level
RL	Richland Operations Office
RI	remedial investigation
ROD	record of decision
RSVP	remaining sites verification package
TCE	trichloroethene
USFWS	U.S. Fish and Wildlife Service

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G1 Introduction

This appendix provides additional information that supports the human health risk assessment presented in Chapter 6 of this remedial investigation (RI) report. Section G2 presents a summary of the risk characterization results, which include background concentrations, for each of the exposure scenarios considered for the 100-KR-1 and 100-KR-2 Source operable units (OUs); Tables G-1 through G-30 present the soil risk assessment results. Section G3 presents the risk estimates associated with RI and limited field investigation (LFI) soil data; associated results are presented in Tables G-31 through G-35. Section G4 presents the risk characterization results for waste sites 100-K-57, 100-K-64, 100-K-83, and 100-K-111; associated results are presented in Tables G-36 through G-55.

Tables G-56 through G-221 support the 100-KR-4 Groundwater OU risk assessment. Section G5 presents the risk characterization results of the Native American risk assessment; associated results are presented in Tables G-227 through 237. Tables G-1 through G-237 are found on the accompanying removable media, and Tables G-31, G-222, G-225, G-228, G-231, G-234, and G-237 are also included in this Appendix. The following bullets list the calculations supporting the 100-KR-1, 100-KR-2, and 100-KR-4 OU risk characterization evaluations and include a link to the file:

- ECF-100KR1-11-0007, 2018, *Waste Site Evaluation Process for the 100-KR-1 and 100-KR-2 Source Operable Units*, Rev. 1, Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064783H.
- ECF-100-KR1-11-0008, 2018, *Computation of Exposure Point Concentrations for the 100-KR-1 and 100-KR-2 Source Operable Units*, Rev. 1, Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064782H.
- ECF-100KR1-11-0009, 2018, *Human Health Risk Evaluation for the 100-KR-1 and 100-KR-2 Source Operable Units*, Rev. 1, Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064781H.
- ECF-100KR4-17-0081, 2018, *Calculation of Exposure Point Concentrations for the 100-KR-4 Groundwater Operable Unit*, Rev. 0, Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064780H.
- ECF-100KR4-17-0082, 2018, *Well-Specific Tap Water Risk Assessment for the 100-KR-4 Groundwater Operable Unit*, Rev. 0, Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064779H.
- ECF-100KR4-17-0083, 2018, *Native American Risk Assessments for the 100-KR-4 Groundwater Operable Unit*, Rev. 0, Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0064778H.

G2 Summary of Risk Estimates by Exposure Scenario

This section summarizes the risk estimates for each of the exposure scenarios considered for the 100-K Source OUs. This discussion pertains to all contaminants of potential concern (COPCs), regardless of their exposure point concentrations (EPCs) relative to background concentrations, for each waste site decision unit. The conceptual exposure models for soil and groundwater are shown in Figures G-1 and G-2, respectively.

G2.1 Residential Scenario

Preliminary remediation goals (PRGs) developed for the residential scenario are the numeric values that represent the remedial action objectives presented in DOE/RL-2018-22, *Feasibility Study for the 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*. PRGs are established to help determine the need for waste site remedial action. The results of comparing EPCs to the risk based screening levels (RBSLs) in this soil risk assessment are used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action records of decision have been met, as demonstrated by verification sampling and analysis. A description of the residential exposure scenario is in Section 6.2.3.3.1.

For completeness, the following subsections summarize the risk estimates, including contributions from background for the residential scenario. Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material, overburden material, and deep vadose zone material. The results with background contribution for the Residential scenario are presented in Tables G-9 through G-15.

Table G-16 through Table G-23 present risk estimates for only those COPCs with EPCs greater than background values or that do not have a background value.

G2.1.1 Shallow Zone

A total of 52 remediated waste sites are reported with cleanup verification package (CVP/RSVP) data associated with the shallow zone in the 100-K Source OUs. The following sample designs were applied to the 52 remediated waste sites evaluated:

- Fifteen waste sites were sampled using a focused sampling design.
- Twenty-two waste sites were sampled using a statistical sampling design (four sites with two statistically distinct decision units and one site with three statistically distinct decision units).
- Fifteen waste sites were sampled using both a statistical and a focused sampling design (one waste site with one focused decision unit and two statistically distinct decision units; one waste site with two focused decision units and one statistically distinct decision unit; one waste site with six focused decision units and one statistically distinct decision unit; one waste site with 13 focused decision units and three statistically distinct decision units; one waste site with 23 focused decision units and six statistically distinct decision units.

The residential scenario results for shallow zone material are summarized in Table G-11 and Table G-12.

G2.1.1.1 Radiological Results

As presented in Table G-11, the potential total excess lifetime cancer risk (ELCR) for radiological analytes is greater than the upper risk threshold of 1×10^{-4} for shallow vadose zone material associated with five remediated waste sites and within the target risk range of 10^{-4} to 10^{-6} for shallow vadose zone material associated with 16 remediated waste sites, and is less than the lower risk threshold of 1×10^{-6} at two remediated waste sites. Risks were not reported for shallow vadose zone material from 29 remediated waste sites because radiological COPCs were not reported.

Radiological risk estimates that include all radiological EPCs relative to background concentrations result in five remediated waste sites greater than the upper risk threshold of 1×10^{-4} and radiological risk estimates including only EPCs greater than background concentrations result in four remediated waste sites greater than the upper risk threshold of 1×10^{-4}.

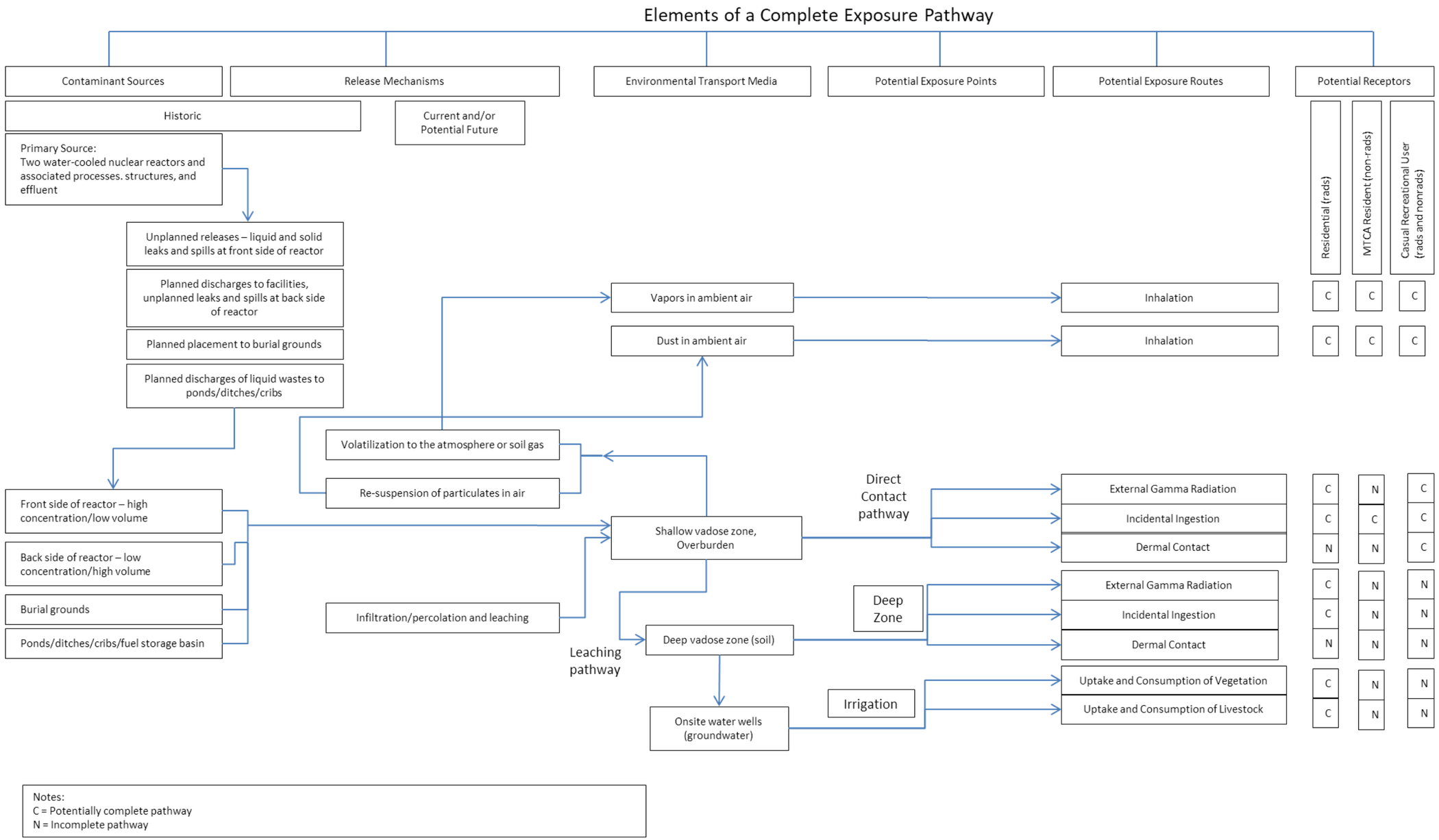
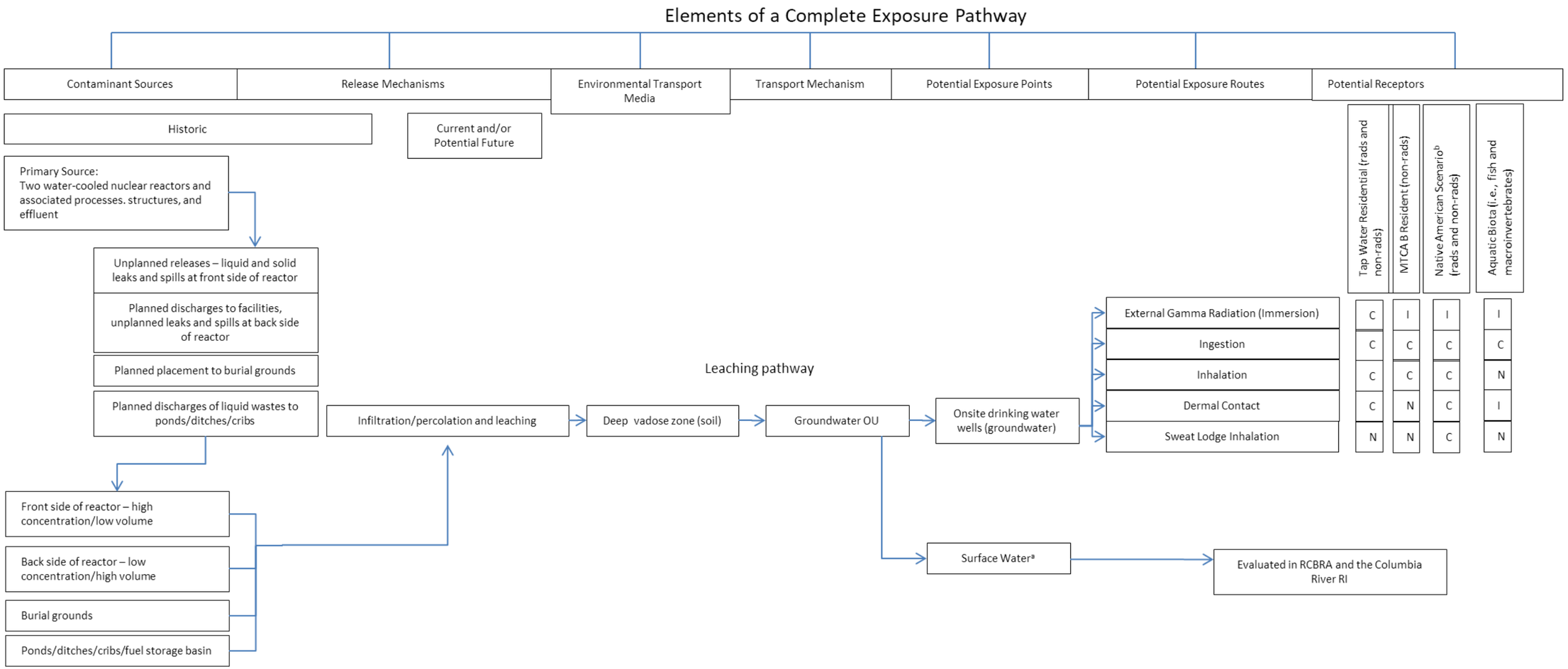


Figure G-1. Conceptual Exposure Model for Soil within the 100-K Source OUs



Notes:
a. Discharge of groundwater to the Columbia River is evaluated through the evaluation of the Ambient Water Quality Criteria
b. These receptors include the Confederated Tribes of the Umatilla Indian Reservation and the Yakama Nation
C = Potentially complete pathway
N = Incomplete pathway
I – This is a potentially complete pathway: however, exposure is considered insignificant

Figure G-2. Conceptual Exposure Model for Groundwater within the 100-K Groundwater OUs

G2.1.1.2 Nonradiological Results (Direct Contact)

As presented in Table G-11, the potential total ELCR for nonradiological carcinogenic analytes is $>1\times10^{-6}$ for shallow vadose zone material associated with 43 remediated waste sites and is $<1 \times 10^{-6}$ for shallow zone material from one remediated waste site. Risks were not reported for shallow vadose zone material associated with eight remediated waste sites because nonradiological carcinogenic COPCs were not reported.

Eight of the 52 remediated waste sites have a total ELCR greater than the 2013 "Model Toxics Control Act—Cleanup" (MTCA) (WAC 173-340) ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. Arsenic was the only contributor to total ELCR for shallow vadose zone material from seven of these eight remediated waste sites; arsenic concentrations were less than Hanford Site background (20 mg/kg). Arsenic, dibenz(a,h)anthracene, and benzo(a)pyrene were contributors to total risk for shallow vadose zone material from one of the eight remediated wastes; arsenic concentrations were less than the Hanford Site background.

When total risks are evaluated for EPCs greater than background, one remediated waste site reports individual carcinogens that exceed the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}; however, this remediated waste site is less than the 2007 MTCA, ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-11, the potential hazard index (HI) is greater than the ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 for shallow vadose zone material from 18 remediated waste sites and is less than or equal to the target HI of 1 for 33 remediated waste sites. Noncancer HIs were not reported for shallow vadose zone material from one remediated waste site because nonradiological noncarcinogenic COPCs were not reported. All individual contributors to HI also reported a health quotient (HQ) less than or equal to 1.

When noncancer hazards are evaluated for EPCs greater than background concentrations, 49 remediated waste sites report an HI less than one. HIs were not reported at two remediated waste sites because nonradiological noncarcinogenic COPCs were less than background and an HI was not reported at one remediated waste site because nonradiological noncarcinogenic COPCs were not reported.

G2.1.1.3 Nonradiological Results (Inhalation)

As presented in Table G-12, the potential total ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs including background contributions ranges from 2.9×10^{-17} to 2.1×10^{-7}. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) risk value of 1×10^{-6} for individual carcinogens for 50 remediated waste sites. Risks were not reported for two remediated waste sites because nonradiological carcinogenic COPCs were not reported.

As presented in Table G-12, the potential HI is less than the U.S. Environmental Protection Agency (EPA) target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 at 51 remediated waste sites. Noncancer hazards were not reported for one remediated waste site because nonradiological noncarcinogenic COPCs were not reported.

Cancer risk and hazard estimates that include all nonradiological EPCs relative to background concentrations are similar to risk and hazard estimates that include only EPCs greater than background values.

G2.1.2 Overburden

A total of ten waste sites are reported with CVP/RSVP data associated with overburden material in the 100-K Source OUs. The following sample designs were applied to the ten waste sites evaluated:

- One waste site was sampled using both a statistical and a focused sampling design (three statistical decision units and one focused decision unit).
- Nine waste sites were sampled using a statistical sampling design (four waste sites with two statistically distinct decision units).

The residential scenario results for overburden material are summarized in Table G-13 and Table G-14.

G2.1.2.1 Radiological Results

As presented in Table G-13, the total ELCR for radiological analytes is within the regulatory target risk range of 10^{-4} to 10^{-6} for overburden material associated with six remediated waste sites. Risks were not reported for overburden material associated with four remediated waste sites because radiological COPCs were not reported.

Radiological risk estimates that include all radiological EPCs relative to background concentrations are similar to risk estimates that include only EPCs greater than background values.

G2.1.2.2 Nonradiological Results (Direct Contact)

As presented in Table G-13, the total ELCR is $>1\times10^{-6}$ for overburden material associated with seven remediated waste sites. Risks were not reported for overburden material associated with three remediated waste sites because nonradiological carcinogenic COPCs were not reported.

No remediated waste site reports a total ELCR associated with overburden material that is greater than the 2007 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

When total risks are evaluated for EPCs greater than background, no remediated waste site reports individual carcinogens associated with overburden material that exceed the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}.

As presented in Table G-13, the potential HI is greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 for overburden material associated with one remediated waste site. The potential HI is less than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 for overburden material from eight remediated waste sites. Nonradiological noncarcinogenic COPCs were not reported in overburden material from one remediated waste site. All individual contributors to HI also reported an HQ <1.

When noncancer hazards are evaluated for EPCs greater than background, all overburden material from remediated waste sites report HIs less than or equal to one.

G2.1.2.3 Nonradiological Results (Inhalation)

As presented in Table G-14, the potential total ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs including background contributions ranges from 1.3×10^{-10} to 7.4×10^{-10}. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk threshold of 1×10^{-6} for individual carcinogens for overburden material associated with eight remediated waste sites. Total risks were not reported for overburden material from two remediated waste sites because nonradiological carcinogenic COPCs were not reported.

As presented in Table G-14, the potential HI is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 for overburden material associated with eight remediated waste sites. Noncancer HIs were not reported for overburden material from two remediated waste sites because nonradiological noncarcinogenic COPCs were not reported.

Cancer risk and hazard estimates that include all nonradiological EPCs relative to background concentrations are similar to risk and hazard estimates that include only EPCs greater than background values.

G2.1.3 Deep Zone

Deep vadose zone soil samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. Although there is no current exposure pathway for deep contamination, the RBSLs developed for the residential exposure scenario were used as a screening value to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

A total of 11 waste sites were reported with CVP/RSVP data for deep zone decision units in the 100-K Source OUs.

The following sample designs were applied to the 11 waste sites evaluated: Two waste sites were sampled using a focused sampling design. Seven waste sites were sampled using a statistical sampling design (one site with two statistically distinct decision units).Two waste sites were sampled using both a statistical and a focused sampling design (one site with two statistically distinct decision units and one focused decision unit and one site with seven statistically distinct decision units and three focused decision units).The remaining 41 waste sites were not evaluated for depths >4.6 m (15 ft) and are not discussed in this section.

The residential scenario results for deep zone material are summarized in Table G-15.

G2.1.3.1 Radiological Results

As presented in Table G-15, the total ELCR is greater than the upper risk threshold of 1×10^{-4} at nine remediated waste sites and is within the regulatory target risk range of 10^{-4} to 10^{-6} for deep vadose zone material associated with two remediated waste sites.

Radiological risk estimates that include all radiological EPCs relative to background concentrations are similar to risk estimates that include only EPCs greater than background values.

G2.2 Casual Recreational User Scenario

PRG developed for the casual recreational user scenario represent reasonably anticipated future land use. The results of this comparison are used to confirm that cleanup actions are protective of the reasonably anticipated future land uses that the U.S. Department of Energy (DOE) and the U.S. Fish and Wildlife Service (USFWS) anticipate for the River Corridor. The casual recreational user scenario is described in Section 6.2.3.3.

For completeness in analysis, the following subsections summarize the risk estimates, including contributions from background for the casual user scenario. Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material and overburden material. The results with background contribution for the casual user scenario are presented in Table G-24 through Table G-26.

Risk estimates for the casual user scenario that include only those COPCs with EPCs greater than background values or that do not have a background value are presented in Table G-27 through Table G-29.

Only the risk estimates without background contributions are summarized and discussed in the risk characterization provided in Section 6.2.5.1. This information is used for decisions concerning appropriate remedial actions.

G2.2.1 Shallow Zone

All 52 remediated waste sites are reported with CVP/RSVP data associated with the shallow zone in the 100-K Source OUs. The following sample designs were applied to the 82 waste sites evaluated:

- Fifteen waste sites were sampled using a focused sampling design.
- Twenty-two waste sites were sampled using a statistical sampling design (four sites with two statistically distinct decision units and one site with three statistically distinct decision units).
- Fifteen waste sites were sampled using both a statistical and a focused sampling design (one waste site with one focused decision unit and two statistically distinct decision units; one waste site with two focused decision unit and one statistically distinct decision unit; one waste site with six focused decision units and one statistically distinct decision units; one waste site with 13 focused decision units and three statistically distinct decision units; one waste site with 23 focused decision units and six statistically distinct decision units).

The casual user scenario results for shallow zone material are summarized in Table G-25.

G2.2.1.1 Radiological Results

As presented in Table G-25, the potential total ELCR for radiological analytes is within the target risk range of 10^{-4} to 10^{-6} for shallow vadose zone material from 10 remediated waste sites and less than the lower risk threshold of 1×10^{-6} for shallow vadose zone material from 13 remediated waste sites. Risks were not reported for shallow vadose zone material associated with 29 remediated waste sites because radiological COPCs were not reported.

Radiological risk estimates that include all radiological EPCs relative to background concentrations are similar to risk estimates that include only EPCs greater than background values.

G2.2.1.2 Nonradiological Results (Direct Contact and Inhalation)

As presented in Table G-25, the potential total ELCR is $>1\times10^{-6}$ for shallow vadose zone material from 11 remediated waste sites and were $<1\times10^{-6}$ for shallow vadose zone material from 39 remediated waste sites. Risks were not reported for 2 remediated waste sites because nonradiological carcinogenic COPCs were not reported.

When EPCs greater than background are considered, no remediated waste site reports individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}. There were no remediated waste sites greater than the 2013 MTCA, ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}.

As presented in Table G-25, the potential hazard index (HI) is less than the ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 for shallow vadose zone material from 51 remediated waste sites. Noncancer hazards were not reported at one remediated waste site because nonradiological COPCs were not reported.

Cancer risks and noncancer hazards that include all nonradiological EPCs relative to background concentrations are similar to risk and hazard estimates that include only EPCs greater than background values.

G2.2.2 Overburden

A total of ten remediated waste sites are reported with CVP/RSVP data associated with overburden material in the 100-K Source OUs. The following sample designs were applied to the ten waste sites evaluated:

- One waste site was sampled using both a statistical and a focused sampling design (three statistical decision units and one focused decision unit).
- Nine waste sites were sampled using a statistical sampling design (four waste sites with two statistically distinct decision units).

The casual recreational user scenario results for overburden material are summarized in Table G-26.

G2.2.2.1 Radiological Results

As presented in Table G-26, the total ELCR for radiological analytes is less than or equal to the lower risk threshold value of 1×10^{-6} for overburden material associated with six remediated waste sites. Risks were not reported for overburden material associated with four remediated waste sites because radiological COPCs were not reported.

When EPCs greater than background concentrations are considered, all overburden material from remediated waste sites were reported with total risks less than the upper risk threshold of 1×10^{-4}; these results are similar to when all EPCs relative to background concentrations are included.

G2.2.2.2 Nonradiological Results (Direct Contact and Inhalation)

As presented in Table G-26, the potential cumulative ELCR for nonradionuclides is $<1\times10^{-6}$ for overburden material associated with eight remediated waste sites. Risks were not reported for overburden material associated with two remediated waste sites because nonradiological carcinogenic COPCs were not reported.

When EPCs greater than background are considered, no remediated waste site reports a total ELCR associated with overburden material that is greater than the WAC 173-340-740 acceptable cancer risk level of 1×10^{-6}.

As presented in Table G-26, the potential HI is less than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 for overburden material associated with nine remediated waste sites. Noncancer hazards were not reported for overburden material from one remediated waste site because noncarcinogenic COPCs were not reported.

Cancer risks and noncancer hazards that include all nonradiological EPCs relative to background concentrations are similar to risk and hazard estimates that include only EPCs greater than background values.

G3 Risk Estimates Associated with Remedial Investigation and Limited Field Investigation Soil Data

In addition to the waste site remediation data (CVP/RSVP), two additional sources of data were considered for use in the risk assessment: vadose zone data collected for the RI to fill data gaps associated with the nature and extent of contamination or associated with understanding the fate and transport of contaminants and LFI data collected in 1991 and 1992 from the 100-K Source OUs. These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used to calculate EPCs or evaluate risks quantitatively. However, these data were evaluated qualitatively by

comparing concentrations of analytes at each screen interval to RBSLs to determine if the results could be useful for risk management decisions.

G3.1 Remedial Investigation Data

Soil data identified as useful for informing risk management decisions include those collected to fill data gaps 2, 3, and 4. Chapter 2, Table 2-1 lists the data gaps and the work conducted per the RI/FS Work Plan (DOE/RL-2008-46-ADD2) for 100-K. Two soil borings and 13 monitoring wells were drilled for the RI. During 2014 and 2015, two additional soil characterization boreholes and 21 wells were drilled for remedial process optimization (soil samples were collected for 15 of the wells and discussed below). In general, the comparison of soil concentrations from RI data to RBSLs are consistent with those risk results reported for closeout documentation data (CVP/RSVP) when borehole data were collected through waste sites that were previously remediated. However, use of the LFI data overstates risks because these waste sites have been subsequently remediated under interim action records of decision (RODs). A more detailed discussion of the results is provided in Appendix G, and comparison results are shown in Tables G-31 through G-35.

G3.2 Limited Field Investigation Data

In the early 1990s, an LFI was performed in the 100-KR-1 OU. Results of the investigation are presented in the 100-KR-1 LFI (DOE/RL-93-78). Data collection and analysis activities were conducted in accordance with DOE/RL-90-20, *Remedial Investigation/Feasibility Work Plan for the 100-KR-1 Operable Unit, Hanford Site, Richland, Washington*. No LFI for the 100-KR-2 OU has been performed.

In the 100-KR-1 OU, the following were identified as high-priority waste sites: the 116-K-1 Crib, 116-K-2 Trench, 116-K-3 Outfall Structure, 116-KW-3 Retention Basin, 116-KE-4 Retention Basin, and the process effluent pipelines. No low-priority waste sites are located in the 100-KR-1 OU. Based on the work plan, four of the six high-priority waste sites were investigated during the LFI: the 116-K-1 Crib, 116-K-2 Trench, 116-KW-3 Retention Basin, and 116-KE-4 Retention Basin. Data from these four waste sites are included in the uncertainty evaluation.

An LFI was also performed in the 100-KR-4 OU. Results of the investigation are presented in the 100-KR-4 LFI (DOE/RL-93-79). Data collection and analysis activities were conducted in accordance with *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington* (DOE/RL-90-21). One deep well (199-K-32B), and six shallow wells (199-K-32A, 199-K-33, 199-K-34, 199-K-35, 199-K-36, and 199-K-37) were installed to define the groundwater quality in areas of potential public or environmental exposure and to define the groundwater quality immediately downgradient of priority and potential sources of groundwater contamination. Soil data from all shallow wells are included in the uncertainty evaluation.

G3.3 Comparison to Human Health RBSLs

All RI and LFI soil data from the soil borings and wells described in the previous section were compared to the human health RBSLs used in the soil risk assessment. The soil borings and wells and associated depth intervals are summarized in Table G-32 (Appendix G).

Similar to the CVP/RSVP data, soil data from each soil boring, well, or test pit were grouped by depth. Soil data were processed and reduced using the same methods as those described in Section 6.2.2.2. Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) below ground surface (bgs) were combined and the maximum detected concentration was compared to the Hanford Site background concentration and the RBSLs developed for the resident and the casual recreational user scenarios. Soil samples collected from depth intervals >4.6 m (15 ft) bgs were combined and the maximum detected

concentration was compared to the Hanford Site background concentration and the RBSLs for the residential and casual recreational user scenarios. EPCs are not calculated using the RI and LFI data.

G3.3.1 Risk Results for Soil Samples Collected from 0 to 4.6 m (15 ft) bgs

Soil samples were collected from 0 to 4.6 m (15 ft) bgs from 8 RI wells, 4 LFI soil borings, and 4 LFI test pit samples. A comparison of maximum detected concentrations to RBSLs from each of these sample locations is provided in Table G-33. A summary of the wells and test pits that report a maximum concentration greater than the residential RBSLs is provided in Table G-31. As shown in Table G-31, only LFI sample locations (100-KR-1-TP1, 100-KR-1-TP-3, 199-K-39, and 199-K-40) report soil concentrations greater than residential RBSLs. In all cases, these waste sites have been remediated under the interim action ROD.

G3.3.2 Risk Results for Soil Samples Collected from Depths Greater Than 4.6 m (15 ft) bgs

Soil samples were collected from depths >4.6 m (15 ft) bgs from 4 RI soil borings, 20 RI wells, 3 LFI soil borings, 4 LFI test pit samples, and 6 LFI wells. A comparison of maximum detected concentrations of radionuclides to RBSLs from each of these sample locations is provided in Table G-34. A summary of the soil borings, wells and test pits that report a maximum concentration greater than the residential RBSLs is provided in Table G-31. As shown in Table G-31, two soil boring samples collected from the west end and the east end of the 116-K-2 trench (199-K-200 and 199-K-201), the characterization borehole for UPR-100-K-1 (199-K-222), and well 199-K-227 (located at southeastern portion of the 118-K-1 burial ground footprint, within the 100-K-132 site) report radionuclide concentrations greater than residential RBSLs. Table G-35 lists the soil boring or well radioisotopes with concentrations greater than their respective residential RBSL, the year the samples were collected, the detected concentration for the depth interval, the half-life for each radioisotope, and the year that each radioisotope decays to an activity level less than the residential RBSL.

At 199-K-200, strontium-90 concentrations are greater than the residential RBSL of 2.3 pCi/g at depths ranging between 8.6 and 11 m (28.2 and 35.5 ft) bgs. Concentrations of strontium-90 decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2033.

At 199-K-201, the following radioisotopes were reported with concentrations greater than residential RBSLs:

- Cesium-137, europium-152, and strontium-90 concentrations at depths ranging between 5.9 and 6.6 m (19.3 and 21.8 ft) bgs are greater than their residential RBSLs of 4.4 pCi/g, 3.6 pCi/g, and 2.3 pCi/g. respectively. Concentrations of this radioisotopes decay to a total cumulative ELCR of <1.0×10-4 by 2171.
- Cesium-137, europium-152, europium-154, and strontium-90 concentrations at depths ranging between 6.4 and 7.2 m (21 and 23.5 ft) bgs are greater than their residential RBSLs of 4.4 pCi/g, 3.6 pCi/g, 4.5 pCi/g, and 2.3 pCi/g, respectively. Concentrations of these radioisotopes decay to a total cumulative ELCR of <1.0×10-4 by 2149.
- Cesium-137, europium-152, europium-154, and strontium-90 concentrations at depths ranging between 6.4 and 7.8 m (23.2 and 25.7 ft) bgs are greater than their residential RBSLs of 4.4 pCi/g, 3.6 pCi/g, 4.5 pCi/g, and 2.3 pCi/g, respectively. Concentrations of these radioisotopes decay to a total cumulative ELCR of <1.0×10-4 by 2158.
- Cesium-137 concentrations at depths ranging between 7.7 and 8.5 m (25.3 and 27.8 ft) bgs are greater than their residential RBSL of 4.4 pCi/g. Concentrations of cesium-137 decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2033.

The 116-K-2 waste site was remediated under the Interim Action ROD and is included in the soil risk assessment in Section 6.2.5.5.1. The results for the 116-K-2 waste site report similar risk contributors when compared to soil borings 199-K-200 and 199-K-201. The 116-K-2 waste site (deep decision unit) reports a cumulative ELCR of 6.3×10^{-3}. The primary contributors to risk include cesium-137 (2.7×10^{-3}, 43% contribution), cobalt-60 (1.7×10^{-4}; 3% contribution), europium-152 (2.8×10^{-3}, 45% contribution), europium-154 (1.6×10^{-4}, 3% contribution), nickel-63 (1.3×10^{-4}, 2% contribution) and strontium-90 (2.8×10^{-4}, 4% contribution). Activity levels of cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 decay to levels less than residential RBSLs by year 2148.

At 199-K-222, the following radioisotopes were reported with concentrations greater than residential RBSL:

- Americium-241, plutonium-239/240, and strontium-90 concentrations at depths ranging between 7.3 and 8.1 m (24.1 and 26.5 ft) bgs are greater than their residential RBSLs of 153 pCi/g, 203 pCi/g, and 2.3 pCi/g, respectively. Concentrations of these radioisotopes decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 100613.

- Americium-241, plutonium-239/240, and strontium-90 concentrations at depths ranging between 8.1 and 8.4 m (26.7 and 27.7 ft) bgs are greater than their residential RBSLs of 153 pCi/g, 203 pCi/g, and 2.3 pCi/g, respectively. Concentrations of these radioisotopes decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 36922.

At 199-K-227, tritium concentrations are greater than the residential RBSL of 624 pCi/g at depths ranging between 8.6 and 11 m (72 and 74.5 ft) bgs. Concentrations of tritium decay to a total cumulative ELCR of $<1.0\times10^{-4}$ by 2058.

G4 Risk Evaluation of the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 Sites

During reactor operations at the 100-K Area, overland flow and seepage from nearby liquid waste sites and structures spread potentially contaminated water to areas along the nearby river shoreline. Three unremediated waste sites (100-K-57, 100-K-64, and 100-K-111) are located adjacent to the Columbia River within the 100-K Source Areas and have not been adequately characterized to determine if the potential contaminant presents a risk to human health and/or the environment. This section includes an evaluation of cancer risks and noncancer hazards for the residential and the casual recreational user scenarios. A portion of the collocated 100-K-83 site is also included in this evaluation. Cancer risk and noncancer hazard estimates are calculated with and without background contributions (see Chapter 6, Section 6.2.5.4 for description).

G4.1 Data Analysis

Characterization data including surface (0 to 0.15 m [0 to 0.5 ft] bgs) and subsurface (0 to 0.8 m [0 to 2.6 ft.] bgs) were collected from these waste sites. The following sample designs were applied to the waste sites. The sites and sampling designs are summarized in Table G-36 and the samples associated with each of the decision units are listed in Table G-37.

- The 100-K-57 waste site consists of one focused surface decision unit, one focused subsurface decision unit, and one focused riparian surface decision unit.

- The 100-K-64 waste site consists of one surface decision unit, one subsurface decision unit, one focused surface decision unit, and one focused subsurface decision unit.

Table G-31. Summary of Human Health Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	CVP/RSVP Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	LFI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?
Soil Borings Installed to Characterize Residual Contamination Beneath the Remediated Waste Site									
116-K-2 Effluent Trench (West end)	199-K-200 (C7831)	No samples collected from this depth range.	Sr-90 > residential RBSL (28.2 to 35.5 ft bgs)	CVP-2006-00001	1×10^{-4} to 1×10^{-6}	6.3×10^{-3} (Cs-137, Co-60, Eu-152, Eu-154, Ni-63, Sr-90)	199-K-41 (A5748)	No individual risks > thresholds	No samples collected from this depth range.
116-K-2 Effluent Trench (East end)	199-K-201 (C7832)	No samples collected from this depth range.	Cs-137 > residential RBSL (19.3 to 27.8 ft bgs) Eu-152, Sr-90 > residential RBSL (19.3 to 25.7 ft bgs) Eu-154 > residential RBSL (21 to 25.7 ft bgs)	--	--	--	--	--	--
Wells Installed to Characterize Contamination in the Unconfined Aquifer									
K Well 1	199-K-183 (C7683)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
Downgradient of 116-KW-3 Retention Basin & 105-KW Reactor area (K Well 2)	199-K-185 (C7685)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
K Well 3	199-K-187 (C7687)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
K Well 4	199-K-190 (C7690)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
Downgradient of 105-KE Reactor (K Well 5)	199-K-189 (C7689)	No individual risks > thresholds	No individual risks > thresholds	--	--	--	--	--	--
K Well 6	199-K-191 (C7691)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
K Well 7	199-K-193 (C7693)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
K Well 8	199-K-194 (C7694)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
Downgradient of 183-KE water treatment facility (K Well 9)	199-K-186 (C7686)	No individual risks > thresholds	No individual risks > thresholds	--	--	--	--	--	--
Wells Installed to Characterize Contamination Beneath the Unconfined Aquifer in the RUM									
K RUM Well 1	199-K-184 (C7684)	No individual risks > thresholds	No individual risks > thresholds	--	--	--	--	--	--
K RUM Well 2	199-K-192 (C7692)	No individual risks > thresholds	No individual risks > thresholds	--	--	--	--	--	--
K RUM Well 3 at 120-KE-6	199-K-188 (C7688)	No individual risks > thresholds	No individual risks > thresholds	--	--	--	--	--	--

Table G-31. Summary of Human Health Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	CVP/RSVP Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	LFI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?
K RUM Well 4 at 100-K-97	199-K-195 (C7695)	No individual risks > thresholds	No individual risks > thresholds	--	--	--	--	--	--
Post-RI Characterization Boreholes and Monitoring Wells									
Monitoring well to characterize 116-KE-3 waste site	199-K-221 (C8796)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
Monitoring well to characterize UPR-100-K-1 waste site	199-K-222 (C8797)	No samples collected from this depth range.	Am-241, Pu-239/240 and Sr-90 > residential RBSL (24.1 to 26.5 and 26.7 to 27.7 ft bgs)	--	--	--	--	--	--
Post-RI Monitoring and Extraction Wells									
Northwest of the KE Reactor and 116-KE-3 Crib (plume delineation and river protection)	199-K-202 (C8289)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
North of the KE Reactor and 116-KE-1 Crib (plume delineation and river protection downgradient of KE Reactor)	199-K-203 (C8290)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--
North of the KW Reactor and 116-KW-1 Crib, within the 116-KW-4 Heat Recovery Station site footprint (monitoring well for plume delineation downgradient of KW Reactor)	199-K-204 (C8291)	No samples collected from this depth range.	No individual risks > thresholds	CVP-2005-00006	Radiological COPCs and chemical carcinogens not reported	Deep zone samples were not collected	--	--	--
At the former 183-KW Headhouse area (extraction well near 183-KW Headhouse to increase mass removal)	199-K-205 (C8292)	No samples collected from this depth range.	No radiological samples collected from this depth range.	--	--	--	--	--	--
Within the norther portion of the 118-K-1 Burial Ground footprint (monitoring well for plume delineation, northeast of KE Reactor at 118-K-1 waste site)	199-K-207 (C8294)	No samples collected from this depth range.	No individual risks > thresholds	CVP-2013-00002	2.5×10^{-4} (Sr-90)	1.9×10^{-3} (Cs-137, Du-152, Sr-90)	--	--	--
In the river embankment north of the 116-KE-4 Retention Basin site; within the 100-K-64 site (extraction well for river protection downgradient of KE Reactor)	199-K-210 (C8297)	No samples collected from this depth range.	No radiological samples collected from this depth range.	--	See Appendix G, Section G.4.	Deep zone samples were not collected	--	--	--

Table G-31. Summary of Human Health Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	CVP/RSVP Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	LFI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?
At the former 183-KE Flocculation and Sedimentation Basins area (Extraction well to increase mass removal near 183-KW Headhouse)	199-K-220 (C8795)	No samples collected from this depth range.	No radiological samples collected from this depth range.	--	--	--	--	--	--
At the former 183-KW Flocculation and Sedimentation Basins area (monitoring well for plume delineation near KW Reactor)	199-K-223 (C8795)	No individual risks > thresholds	No radiological samples collected from this depth range.	--	--	--	--	--	--
At the former 183-KW Flocculation and Sedimentation Basins area, northwest of Well 199-K-223 (Monitoring well for plume delineation near KW Reactor)	199-K-224 (C9596)	No individual risks > thresholds	No radiological samples collected from this depth range.	--	--	--	--	--	--
At the former 183-KE Flocculation and Sedimentation Basins area, northwest of Well 199-K-220 (Extraction well near 183 KE Headhouse for source area remediation)	199-K-225 (C9597)	No samples collected from this depth range.	No radiological samples collected from this depth range.	--	--	--	--	--	--
At the northeastern corner of the 100-K operational area, within the 116-KE-4 Retention Basin site footprint (Extraction well northeast of KE Reactor for source area remediation)	199-K-226 (C9598)	No samples collected from this depth range.	No individual risks > thresholds	CVP-2005-00002	1×10^{-4} to 1×10^{-6}	Deep zone samples were not collected	--	--	--
Within the southeastern portion of the 118-K-1 Burial Ground footprint, at the 100-K-132 site	199-K-227 (C9711)	No samples collected from this depth range.	Tritium > residential RBSL (72-74.5 ft bgs)	CVP-2013-00002	2.5×10^{-4} (Sr-90)	1.9×10^{-3} (Cs-137, Du-152, Sr-90)	--	--	--
East of the KE Reactor and southwest of the 118-K-1 Burial Ground site	199-K-228 (C9712)	No samples collected from this depth range.	No radiological samples collected from this depth range.	--	--	--	--	--	--
North of the northwest corner of the former 183-KW Flocculation and Sedimentation Basin area	199-K-229 (C9713)	No samples collected from this depth range.	No radiological samples collected from this depth range.	--	--	--	--	--	--
Northeast of the 116-KE-3 Retention Basin site	199-K-230 (C9714)	No samples collected from this depth range.	No individual risks > thresholds	--	--	--	--	--	--

Table G-31. Summary of Human Health Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

Waste Site	RI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	CVP/RSVP Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?	LFI Data	Shallow Zone (<4.6 m [<15 ft] bgs) Direct Contact Human Health Risks?	Deep Zone (>4.6 m [>15 ft] bgs) Radiological Risks?
Soil Borings Installed during LFI to Characterize Priority Waste Site in 100-KR-1 OU									
116-K-1 Crib	--	--	--	CVP-2003-00024	1×10^{-4} to 1×10^{-6}	1.0×10^{-3} (Cs-137, Co-60, Eu-152, Sr-90)	199-K-40 (A5747)	Cs-137, Co-60, Eu-154, Sr-90 > residential RBSL (4-6 ft bgs) Eu-152, Sr-90 > residential RBSL (10-12 ft bgs)	No individual risks > thresholds
116-KW-3 Retention Basin	--	--	--	CVP-2004-00001	1×10^{-4} to 1×10^{-6}	No samples collected from this depth range.	199-K-38 (A5745)	No individual risks > thresholds	No individual risks > thresholds
--	--	--	--	--	--	--	100-KR-1-TP-3 (7105)	Benzo(a)pyrene, Cs-137, Eu-152 > residential RBSL (0 ft bgs)	No individual risks > thresholds
--	--	--	--	--	--	--	100-KR-1-TP-4 (7106)	No individual risks > thresholds	No individual risks > thresholds
116-KE-4 Retention Basin	--	--	--	CVP-2005-00002	1×10^{-4} to 1×10^{-6}	No samples collected from this depth range.	199-K-39 (A5746)	Eu-152 > Residential RBSL (0 - 1 ft bgs)	No individual risks > thresholds
--	--	--	--	--	--	--	100-KR-1-TP-1 (7103)	Eu-152 > Residential RBSL (0 ft bgs)	No individual risks > thresholds
--	--	--	--	--	--	--	100-KR-1-TP-2 (7104)	No individual risks > thresholds	No individual risks > thresholds
Wells Installed During LFI to Characterize Water Quality in 100-KR-4 OU									
--	--	--	--	--	--	--	199-K-32A	No samples collected from this depth range.	No individual risks > thresholds
--	--	--	--	--	--	--	199-K-33	No samples collected from this depth range.	No individual risks > thresholds
--	--	--	--	--	--	--	199-K-34	No samples collected from this depth range.	No individual risks > thresholds
--	--	--	--	--	--	--	199-K-35	No samples collected from this depth range.	No individual risks > thresholds
--	--	--	--	--	--	--	199-K-36	No samples collected from this depth range.	No individual risks > thresholds
--	--	--	--	--	--	--	199-K-37	No samples collected from this depth range.	No individual risks > thresholds

Sources: CVP-2003-00024, *Cleanup Verification Package for the 116-K-1 Crib*.
CVP-2004-00001, *Cleanup Verification Package for the 116-KW-3 Retention Basin*.
CVP-2005-00002, *Cleanup Verification Package for the 116-KE-4 Crib*.
CVP-2006-00001, *Cleanup Verification Package for the 116-K-2 Effluent Trench*.

bgs = below ground surface
COPC = contaminant of potential concern
CVP = cleanup verification package
LFI = limited field investigation
OU = operable unit
RBSL = risk based screening level
RI = remedial investigation
RSVP = remaining site verification package

- The 100-K-111 waste site was subdivided into east and west subsites. The east subsite consists of one surface decision unit, one subsurface decision unit, and one focused riparian surface decision unit. The west subsite consists of one surface decision unit, three focused surface decision units, one subsurface decision unit, three focused subsurface decision units, one focused riparian surface decision unit, and one focused riparian subsurface decision unit.

- The 100-K-83 waste site consists of one focused surface decision unit, one focused subsurface decision unit, and one focused riparian surface decision unit.

G4.1.1 Data Processing and Reduction and Calculation of EPCs

The data were processed and reduced using the same methodology described in Chapter 6, Section 6.2.2.2. Similarly, the steps described in Chapter 6, Section 6.2.2.2.3 were used to identify analytes for 95 and 97.5% UCL calculation. Analytes that were not detected in any sample are listed in Table G-38, analytes that meet exclusion criteria are listed in Table G-39. A summary of the EPCs for each detected analyte in a decision unit is provided in Table G-40.

G4.2 Toxicity Assessment

The toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with contaminant exposure. The toxicity assessment contains two steps (hazard characterization and dose-response evaluation), as discussed in the following subsections. Hazard characterization and the dose-response evaluation process was previously discussed in Chapter 6, Section 6.2.4 of this report.

G4.2.1 Toxicity Values

The sources of toxicity values are the same as those described in Chapter 6, Section 6.2.4.2 of this report. The cancer slope factors and the reference dose values used in this evaluation are summarized in Table G-6. Cancer slope factors for radionuclides are also summarized in Table G-6.

G4.3 Risk Characterization

A description of the risk characterization steps including the cancer risk estimation method and the noncancer hazard estimation method are described in Chapter 6, Section 6.2.5. A comparison of EPCs for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 sites to Hanford Site background values is provided in Table G-41.

G4.3.1 Residential Scenario

PRGs developed for the residential scenario represent unrestricted land use and are used to determine if evaluation of remedial alternative is warranted in the feasibility study. The residential scenario is described in Chapter 6, Section 6.2.3.3.1.

Risk estimates were calculated for each decision unit associated with the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites. The results with background contribution for the Residential scenario are presented in Tables G-42 through G-45.

This appendix also includes risk estimates for those COPCs with EPCs greater than background values or that do not have a background value are presented in Table G-46 through Table G-50.

G4.3.2 Risk and Hazard Estimates with and without Background Contributions

The following provides a summary and discussion of the risk and hazards estimates without background contributions (i.e., considering only those analytes with EPCs greater than background concentrations) and with background contributions (i.e., considering all analytes regardless of EPCs relative to background) for the waste sites.

G4.3.2.1 Radiological Results

As presented in Table G-44, the potential total ELCR with background contributions is greater than the upper risk threshold of 1×10^{-4} for the 100-K-64 waste site and is within the acceptable risk range of 1×10^{-4} to 1×10^{-6} for the 100-K-57, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-49, the potential total ELCR without background contributions is greater than the upper risk threshold of 1×10^{-4} for the 100-K-64 waste site and is within the target risk range of 1×10^{-4} to 1×10^{-6} for the 100-K-57, 100-K-83, and 100-K-111 waste sites. The total cumulative ELCR will decay to $<1\times10^{-4}$ by year 2043 (see Table G-55).

G4.3.2.2 Nonradiological Results (Direct Contact)

As presented in Table G-44, the potential total ELCR with background contributions is within the acceptable risk range of 1×10^{-4} to 1×10^{-6} for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-44, the potential HIs with background contributions are greater than the ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites. The primary contributor to risk is arsenic, which is present at concentrations less than background (Table G-41).

As presented in Table G-48, lead and arsenic were less than the MTCA A cleanup levels at the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-49, the potential total ELCR without background contributions was not reported for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites because nonradiological carcinogenic COPCs were not reported above background concentrations.

As presented in Table G-49, the potential HIs without background contributions are less than the ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

G4.3.2.3 Nonradiological Results (Inhalation)

As presented in Table G-45, the potential total ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs including background contributions ranges from 3.4×10^{-10} to 9.8×10^{-9}. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) risk value of 1×10^{-6} for individual carcinogens at the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-45, the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 at 100-K-57, 100-K-64, 100-K-83, and 100-K-111waste sites.

As presented in Table G-50, the potential total ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contributions ranges from 7.3×10^{-11} to 9.3×10^{-9}. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) risk

value of 1×10^{-6} for individual carcinogens for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-50, the potential HI for the inhalation pathway without background contributions is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 at the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

G4.4 Casual Recreational User Scenario

PRGs developed for the casual recreational user scenario represent reasonably anticipated future land use. The results of this comparison are used to confirm that the current condition of the culturally sensitive waste sites is protective of the reasonably anticipated future land uses that DOE and USFWS anticipate for the River Corridor. The casual recreational user scenario is described in Chapter 6, Section 6.2.3.3.

For completeness in analysis, risk and hazard estimates, which include all COPCs regardless of their EPCs relative to background concentrations for each waste site decision unit, are provided in Table G-51 and Table G- 52. Risk and hazards estimates that include only those COPCs with EPCs greater than background values or that do not have a background value are presented in Table G-53 and Table G-54.

The risk and hazard estimates without background contributions are discussed as follows.

G4.4.1 Risk and Hazard Estimates with and without Background Contributions

The following provides a summary and discussion of the risk and hazards estimates with background contributions (i.e., considering only those analytes with EPCs greater than background concentrations) and without background contributions (i.e., considering all analytes regardless of EPCs relative to background) for the waste sites.

G4.4.1.1 Radiological Results

As presented in Table G-52, the potential total ELCR with background contributions is within the target risk range of 1×10^{-4} to 1×10^{-6} for the 100-K-57, 100-K-64, and 100-K-111 waste sites, and less than the lower risk threshold of 1×10^{-6} for the 100-K-83 waste site.

As presented in Table G- 54, the potential total ELCR without background contributions is within the target risk range of 1×10^{-4} to 1×10^{-6} for the 100-K-57 and 100-K-64 waste sites and less than the lower risk threshold of 1×10^{-6} for the 100-K-111 and 100-K-83 waste sites.

G4.4.1.2 Nonradiological Results (Direct Contact and Inhalation)

As presented in Table G-52, the potential total ELCR with background contributions is within the acceptable risk range of 1×10^{-4} to 1×10^{-6} for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-54, the potential total ELCR without background contributions is $<1\times10^{-6}$ for shallow vadose zone material for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

As presented in Table G-52 and Table G-54 respectively, the potential HIs with and without background contributions are less than the ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 for the 100-K-57, 100-K-64, 100-K-83, and 100-K-111 waste sites.

G5 Risk Characterization Results of the Native American Risk Assessment

Several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. DOE has requested that each Tribe provide an exposure scenario that reflects their traditional activities. At this time, Harris and Harper, 2004, *Exposure Scenario for CTUIR Traditional Subsistence Lifeways*, and Harris, 2008, *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments*, have been provided by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), and Ridolfi, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment*, has been provided by the Yakama Nation.

The CTUIR and Yakama Nation scenarios reflect exposure conditions that assume groundwater from the 100-KR-4 Groundwater OU is restored to its highest beneficial use and is used as a drinking water source and to generate steam in a sweat lodge. Use of groundwater to irrigate crops and water livestock is not evaluated in this risk evaluation because those exposure pathways, although potentially complete, are considered insignificant and secondary to the drinking water and sweat lodge exposure pathways. Food chain pathways are generally evaluated quantitatively in the source area OUs because the RESRAD model (ANL, 2009, RESRAD, Version 6.5) estimates exposure from these pathways.

Potentially complete exposure routes for adult and child Tribal members associated with use of groundwater as a drinking water source are as follows:

- Ingestion of drinking water
- Inhalation of volatiles when showering and other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (such as, washing dishes)

Potentially complete exposure routes for adult Tribal members associated with the use of groundwater to generate steam in a sweat lodge are as follows:

- Inhalation of carbon-14, tritium, volatiles, and semivolatiles as vapors
- Inhalation of aerosolized nonvolatiles
- Dermal contact with vapors from volatile and semivolatile compounds
- Dermal contact with vapor and aqueous condensate

A complete description of each Tribal use exposure scenario is provided in ECF-100KR4-17-0083, *Native American Risk Assessment for the 100-KR-4 Groundwater Operable Unit*. This calculation describes the methodology, assumptions and inputs, and the calculation of risks and hazards, and discusses the results of the groundwater risk assessment for each of the Native American scenarios.

G5.1 Summary of the CTUIR Groundwater Risk Assessment

This section summarizes the results for each of the exposure pathways associated with use of groundwater as a drinking water source and use of groundwater to generate steam in a sweat lodge.

G5.1.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to groundwater as a drinking water source is evaluated based on the CTUIR exposure scenario. Potential routes of exposure to groundwater include ingestion, dermal contact (nonradionuclides only), and inhalation of volatiles during household activities. Table G-222 provides a summary of the cancer risk and noncancer hazard estimates by exposure route for the 100-KR-4 Groundwater OU.

Additional detail including analyte-specific risk contributions are provided in Tables G-223 and G-224 and also in ECF-100KR4-17-0083.

The total cumulative ELCR for the 100-KR-4 Groundwater OU is 2.0×10^{-2}. The total ELCR for nonradiological analytes is 5.4×10^{-3}, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.5×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR are 1,2,4-trichlorobenzene (ELCR = 2.0×10^{-6}, 0.01% contribution), aldrin (ELCR = 4.7×10^{-3}, 23% contribution), bis(2-ethylhexyl) phthalate (ELCR = 3.5×10^{-4}, 1.8% contribution), bromodichloromethane (ELCR = 2.1×10^{-6}, 0.01% contribution), carbon tetrachloride (ELCR = 8.5×10^{-6}, 0.04% contribution), carbon-14 (ELCR = 9.5×10^{-3}, 48% contribution), chloroform (ELCR = 9.7×10^{-6}, 0.05% contribution), ethylbenzene (ELCR = 5.3×10^{-6}, 0.03% contribution), trichloroethene (TCE) (ELCR = 1.5×10^{-5}, 0.08% contribution), and tritium (ELCR = 5.0×10^{-3}, 25% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 3.1×10^{-4}, 1.5% contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 5.1×10^{-3}, which is greater than the 2013 MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table G-222. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
Nonradionuclides	Ingestion	6.4×10^{-4}	1,2,4-Trichlorobenzene, (ELCR = 2.0×10^{-6}, 0.01%) Aldrin, (ELCR = 4.7×10^{-3}, 23%) Arsenic, (ELCR = 3.1×10^{-4}, 1.5%) Bis(2-ethylhexyl) phthalate, (ELCR = 3.5×10^{-4}, 1.8%) Bromodichloromethane, (ELCR = 2.1×10^{-6}, 0.01%) Carbon tetrachloride, (ELCR = 8.5×10^{-6}, 0.04%) Carbon-14, (ELCR = 9.5×10^{-3}, 48%) Chloroform, (ELCR = 9.7×10^{-6}, 0.05%) Ethylbenzene, (ELCR = 5.3×10^{-6}, 0.03%) Trichloroethene, (ELCR = 1.5×10^{-5}, 0.08%) Tritium, (ELCR = 5.0×10^{-3}, 25%)	6.1	1,2,4-Trichlorobenzene, (HQ = 0.17, 0.86%) 2-Propanol, (HQ = 0.26, 1.3%) Aldrin, (HQ = 9.8, 49%) Arsenic, (HQ = 0.79, 4.0%) Bis(2-ethylhexyl) phthalate, (HQ = 1.6, 8.1%) Cyanide, (HQ = 1.7, 8.5%) Fluoride, (HQ = 0.20, 1%) Hexavalent chromium, (HQ = 1.5, 7.7%) Lithium, (HQ = 0.50, 2.5%) Manganese, (HQ = 0.71, 3.5%) Nitrate, (HQ = 0.23, 1.2%) Thallium, (HQ = 0.52, 2.6%) Trichloroethene, (HQ = 1.2, 6.1%) Vanadium, (HQ = 0.16, 0.79%)
	Dermal Contact	4.0×10^{-3}		11	
	Inhalation of Volatiles	7.9×10^{-4}		2.7	
	Total Risk	5.4×10^{-3}		Total HI	20

Table G-222. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
Radionuclides	Ingestion	5.0×10^{-4}		--	
	Inhalation of Volatiles	1.4×10^{-2}			
	Total Risk	1.5×10^{-2}			
	Total Cumulative ELCR [c]		2.0×10^{-2}		

a. Percent risk contribution listed for those contributors with an individual ELCR $>1\times10^{-4}$ (radionuclides) or individual ELCR $>1\times10^{-6}$ (chemicals).

b. Percent HI contribution listed for those contributors with an HQ >0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

-- = not applicable.
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI is 20, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI are 1,2,4-trichlorobenzene (HQ = 0.17, 0.86% contribution), 2-propanol (HQ = 0.26, 1.3% contribution), aldrin (HQ = 9.8, 49% contribution), arsenic (HQ = 0.79, 4.0% contribution), bis(2-ethylhexyl) phthalate (HQ = 1.6, 8.1% contribution), cyanide (HQ = 1.7, 8.5% contribution), fluoride (HQ = 0.20, 1% contribution), hexavalent chromium (Cr(VI)) (HQ = 1.5, 7.7% contribution), lithium (HQ = 0.50, 2.5% contribution), manganese (HQ = 0.71, 3.5% contribution), nitrate (HQ = 0.23, 1.2% contribution), thallium (HQ = 0.52, 2.6% contribution), TCE (HQ = 1.2, 6.1% contribution), and vanadium (HQ = 0.16, 0.79% contribution). The EPC for thallium is 0.078 µg/L, which is less than the 90th percentile Hanford site background value of 1.67 µg/L. The HI without contribution from arsenic and thallium is 19, which is greater than the target HI of 1.

- 1,2,4-Trichlorobenzene: increased adrenal weights; vacuolization of zona fasciculata in the cortex
- 2-Propanol: decreased fetal body weight
- Aldrin: liver toxicity
- Bis(2-ethylhexyl) phthalate: increased relative liver weight
- Cyanide: decreased cauda epididymis weight in male F344/N rats
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity and heart malformations
- Vanadium: decreased hair cysteine

With the exception of exposure to 2-propanol and TCE, aldrin and bis(2-ethylhexyl) phthalate, fluoride and vanadium, and lithium and manganese, exposure to each of the analytes that contribute to the HI of 19 result in a different critical effect. As such, it is appropriate to segregate their contributions for each analyte. Combining the effects for 2-propanol and TCE results in a HI of 1.5, which is greater than the target HI of 1. Combining the effects for aldrin and bis(2-ethylhexyl) phthalate results in a HI of 11, which is greater than the target HI of 1. Combining the effects for fluoride and vanadium results in a HI of 0.36, which is less than the target HI of 1. Combining the effects for lithium and manganese results in a HI of 1.2, which is greater than the target HI of 1. Evaluating the analytes individually also results in an HI >1 cyanide and Cr(VI). Evaluating the remaining analytes individually results in an HI <1 for each contributor.

G5.1.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to groundwater as a source of steam in a sweat lodge is evaluated under the CTUIR scenario. Potential routes of exposure to steam generated from groundwater include inhalation of vaporized volatiles, semivolatiles, and aerosolized nonvolatiles and dermal contact with vaporized volatiles, semivolatiles, and nonvolatiles and condensed liquid while spending time in a sweat lodge. Table G-225 provides a summary of the cancer risk and noncancer hazard estimates by exposure route for the 100-KR-4 Groundwater OU. Additional detail including analyte-specific risk contributions are provided in Tables G-226 and G-227 and also in ECF-100KR4-17-0083.

Table G-225. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
Nonradionuclide Analytes	Inhalation in Sweat Lodge		Aldrin, (ELCR = 7.5×10^{-5}, 0.19%) Arsenic, (ELCR = 1.3×10^{-4}, 0.33%) Beryllium, (ELCR = 2.0×10^{-6}, 0.01%) Bis(2-ethylhexyl) phthalate, (ELCR = 4.0×10-5, 0.10%) Cadmium, (ELCR = 1.5×10^{-6}, 0.004%) Carbon-14, (ELCR = 7.4×10^{-4}, 1.9%) Cobalt, (ELCR = 2.5×10^{-5}, 0.06%) Hexavalent chromium, (ELCR = 3.7×10^{-2}, 96%) Nickel, (ELCR = 1.6×10^{-5}, 0.04%) Tritium, (ELCR = 3.9×10^{-4}, 1.0%) Uranium-233/234, (ELCR = 1.5×10^{-4}, 0.38%)		Arsenic, (HQ = 2.0, 3.9%) Barium, (HQ = 0.61, 1.2%) Bis(2-ethylhexyl) phthalate, (HQ = 0.15, 0.29%) Cobalt, (HQ = 0.47, 0.92%) Cyanide, (HQ = 0.14, 0.28%) Fluoride, (HQ = 0.12, 0.23%) Hexavalent chromium, (HQ = 5.0, 9.7%) Manganese, (HQ = 40, 78%) Nickel, (HQ = 0.72, 1.4%) Uranium, (HQ = 0.73, 1.4%) Vanadium, (HQ = 0.92, 1.8%)
	Volatile and Semivolatiles (vapor)	7.7×10^{-5}		0.27	
	Nonvolatile (aerosol)	3.7×10^{-2}		51	
	Total (Inh)	3.7×10^{-2}		51	
	Dermal Exposure in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor only)	3.7×10^{-7}		<0.01	
	Nonvolatile (vapor and aqueous condensate)	4.1×10^{-5}		0.62	
	Total (Dermal)	4.2×10^{-5}		0.62	
	Total Risk	3.7×10^{-2}		Total HI	51

Table G-225. CTUIR Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
Radionuclide Analytes	Inhalation in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor)	1.1×10^{-3}			
	Nonvolatile (aerosol)	2.8×10^{-4}			
	Total Risk	1.4×10^{-3}			
Total Cumulative ELCR [c]		3.9×10^{-2}			

a. Percent risk contribution listed for those contributors with an individual ELCR >1×10-4 (radionuclides) or individual ELCR >1×10-6 (chemicals).

b. Percent HI contribution listed for those contributors with an HQ >0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = not applicable.
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the 100-KR-4 Groundwater OU is 3.9×10^{-2}. The total ELCR for nonradiological analytes is 3.7×10^{-2}, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.4×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR are aldrin (ELCR = 7.5×10^{-5}, 0.19% contribution), beryllium (ELCR = 2.0×10^{-6}, 0.01% contribution), bis(2-ethylhexyl) phthalate (ELCR = 4.0×10^{-5}, 0.10% contribution), cadmium (ELCR = 1.5×10^{-6}, 0.004% contribution), carbon-14 (ELCR = 7.4×10^{-4}, 1.9% contribution), cobalt (ELCR = 2.5×10^{-5}, 0.06% contribution), Cr(VI) (ELCR = 3.7×10^{-2}, 96% contribution), nickel (ELCR = 1.6×10^{-5}, 0.04% contribution), tritium (ELCR = 3.9×10^{-4}, 1.0% contribution), and uranium-233/234 (ELCR = 1.5×10^{-4}, 0.38% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 1.3×10^{-4}, 0.33% contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 3.7×10^{-2}, which is greater than the 2013 MTCA (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI is 51, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI are arsenic (HQ = 2.0, 3.9% contribution), barium, (HQ = 0.61, 1.2% contribution), bis(2-ethylhexyl) phthalate, (HQ = 0.15, 0.29%), cobalt, (HQ = 0.47, 0.92% contribution), cyanide, (HQ = 0.14, 0.28% contribution), fluoride, (HQ = 0.12, 0.23% contribution), Cr(VI) (HQ = 5.0, 9.7% contribution), manganese (HQ = 40, 78% contribution), nickel, (HQ = 0.72, 1.4% contribution), uranium, (HQ = 0.73, 1.4% contribution), and vanadium, (HQ = 0.92, 1.8% contribution). The HI without contribution from arsenic is 49, which is greater than the target HI of 1.

The mechanisms of action (critical effect) for each of the analytes that contribute to the HI are as follows:

- Barium: nephropathy
- Bis(2-ethylhexyl) phthalate: increased relative liver weight
- Cobalt: thyroid, decreased iodine uptake
- Cyanide: decreased cauda epididymis weight in male F344/N rats
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Manganese: nervous system effects
- Nickel: decreased body and organ weight
- Uranium: initial body weight loss moderate and nephrotoxicity
- Vanadium: decreased hair cysteine

With the exception of exposure to barium and uranium, and fluoride and vanadium, exposure to each of the analytes that contribute to the HI of 1 result in a different critical effect. As such, it is appropriate to segregate the contribution to the HI for each analyte. Summing the HQs for barium and uranium results in a HQ of 1.3, which is greater than the target HI of 1. Summing the HQs for fluoride and vanadium results in an HQ of 1.0, which is equal to the target of 1. Evaluating Cr(VI) and manganese each individually results in an HI >1. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

G5.2 Summary of the Yakama Nation Groundwater Risk Assessment

This section summarizes the results for each of the exposure pathways associated with use of groundwater as a drinking water source and use of groundwater to generate steam in a sweat lodge.

G5.2.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to groundwater as a drinking water source is evaluated based on the Yakama Nation exposure scenario. Potential routes of exposure to groundwater include ingestion, dermal contact (nonradionuclides only), and inhalation of volatiles during household activities. Table G-228 provides a summary of the cancer risk and noncancer hazard estimates by exposure route for the 100-KR-4 Groundwater OU. Additional detail including analyte-specific risk contributions are provided in Tables G-229 and G-230 and also in ECF-100KR4-17-0083.

Table G-228. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
Nonradionuclides	Ingestion	7.0×10^{-4}	1,2,4-Trichlorobenzene, (ELCR = 2.1×10^{-6}, 0.01%) Aldrin, (ELCR = 4.7×10^{-3}, 23%) Arsenic, (ELCR = 3.4×10^{-4}, 1.6%) Bis(2-ethylhexyl) phthalate, (ELCR = 3.5×10^{-4}, 1.7%) Bromodichloromethane, (ELCR = 2.1×10^{-6}, 0.01%) Carbon tetrachloride, (ELCR = 8.9×10^{-6}, 0.04%) Carbon-14, (ELCR = 9.9×10^{-3}, 48%)	12	1,2,4-Trichlorobenzene, (HQ = 0.17, 0.71%) 2-Propanol, (HQ = 0.26, 1.1%) Aldrin, (HQ = 9.8, 40%) Antimony, (HQ = 0.10, 0.41%) Arsenic, (HQ = 1.5, 6.0%) Bis(2-ethylhexyl) phthalate, (HQ = 1.5,
	Dermal Contact	3.9×10^{-3}		10	
	Inhalation of Volatiles	7.9×10^{-4}		2.7	

Table G-228. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater as a Potential Drinking Water Source

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
			Chloroform, (ELCR = 9.8×10^{-6}, 0.05%) Ethylbenzene, (ELCR = 5.4×10^{-6}, 0.03%) Trichloroethene, (ELCR = 1.6×10^{-5}, 0.08%) Tritium, (ELCR = 5.2×10^{-3}, 25%)		6.3%) Bromomethane, (HQ = 0.12, 0.49%) Cobalt, (HQ = 0.14, 0.56%) Cyanide, (HQ = 1.9, 7.8%) Fluoride, (HQ = 0.38, 1.5%) Hexavalent chromium, (HQ = 2.6, 10%) Lithium, (HQ = 0.93, 3.8%) Manganese, (HQ = 1.3, 5.2%) Nitrate, (HQ = 0.43, 1.8%) Thallium, (HQ = 0.98, 4.0%) Trichloroethene, (HQ = 1.6, 6.4%) Uranium, (HQ = 0.14, 0.58%) Vanadium, (HQ = 0.28, 1.1%)
	Total Risk	5.4×10-3		Total HI	25
Radionuclides	Ingestion	5.1×10-4		--	
	Inhalation of Volatiles	1.5×10-2			
	Total Risk	1.5×10^{-2}			
Total Cumulative ELCR [c]		2.1×10^{-2}			

a. Percent risk contribution listed for those contributors with an individual ELCR $>1\times10^{-4}$ (radionuclides) or individual ELCR $>1\times10^{-6}$ (chemicals).

b. Percent HI contribution listed for those contributors with an HQ >0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

-- = not applicable
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the 100-KR-4 Groundwater OU is 2.1×10^{-2}. The total ELCR for nonradiological analytes is 5.4×10^{-3}, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.5×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to ELCR are 1,2,4-trichlorobenzene (ELCR = 2.1×10^{-6}, 0.01% contribution), aldrin (ELCR = 4.7×10^{-3}, 23% contribution), bis(2-ethylhexyl) phthalate (ELCR = 3.5×10^{-4}, 1.7%

contribution), bromodichloromethane (ELCR = 2.1×10^{-6}, 0.01% contribution), carbon-14 (ELCR = 9.9×10^{-3}, 48% contribution), carbon tetrachloride (ELCR = 8.9×10^{-6}, 0.04% contribution), chloroform (ELCR = 9.8×10^{-6}, 0.05% contribution), ethylbenzene (ELCR = 5.4×10^{-6}, 0.03% contribution), TCE (ELCR = 1.6×10^{-5}, 0.08% contribution), and tritium (ELCR = 5.2×10^{-3}, 25% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 3.4×10^{-4}, 1.6% contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 5.1×10^{-3}, which is greater than the 2013 MTCA (173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI is 25, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to HI are 1,2,4-trichlorobenzene (HQ =0.17, 0.71% contribution), 2-propanol (HQ = 0.26, 1.1% contribution), aldrin (HQ = 9.8, 40% contribution), antimony (HQ = 0.10, 0.41% contribution), arsenic (HQ = 1.5, 6.0% contribution), bis(2-ethylhexyl) phthalate (HQ = 1.5, 6.3% contribution), bromomethane (HQ = 0.12, 0.49% contribution), cobalt (HQ = 0.14, 0.56% contribution), cyanide (HQ = 1.9, 7.8% contribution), fluoride (HQ = 0.38, 1.5% contribution), Cr(VI) (HQ = 2.6, 10% contribution), lithium (HQ = 0.93, 3.8% contribution), manganese (HQ = 1.3, 5.2% contribution), nitrate (HQ = 0.43, 1.8% contribution), thallium (HQ = 0.98, 4.0% contribution), TCE (HQ = 1.6, 6.4% contribution), uranium (HQ = 0.14, 0.58% contribution), and vanadium (HQ = 0.28, 1.1% contribution). The EPC for thallium is 0.078 µg/L, which is less than the 90th percentile Hanford site background value of 1.67 µg/L. The HI without contribution from arsenic and thallium is 23, which is greater than the target HI of 1.

- 1,2,4-Trichlorobenzene: increased adrenal weights; vacuolization of zona fasciculata in the cortex
- 2-Propanol: decreased fetal body weight
- Aldrin: liver toxicity
- Antimony: longevity, blood glucose, and cholesterol
- Bis(2-ethylhexyl) phthalate: increased relative liver weight
- Bromomethane: epithelial hyperplasia of the forestomach and degenerative and proliferative lesions of the olfactory epithelium of the nasal cavity
- Cobalt: thyroid, decreased iodine uptake
- Cyanide: decreased cauda epididymis weight in male F344/N rats
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Lithium: nervous system and kidney effects
- Manganese: nervous system effects
- Nitrate: early clinical signs of methemoglobinemia
- TCE: developmental immunotoxicity and heart malformations
- Uranium: kidney effects
- Vanadium: decreased hair cysteine

With the exception of exposure to aldrin and bis(2-ethylhexyl) phthalate, bromomethane and Cr(VI), lithium and manganese, and lithium and uranium, exposure to each of the analytes that contribute to the HI of 23 result in a different critical effect. As such, it is appropriate to segregate their contributions for each analyte. Combining the effects for aldrin and bis(2-ethylhexyl) phthalate results in a HI of 11, which is greater than the target HI of 1. Combining the effects for bromomethane and Cr(VI) results in a HI of 2.7, which is greater than the target HI of 1. Combining the effects for lithium and manganese results in a HI of 2.2, which is greater than the target HI of 1. Combining the effects for lithium and uranium results in a HI of 1.1, which is greater than the target HI of 1. Evaluating the analytes individually also results in an HI >1 for aldrin, bis(2-ethylhexyl) phthalate, cyanide, Cr(VI), manganese, and TCE. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

G5.2.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to groundwater as a source of steam in a sweat lodge is evaluated under the Yakama Nation scenario. Potential routes of exposure to steam generated from groundwater while spending time in a sweat lodge include the following:

- inhalation of vaporized volatiles and semivolatiles *and* aerosolized nonvolatiles
- dermal contact with vaporized volatiles and semivolatiles, nonvolatiles in condensed liquid, *and* aerosolized nonvolatiles

or

- inhalation of vaporized volatiles, semivolatiles, *without* aerosolized nonvolatiles
- dermal contact with vaporized volatiles and semivolatiles and nonvolatiles in condensed liquid, *without* aerosolized nonvolatiles

Table G-231 provides a summary of the cancer risk and noncancer hazard estimates by exposure route for the 100-KR-4 Groundwater OU from use of groundwater in a sweat lodge (with aerosolized nonvolatile analytes). Additional detail including analyte-specific risk contributions are provided in Tables G-232 and G-233, and also in ECF-100KR4-17-0083. Table G-234 provides a summary of the cancer risk and noncancer hazard estimates by exposure route for the 100-KR-4 Groundwater OU from use of groundwater in a sweat lodge (without aerosolized nonvolatile analytes). Additional detail including analyte-specific risk contributions are provided in Tables G-233 and G-236, and also in ECF-100KR4-17-0083.

Table G-231. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (with Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
Nonradionuclide Analytes	Inhalation in Sweat Lodge		Aldrin (ELCR = 5.6×10^{-4}, 0.22%) Arsenic (ELCR = 9.6×10^{-4}, 0.37%) Beryllium (ELCR = 1.5×10^{-5}, 0.01%) Bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 0.11%) Bromodichloromethane (ELCR = 1.3×10^{-6}, 0.0005%) Cadmium (ELCR = 1.1×10^{-5}, 0.004%) Carbon tetrachloride (ELCR =		1,2,4-Trichlorobenzene (HQ = 0.12, 0.03%) 2-Propanol (HQ = 0.18, 0.05%) Aluminum (HQ = 0.55, 0.15%) Arsenic (HQ = 15, 3.9%) Barium (HQ = 4.5, 1.2%) Beryllium (HQ = 0.33, 0.09%) Bis(2-ethylhexyl) phthalate (HQ = 1.0,
	Volatile and Semivolatiles (vapor)	5.7×10^{-4}		2.0	
	Nonvolatile (aerosol)	2.5×10^{-1}		368	
	Total (Inh)	2.5×10^{-1}		370	
	Dermal Exposure in Sweat Lodge			--	

Table G-231. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (with Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution [a]	HI	% HI Contribution [b]
	Volatile and Semivolatiles (vapor only)	2.7×10^{-6}	2.4×10^{-6}, 0.0009%) Carbon-14 (ELCR = 5.6×10^{-3}, 2.1%) Chloroform (ELCR = 6.0×10^{-6}, 0.002%) Cobalt (ELCR = 1.9×10^{-4}, 0.07%) Ethylbenzene (ELCR = 2.3×10^{-6}, 0.0008%) Hexavalent chromium (ELCR = 2.5×10^{-1}, 95%) Nickel (ELCR = 1.2×10^{-4}, 0.05%) Strontium-90 (ELCR = 1.7×10^{-4}, 0.07%) Trichloroethene (ELCR = 4.5×10^{-6}, 0.002%) Tritium (ELCR = 2.9×10^{-3}, 1.1%) Uranium-233/234 (ELCR = 1.1×10^{-3}, 0.43%) Uranium-235 (ELCR = 1.2×10^{-4}, 0.05%) Uranium-238 (ELCR = 5.9×10^{-4}, 0.23%)	0.01	0.27%) Boron (HQ = 0.10, 0.03%) Cadmium (HQ = 0.63, 0.17%) Cobalt (HQ = 3.5, 0.92%) Cyanide (HQ = 1.0, 0.28%) Fluoride (HQ = 0.87, 0.23%) Hexavalent chromium (HQ = 36, 9.7%) Manganese (HQ = 292, 78%) Nickel (HQ = 5.3, 1.4%) Trichloroethene (HQ = 0.55, 0.15%) Uranium (HQ = 5.3, 1.4%) Vanadium (HQ = 6.7, 1.8%)
	Nonvolatile (vapor and aqueous condensate)	3.0×10^{-4}		4.3	
	Total (Dermal)	3.0×10^{-4}		4.3	
	Total Risk	2.5×10^{-1}		Total HI	374
Radionuclide Analytes	Inhalation in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor)	8.5×10^{-3}			
	Nonvolatile (aerosol)	2.1×10^{-3}			
	Total Risk	1.1×10^{-2}			
Total Cumulative ELCR [c]		2.6×10^{-1}			

a. Percent risk contribution listed for those contributors with an individual ELCR >1×10-4 (radionuclides) or individual ELCR >1×10-6 (chemicals).

b. Percent HI contribution listed for those contributors with an HQ >0.1.

c. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

-- = not applicable
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR *with* contributions from aerosolized nonvolatile analytes for the 100-KR-4 Groundwater OU is 2.6×10^{-1}. The total ELCR for nonradiological analytes *with* contributions from aerosolized nonvolatile analytes is 2.5×10^{-1}, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.1×10^{-2}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR *with* contributions from aerosolized nonvolatile analytes are aldrin (ELCR = 5.6×10^{-4}, 0.22%), beryllium (ELCR = 1.5×10^{-5}, 0.01%), bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 0.11%), bromodichloromethane (ELCR = 1.3×10^{-6}, 0.0005%), cadmium (ELCR = 1.1×10^{-5}, 0.004%), carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.0009%), carbon-14 (ELCR = 5.6×10^{-3}, 2.1%), chloroform (ELCR = 6.0×10^{-6}, 0.002%), cobalt (ELCR = 1.9×10^{-4}, 0.07%), ethylbenzene (ELCR = 2.3×10^{-6}, 0.0008%), Cr(VI) (ELCR = 2.5×10^{-1}, 95% contribution), nickel (ELCR = 1.2×10^{-4}, 0.05%), strontium-90 (ELCR = 1.7×10^{-4}, 0.07%), TCE (ELCR = 4.5×10^{-6}, 0.002%), tritium (ELCR = 2.9×10^{-3}, 1.1%), uranium-233/234 (ELCR = 1.1×10^{-3}, 0.43%), uranium-235 (ELCR = 1.2×10^{-4}, 0.05%), and uranium-238 (ELCR = 5.9×10^{-4}, 0.23%). Contribution to ELCR is elevated for arsenic (ELCR = 9.6×10^{-4}, 0.37% contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 2.5×10^{-1}, which is greater than the 2013 MTCA (173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI *with* contributions from aerosolized nonvolatile analytes is 374, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI *with* contributions from aerosolized nonvolatile analytes are 1,2,4-trichlorobenzene (HQ = 0.12, 0.03%), 2-propanol (HQ = 0.18, 0.05%), aluminum (HQ = 0.55, 0.15%), arsenic (HQ = 15, 3.9% contribution), barium (HQ = 4.5, 1.2%), beryllium (HQ = 0.33, 0.09%), bis(2-ethylhexyl) phthalate (HQ = 1.0, 0.27%), boron (HQ = 0.10, 0.03%), cadmium (HQ = 0.63, 0.17%), cobalt (HQ = 3.5, 0.92%), cyanide (HQ = 1.0, 0.28%), fluoride (HQ = 0.87, 0.23%), Cr(VI) (HQ = 36, 9.7% contribution), manganese (HQ = 292, 78% contribution), nickel (HQ = 5.3, 1.4%), TCE (HQ = 0.55, 0.15%), uranium (HQ = 5.3, 1.4%), and vanadium (HQ = 6.7, 1.8%). The HI without contribution from arsenic is 360, which is greater than the target HI of 1.

- 1,2,4-Trichlorobenzene: increased adrenal weights; vacuolization of zona fasciculata in the cortex
- 2-Propanol: decreased fetal body weight
- Barium: nephropathy
- Beryllium: small intestinal lesions
- Bis(2-ethylhexyl) phthalate: increased relative liver weight
- Boron: decreased fetal weight (developmental)
- Cadmium: significant proteinuria
- Cobalt: thyroid, decreased iodine uptake
- Cyanide: decreased cauda epididymis weight in male F344/N rats
- Fluoride: objectionable dental fluorosis, a cosmetic effect
- Cr(VI): nasal septum atrophy
- Manganese: nervous system effects
- Nickel: decreased body and organ weight
- TCE: developmental immunotoxicity and heart malformations
- Uranium: kidney effects
- Vanadium: decreased hair cysteine

With the exception of exposure to 2-propanol, boron and TCE, barium and uranium, and fluoride and vanadium, exposure to each of the analytes that contribute to the HI of 360 result in a different critical effect. As such, it is appropriate to segregate their contributions for each analyte. Combining the effects for 2-propanol, boron and TCE results in a HI of 0.83, which is less than the target HI of 1. Combining the effects for barium and uranium results in a HI of 10, which is greater than the target HI of 1. Combining the effects for fluoride and vanadium results in a HI of 7.6, which is greater than the target HI

of 1. Evaluating the analytes individually also results in an HI >1 for cobalt, Cr(VI), manganese, and nickel. Evaluating the remaining analytes individually results in an HI <1 for each contributor.

The total cumulative ELCR *without* contributions from aerosolized nonvolatile analytes for the 100-KR-4 Groundwater OU is 9.3×10^{-3}. The total ELCR for nonradiological analytes *without* contributions from aerosolized nonvolatile analytes is 8.7×10^{-4}, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes *without* contributions from aerosolized nonvolatile analytes is 8.5×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the ELCR *without* contributions from aerosolized nonvolatile analytes are aldrin (ELCR = 5.6×10^{-4}, 6.0% contribution), bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 3.1% contribution), bromodichloromethane (ELCR = 1.3×10^{-6}, 0.01% contribution), carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.03% contribution), carbon-14 (ELCR = 5.6×10^{-3}, 59% contribution), chloroform (ELCR = 6.0×10^{-6}, 0.06% contribution), ethylbenzene (ELCR = 2.3×10^{-6}, 0.02% contribution), TCE (ELCR = 4.5×10^{-6}, 0.05% contribution), and tritium (ELCR = 2.9×10^{-3}, 31% contribution). Contribution to ELCR is elevated for arsenic (ELCR = 9.6×10^{-6}, 0.1% contribution) where the EPC (3.5 µg/L) is less than the 90th percentile Hanford site background value of 7.85 µg/L. The ELCR for nonradiological analytes without contribution from arsenic is 8.7×10^{-4}, which is greater than the 2013 MTCA (173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

Table G-234. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (without Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclide Analytes	Inhalation in Sweat Lodge		Aldrin (ELCR = 5.6×10^{-4}, 6.0%) Arsenic (ELCR = 9.6×10^{-6}, 0.10%) Bis(2-ethylhexyl) phthalate (ELCR = 2.9×10^{-4}, 3.1%) Bromodichloromethane (ELCR = 1.3×10^{-6}, 0.01%) Carbon tetrachloride (ELCR = 2.4×10^{-6}, 0.03%) Carbon-14 (ELCR = 5.6×10^{-3}, 59%) Chloroform (ELCR = 6.0×10^{-6}, 0.06%) Ethylbenzene (ELCR = 2.3×10^{-6}, 0.02%) Trichloroethene (ELCR = 4.5×10^{-6}, 0.05%) Tritium (ELCR = 2.9×10^{-3}, 31%)		1,2,4-Trichlorobenzene (HQ = 0.12, 1.9%) 2-Propanol (HQ = 0.18, 2.9%) Bis(2-ethylhexyl) phthalate (HQ = 1.0, 16%) Cyanide (HQ = 1.0, 17%) Hexavalent chromium (HQ = 2.6, 41%) Manganese (HQ = 0.44, 7.0%) Trichloroethene (HQ = 0.55, 8.7%) Vanadium (HQ = 0.15, 2.3%)
	Volatile and Semivolatiles (vapor)	5.7×10^{-4}		2.0	
	Nonvolatile (aerosol)	-- [b]		--(b)	
	Total (Inh)	5.7×10^{-4}		2.0	
	Dermal Exposure in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor only)	2.7×10^{-6}		0.01	
	Nonvolatile (aqueous condensate)	3.0×10^{-4}		4.3	

Table G-234. Yakama Nation Exposure Scenario—Summary of Cancer Risk and Noncancer Hazard Estimates from Use of Groundwater in a Sweat Lodge (without Aerosolized Nonvolatile Analytes)

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
	Total (Dermal)	3.0×10^{-4}		4.3	
	Total Risk	8.7×10^{-4}		Total HI	6.3
Radionuclide Analytes	Inhalation in Sweat Lodge			--	
	Volatile and Semivolatiles (vapor)	8.5×10^{-3}			
	Nonvolatile (aerosol)	-- [b]			
	Total Risk	**8.5×10^{-3}**			
Total Cumulative ELCR [a]		9.3×10^{-3}			

a. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
b. The inhalation and dermal vapor contact exposure pathways are considered incomplete for nonvolatile contaminants.
-- = not applicable
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI *without* contributions from aerosolized nonvolatile analytes is 6.3, which is greater than the 2013 MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The primary contributors to the HI *without* contributions from aerosolized nonvolatile analytes are 1,2,4-trichlorobenzene, (HQ = 0.12, 1.9% contribution), 2-propanol, (HQ = 0.18, 2.9% contribution), bis(2-ethylhexyl) phthalate (HQ = 1.0, 16% contribution), cyanide (HQ = 1.0, 17% contribution), Cr(VI) (HQ = 2.6, 41% contribution), manganese (HQ = 0.44, 7.0% contribution), TCE (HQ = 0.55, 8.7% contribution), and vanadium (HQ = 0.15, 2.3% contribution). The HI without contribution from arsenic is 6.3, which is greater than the target HI of 1.

- 1,2,4-Trichlorobenzene: increased adrenal weights; vacuolization of zona fasciculata in the cortex
- 2-Propanol: decreased fetal body weight
- Bis(2-ethylhexyl) phthalate: increased relative liver weight
- Cyanide: decreased cauda epididymis weight in male F344/N rats
- Cr(VI): nasal septum atrophy
- Manganese: nervous system effects
- TCE: developmental immunotoxicity and heart malformations
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 6.3 result in a different critical effect. As such, it is appropriate to segregate their contributions for each analyte. Evaluating the analytes individually results in an HI >1 for Cr(VI). Evaluating the remaining analytes individually results in an HI <1 for each contributor.

G5.3 Comparison of Native American and EPA Tap Water Risk Characterization Results

A summary of the risk estimates and HIs for each of the Native American scenarios and the EPA tap water scenario is provided in Table G-237. Results are provided for ingestion, dermal contact, and inhalation of volatiles during household activities.

Exposure parameters for the Native American exposure scenarios and the EPA tap water scenario differ in exposure frequency (Native American 365 day/yr; EPA tap water 350 day/yr), exposure duration (Native American 70 years; EPA tap water 30 years), drinking water ingestion rate (Native American 4 L/day; EPA tap water 2 L/day), and inhalation rate (CTUIR 25 m^3/day, Yakama Nation 26 m^3/day; EPA tap water 20 m^3/day). As a result, the EPA tap water scenario has a lower total ELCR and HI than the Native American exposure scenarios.

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Table G-237. Comparison of Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Risk Assessments

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Inhalation of Volatiles		Dermal Contact with Water		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total ELCR	Primary Contributors to Risk	Total HI	Primary Contributors to HI
100- KR-4 Groundwater OU											
CTUIR [a]	Nonradiological	6.4×10^{-4}	6.1	7.9×10^{-4}	2.7	4.0×10^{-3}	11	5.4×10^{-3}	1,2,4-Trichlorobenzene (2.0×10^{-6}, 0.01%) Aldrin (4.7×10^{-3}, 23%) Arsenic (3.1×10^{-4}, 1.5%) Bis(2-ethylhexyl) phthalate (3.5×10^{-4}, 1.8%) Bromodichloromethane (2.1×10^{-6}, 0.01%) Carbon tetrachloride (8.5×10^{-6}, 0.04%) Carbon-14 (9.5×10^{-3}, 48%) Chloroform (9.7×10^{-6}, 0.05%) Ethylbenzene (5.3×10^{-6}, 0.03%) Trichloroethene (1.5×10^{-5}, 0.08%) Tritium (5.0×10^{-3}, 25%)	20	1,2,4-Trichlorobenzene (HQ = 0.17, 0.86%) 2-Propanol (HQ = 0.26, 1.3%) Aldrin (HQ = 9.8, 49%) Arsenic (HQ = 0.79, 4.0%) Bis(2-ethylhexyl) phthalate (HQ = 1.6, 8.1%) Cyanide (HQ = 1.7, 8.5%) Fluoride (HQ = 0.20, 1%) Hexavalent chromium (HQ = 1.5, 7.7%) Lithium (HQ = 0.50, 2.5%) Manganese (HQ = 0.71, 3.5%) Nitrate (HQ = 0.23, 1.2%) Thallium (HQ = 0.52, 2.6%) Trichloroethene (HQ = 1.2, 6.1%) Vanadium (HQ = 0.16, 0.79%)
	Radiological	5.0×10^{-4}	--	1.4×10^{-2}	--	--	--	1.5×10^{-2}		--	
	Total	1.1×10^{-4}	6.1	1.5×10^{-2}	2.7	4.0×10^{-3}	11	2.0×10^{-2}		20	
Yakama Nation [a]	Nonradiological	7.0×10^{-4}	12	7.9×10^{-4}	2.7	3.9×10^{-3}	10	5.4×10^{-3}	1,2,4-Trichlorobenzene (2.1×10^{-6}, 0.01%) Aldrin (4.7×10^{-3}, 23%) Arsenic (ELCR = 3.4×10^{-4}, 1.6%) Bis(2-ethylhexyl) phthalate (3.5×10^{-4}, 1.7%) Bromodichloromethane (2.1×10^{-6}, 0.01%) Carbon tetrachloride (8.9×10^{-6}, 0.04%) Carbon-14 (9.9×10^{-3}, 48%) Chloroform (9.8×10^{-6}, 0.05%) Ethylbenzene (5.4×10^{-6}, 0.03%) Trichloroethene (1.6×10^{-5}, 0.08%) Tritium (5.2×10^{-3}, 25%)	25	1,2,4-Trichlorobenzene (HQ = 0.17, 0.71%) 2-Propanol (HQ = 0.26, 1.1%) Aldrin (HQ = 9.8, 40%) Antimony (HQ = 0.10, 0.41%) Arsenic (HQ = 1.5, 6.0%) Bis(2-ethylhexyl) phthalate (HQ = 1.5, 6.3%) Bromomethane (HQ = 0.12, 0.49%) Cobalt (HQ = 0.14, 0.56%) Cyanide (HQ = 1.9, 7.8%) Fluoride (HQ = 0.38, 1.5%) Hexavalent chromium (HQ = 2.6, 10%) Lithium (HQ = 0.93, 3.8%) Manganese (HQ = 1.3, 5.2%) Nitrate (HQ = 0.43, 1.8%) Thallium (HQ = 0.98, 4.0%) Trichloroethene (HQ = 1.6, 6.4%) Uranium (HQ = 0.14, 0.58%) Vanadium (HQ = 0.28, 1.1%)
	Radiological	5.1×10^{-4}	--	1.5×10^{-2}	--	--	--	1.5×10^{-2}		--	
	Total	1.2×10^{-3}	12	1.6×10^{-2}	2.7	3.9×10^{-3}	10	2.1×10^{-2}		25	
EPA Tap Water [b]	Nonradiological	1.4×10^{-4}	4.6	2.8×10^{-4}	2.6	1.4×10^{-3}	11	1.8×10^{-3}	Aldrin (1.6×10^{-3}, 28%) Arsenic (6.9×10^{-5}, 1.2%) Bis(2-ethylhexyl) phthalate (1.2×10^{-4}, 2.2%) Carbon tetrachloride (2.4×10^{-6}, 0.043%) Chloroform (3.3×10^{-6}, 0.059%) Ethylbenzene (1.7×10^{-6}, 0.030%) TCE (4.3×10^{-6}, 0.077%) Carbon-14 (2.5×10^{-3}, 44%) Tritium (1.3×10^{-3}, 23%)	18	1,2,4-Trichlorobenzene (HQ = 0.16, 0.91%) 2-Propanol (HQ = 0.25, 1.4%) Aldrin (HQ = 9.2, 52%) Arsenic (HQ = 0.59, 3.3%) Bis(2-ethylhexyl) phthalate (HQ = 1.5, 8.6%) Cyanide (HQ = 1.6, 8.9%) Fluoride (HQ = 0.15, 0.85%) Cr(VI) (HQ = 1.2, 6.8%) Lithium (HQ = 0.37, 2.1%) Manganese (HQ = 0.54, 3.0%) Nitrate (HQ = 0.17, 0.97%) Thallium (HQ = 0.39, 2.2%) TCE (HQ = 1.1, 6.0%) Vanadium (HQ = 0.12, 0.69%)
	Radiological	1.0×10^{-4}	--	3.7×10^{-3}	--	2.1×10^{-10}	--	3.8×10^{-3}		--	
	Total	2.4×10^{-4}	4.6	4.0×10^{-3}	2.6	1.4×10^{-3}	--	5.6×10^{-3}		18	

a. ECF-100KR4-17-0083, *Native American Risk Assessments for the 100-KR-4 Groundwater Operable Unit*.
b. ECF-100KR4-17-0082, *Well-Specific Tap Water Risk Assessment for the 100-KR-4 Groundwater Operable Unit*.
ELCR = excess lifetime cancer risk
HI = hazard index

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Appendix H

Ecological Risk Assessment Supporting Documentation

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Supporting Information

The following supporting information is contained on the removable media.

Environmental Calculations

ECF-100KR1-11-0010	*Ecological Risk Evaluation for the 100-K-1 and 100-KR-2 Source Operable Units*
ECF-HANFORD-11-0158	*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site*

Standard

DOE-STD-1153-2002	*A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, Module 1 – Principles and Application*

Other Documents

CH2M HILL, 2018	*Potential for the Presence of Two Federal Threatened Species (White Bluffs Bladderpod and Umtanum Desert Buckwheat) within Hanford Site, 100-K Source Operable Units*
CHPRC-00784	*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*
CHPRC-01311	*Tier 2 Risk Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*
Nautilus, 2011	*Evaluation of the Role of Hardness in Modifying the Toxicity of Nitrate to Rainbow Trout*
Nautilus, 2013	*Evaluation of the Role of Hardness in Modifying the Toxicity of Nitrate to Freshwater Organisms*

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Terms

AUF	area use factor
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
EPC	exposure point concentration
NEPA	National Environmental Policy Act
PRG	preliminary remediation goal
RCBRA	*River Corridor Baseline Risk Assessment*
SMDP	scientific management decision point
SOF	sum of fractions
SSL	soil screening level

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H1 Introduction

This appendix provides supporting documentation for ecology-related information presented in Chapter 7 of this report. Details include flora and fauna lists potentially onsite or in the county, risk evaluation tables, and other related information described in the following sections. This appendix also contains environmental calculations and standards along with their associated tables, as listed in the contents section. Supporting documents that are available on removable media and at the administrative record links are as follows:

- ECF-100KR1-11-0010, 2018, *Ecological Risk Evaluation for the 100-K-1 and 100-KR-2 Source Operable Units*, Rev. 0. (Attached removable media.)
- ECF-HANFORD-11-0158, 2014, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site*, Rev. 1. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081636H.
- DOE-STD-1153-2002, 2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota, Module 1 – Principles and Application.* Available at: https://www.standards.doe.gov/standards-documents/1100/1153-AStd-2002.
- CHPRC-00784, 2014, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*, Rev. 0. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081638H.

  CHPRC-01311, 2014, *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*, Rev. 2. Available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0068835H.

H2 Sample Locations

This section contains the sample locations for the contaminants of potential ecological concern at waste sites identified in the scientific management decision point (SMDP), as shown in Figures H-1 through H-46.

H3 Terrestrial Ecological Risk Evaluation

This section contains the terrestrial ecological risk evaluation calculations presented in Tables H-1 through Table H-18 as referenced in Chapter 7 of this report. Tables H-1 through H-17 listed in the Table of Contents are in electronic format and recorded on the USB included with this appendix.

Tables H-1 through H-6 present the supporting documentation of the values included in the terrestrial ecological risk evaluation (toxicity reference values, exposure factors, bioconcentration factors, and area use factors [AUFs]). Tables H-7 through H-17 present the ecological risk calculations. These tables include the soil exposure point concentration (EPC) comparison to soil screening levels (SSLs), background concentrations, and preliminary remediation goals (PRGs) for each waste site.

H4 Flora and Fauna Occurrence

This section includes a brief discussion of the fauna occurring or potentially occurring on the Hanford Site, as referenced in Chapter 3 of this report. Table H-18 contains the functional type, scientific name, common name, habitat type, and whether data are available to identify the species at the Hanford Site.

Wildlife use of habitat overlaps considerably between the riparian and upland zones. Use of the riparian zone is likely higher than that of the upland zone associated with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) waste sites because of its proximity to the Columbia River. River access results in greater species diversity and the presence of higher density and higher stature vegetation that remains productive over a longer period of time (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*, hereinafter called RCBRA). Species lists have been compiled for the major classes of vertebrates that have been observed on the Hanford Site or within the Hanford Reach of the Columbia River and include 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and more than 45 species of fish (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*). For invertebrates, a total of 1,509 species-level identifications have been completed, and the collection of 40,000 specimens has resulted in the identification of 43 new taxa and 142 new findings in the State of Washington (Soll et al., 1999, *Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999*). The high diversity of insect species on the Hanford Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat. Table H-16 presents an extensive list of species known or with potential to occur on the Hanford Site classified by habitat type.

Terrestrial mammals of the upland environment that might be found in and adjacent to the 100 and 300 Areas include mule deer (*Odocoileus hemionus*), badger (*Taxidea taxus*), coyote (*Canis latrans*), Great Basin pocket mouse (*Perognathus parvus*), northern pocket gopher (*Thomomys talpoides*), black-tailed jackrabbit (*Lepus californicus*), and cottontail rabbit (*Sylvilagus nuttalii*) (WHC-EP-0620, *100 Areas CERCLA Ecological Investigations*). The abundance of these species and the occurrence of others vary according to the soil type and vegetative community. While other large mammals, such as elk (*Cervus elaphus*), are infrequently observed in the 100 and 300 Areas upland reactor areas, the number of individual large mammals present per unit area may increase as habitat quality and shrub cover improve through natural recovery and waste site restoration. Because most of the site is dominated by shrub-steppe, the Hanford mammal community is representative of upland species that occur in shrub-steppe habitats. Habitat generalists, such as the ubiquitous coyote (*Canis latrans*), mule deer (*Odocoileus hemionus*), deer mouse (*Peromyscus maniculatis*), and Great Basin pocket mouse (*P. parvus*) can be found in many different habitats (DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*).

Nine bat species were identified at the Hanford Site during The Nature Conservancy surveys in 1997 and 1998, and an additional eight species were listed as potentially present (Soll et al., 1999). Eleven bat roosts have been identified; however, none of the roosts have been identified within the 100-K Area (HNF-56359, *Hanford Site Summer Bat Monitoring Report for Calendar Year 2013*). Roosts along the River Corridor, including maternity colonies of Yuma myotis (*Myotis yumanensis*) and pallid bats (*Antrozous pallidus*), were at the 100-F and 100-D/H Areas (WCH-512, *2011 River Corridor Closure Contractor Revegetation and Mitigation Monitoring Report*).

Several species of birds present in the upland zones rely on structures such as buildings, fences, and utility poles for some of their habitat needs. Raptors, such as red-tailed hawk (*Buteo jamaicensis*), are present and frequently nest on buildings, utility poles and towers, and trees along the river. Nonvegetated areas provide nesting habitat for nighthawks (*Chordeiles minor*) and killdeer (*Charadrius vociferus*). Canada geese (*Branta canadensis*) use open cheatgrass areas for winter grazing. Following restoration, improvements in shrub coverage will provide important habitat for native shrub-steppe bird species such as the horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), savannah sparrow (*Passerculus sandwichensis*), loggerhead shrike (*Lanius ludovicianus*), and possibly sage sparrow (*Amphispiza belli*). Raptors will continue to be present, but as the shrubs develop and the open grassy areas shrink in size, wintering geese will likely avoid the area, preferring the cheatgrass areas associated with nearby abandoned

farm fields and orchards. A list of bird species observed in the 100 Area is available in WHC-EP-0620. A catalogue of Hanford Site avian species is presented in PNNL-6415.

Research efforts have assessed winter bird populations in cottonwood/willow (*Populus*/*Salix*) communities of the Columbia River shoreline (Rickard, 1964, "A Vagrant Occurrence of the Black Phoebe in Southeastern Washington"; Rickard and Rickard, 1972, "Comparison of Winter Bird Populations After a Decade"), and quantified shorebird response to water fluctuations in the Columbia River nearshore environment (Books, 1985, "Avian Interactions with Mid-Columbia River Water Level Fluctuations"). The information gathered during these research efforts has been used to document the status and ecology of the Hanford Site's avian wildlife.

Common reptiles found in upland environments at the Hanford Site include the rattlesnake (*Crotalus viridis*), gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and side blotch lizard (*Uta stansburiana*) (PNL-8942, *Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern*; WHC-EP-0601, *A Synthesis of Ecological Data from the 100 Areas of the Hanford Site*). A variety of snakes common to the upland areas may also use the riparian habitat. Other reptiles that may be found in the riparian zone include the western terrestrial garter snake (*Thamnophis sirtalis*) and the painted turtle (*Chrysemys picta*) (Hallock, 1998, *Herpetofauna of the Hanford Nuclear Reservation, Grant, Franklin and Benton Counties, Washington*). Amphibians in the riparian and near-shore environments of the Hanford Reach include mostly Woodhouse's toads (*Bufo woodhousii*), but bullfrogs (*Rana catesbeiana*) and Great Basin spadefoot toads (*Scaphiopus intermontanus*) have been documented (HNF-56676, *Hanford Site Anuran Monitoring Report for Calendar Year 2013*).

The dominant ground-dwelling invertebrate species in the upland environment are harvester ants (*Pogonomyrmex owyheei*) and darkling beetles (family *Tenebrionidae*). Harvester ants can exist on vegetated and nonvegetated soils and have been documented on waste sites (PNL-2774, *Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport*). Darkling beetles, however, rely on vegetative matter in the soil during their larval stage and, therefore, are not expected to occur in areas void of vegetation (PNL-2465, *Darkling Beetle Populations (Tenebrionidae) of the Hanford Site in Southcentral Washington*). Areas that were not used as waste sites or have not been affected by Hanford Site operations likely have less soil disturbance and may support a more robust and diverse community of soil-dwelling fauna than previously disturbed or remediated sites.

More than 45 species of fish have been identified in the Hanford Reach of the Columbia River. Of these species, Chinook salmon (*Oncorhynchus tshawytscha*), Sockeye salmon (*Oncorhynchus nerka*), Coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Other fish of importance to sport anglers are the native mountain whitefish (*Prosopium williamsoni*) and white sturgeon (*Acipenser transmontanus*). Introduced species like smallmouth bass (*Micropterus dolomieui*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizostedion vitreum*) are also popular. Other large fish populations include introduced common carp (*Cyprinus carpio*) and native species such as redside shiner (*Richardsonius balteatus*) and largescale suckers (*Catostomus macrocheilus*). Smaller fish, such as sculpin (*Cottus* sp.), are associated with shoreline habitats and have small home ranges (RCBRA Report [DOE/RL-2007-21]).

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Avian Herbivore					
Callipepla californica	California quail	X	X		X
Branta Canadensis moffitti	Canada goose	X	X	X	
Eremophila alpestris	Horned lark				X
Anas platyrhynchos	Mallard	X	X	X	
Zenaida macroura	Mourning dove	X	X		X
Melospiza melodia	Song sparrow	X	X		X
Avian Predator					
Recurvirostra Americana	American avocet	X	X		
Fulica Americana	American coot	X		X	
Corvus brachyrhynchos	American crow	X	X		X
Carduelis tristis	American goldfinch	X	X		X
Falco sparverius	American kestrel	X	X		X
Anthus rubescens	American pipit	X			X
Turdus migratorius	American robin	X	X		X
Spizella arborea	American tree sparrow	X	X		X
Pelecanus erythrorhynchos	American white pelican	X	X	X	
Anas Americana	American wigeon	X		X	
Haliaeetus leucocephalus	Bald eagle	X	X		X
Riparia riparia	Bank swallow	X	X		X
Tyto alba	Barn owl	X	X		X
Hirundo rustica	Barn swallow	X	X		X
Bucephala islandica	Barrow's goldeneye	X		X	
Ceryel alcyon	Belted kingfisher	X	X	X	
Thryomanes bewickii	Bewick's wren	X	X		
Sayomis nigricans	Black phoebe	X			X
Pica hudsonia	Black-billed magpie	X	X		X
Nycticorax nycticorax	Black-crowned night heron	X	X	X	
Pheucticus melanocephalus	Black-headed grosbeak	X	X		X
Amphispiza bilineata	Black-throated sparrow	X			X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Anas discors	Blue-winged teal	X		X	
Vireo solitaries	Blue-headed vireo	X	X		
Euphagus cyanocephalus	Brewer's blackbird	X	X		X
Spizella breweri	Brewer's sparrow	X			X
Molothrus ater	Brown-headed cowbird	X	X		X
Bucephala albeola	Bufflehead	X		X	
Icterus galbula	Bullock's oriole	X	X		X
Athene cunicularia hypugea	Burrowing owl	X			X
Larus californicus	California gull	X		X	
Aythya valisineria	Canvasback	X		X	
Catherpes mexicanus	Canyon wren	X			X
Sterna caspia	Caspian tern	X		X	
Carpodacus cassinii	Cassin's finch	X			X
Bombycilla cedrorum	Cedar waxwing	X	X		X
Spizella passerine	Chipping sparrow	X	X		X
Alectoris chukar	Chukar	X			X
Anas cyanoptera	Cinnamon teal	X		X	
Hirundo pyrrhonota	Cliff swallow	X	X		X
Bucephala clangula	Common goldeneye	X		X	
Gavia immer	Common loon	X		X	
Mergus merganser	Common merganser	X		X	
Chordeiles minor	Common nighthawk	X	X		X
Phalaenoptilus nuttallii	Common poorwill	X	X		
Corvus corax	Common raven	X	X		X
Carduelis flammea	Common redpoll	X			X
Gallinago gallinago	Common snipe	X	X		
Accipiter cooperii	Cooper's hawk	X	X		X
Junco hyemalis	Dark-eyed junco	X	X		X
Phalacrocorax auritus	Double-crested cormorant	X		X	
Picoides pubescens	Downy woodpecker	X	X		X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Calidris alpine	Dunlin	X	X		
Podiceps nigricollis	Eared grebe	X		X	
Tyrannus tyrannus	Eastern kingbird	X	X		X
Empidonax spp.	Empidonax flycatcher	X	X		X
Sturnus vulgaris	European starling	X			X
Coccothraustes vespertinus	Evening grosbeak	X			X
Buteo regalis	Ferruginous hawk	X			X
Sterna forsteri	Forster's tern	X		X	
Passerella iliaca	Fox sparrow	X	X		X
Anas strepera	Gadwall	X		X	
Larus glaucescens	Glaucous-winged gull	X		X	
Aquila chrysaetos	Golden eagle	X			X
Regulus satrapa	Golden-crowned kinglet	X	X		X
Zonotrichia atricapilla	Golden-crowned sparrow	X	X		X
Ammodramus savannarum	Grasshopper sparrow	X			X
Perdix perdix	Grey partridge	X			X
Leucosticte tephrocotis	Gray-crowned rosy-finch	X			X
Ardea herodias	Great blue heron	X	X	X	
Casmerodius albus	Great egret	X	X	X	
Bubo virginianus	Great horned owl	X	X		X
Aythya marila	Greater scaup	X		X	
Tringa melanoleuca	Greater yellowlegs	X		X	
Anas crecca	Green-winged teal	X		X	
Empidonax hammondii	Hammond's flycatcher	X	X		X
Larus argentatus	Herring gull	X		X	X
Catharus guttatus	Hermit thrush	X	X		X
Lophodytes cucullatus	Hooded merganser	X		X	
Podiceps auritus	Horned grebe	X		X	
Carpodacus mexicanus	House finch	X	X		X
Passer domesticus	House sparrow	X	X		X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Troglodytes aedon	House wren	X	X		X
Charadrius vociferous	Killdeer	X	X		X
Calcarius lapponicus	Lapland longspur	X			X
Chondestes grammacus	Lark sparrow	X			X
Passerina amoena	Lazuli bunting	X			X
Aythya affinis	Lesser scaup	X		X	
Tringa flavipes	Lesser yellowlegs	X		X	
Melanerpes lewis	Lewis's woodpecker	X	X		X
Melospiza lincolnii	Lincoln's sparrow	X	X		X
Lanius ludovicianus	Loggerhead shrike	X			X
Numenius americanus	Long-billed curlew	X			X
Limnodromus scolopaceus	Long-billed dowitcher	X		X	
Asio otus	Long-eared owl	X	X		X
Oporornis tolmiei	MacGillivray's warbler	X	X		X
Cistothorus palustris	Marsh wren	X	X		X
Falco columbarius	Merlin	X			X
Sialia currucoides	Mountain bluebird	X			X
Vermivora ruficapilla	Nashville warbler	X	X		X
Colaptes auratus	Northern flicker	X	X		X
Accipiter gentilis	Northern goshawk	X			X
Circus cyaneus	Northern harrier	X			X
Mimus polyglottos	Northern mockingbird	X			X
Anas acuta	Northern pintail duck	X		X	
Stelgidopteryx serripennis	Northern rough-winged swallow	X	X		X
Anas clypeata	Northern shoveler	X		X	
Lanius excubitor	Northern shrike	X			X
Contopus borealis	Olive-sided flycatcher	X	X		X
Vermivora celata	Orange-crowned warbler	X	X		X
Pandion haliaetus	Osprey	X	X	X	
Empidonax difficilis	Pacific-slop flycatcher	X	X		

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Falco peregrines anatum	Peregrine falcon	X		X	X
Podilymbus podiceps	Pied-billed grebe	X		X	
Falco mexicanus	Prairie falcon	X			X
Mergus serrator	Red-breasted merganser	X		X	
Sitta Canadensis	Red-breasted nuthatch	X			X
Aythya Americana	Redhead	X		X	
Sphyrapicus nuchalis	Red-naped sapsucker	X	X		X
Podiceps grisegena	Red-necked grebe	X		X	
Phalaropus lobatus	Red-necked phalarope	X			
Buteo jamaicensis	Red-tailed hawk	X			X
Agelaius phoeniceus	Red-winged blackbird	X	X		X
Larus delawarensis	Ring-billed gull	X	X		
Aythya collaris	Ring-necked duck	X		X	
Phasianus colchicus	Ring-necked pheasant	X	X		X
Columbia livia	Rock dove	X			X
Salpinctes obsoletus	Rock wren	X			X
Buteo lagopus	Rough-legged hawk	X			X
Regulus calendula	Ruby-crowned kinglet	X	X		X
Oxyura jamaicensis	Ruddy duck	X		X	
Selasphorus rufus	Rufous hummingbird	X	X		X
Amphispiza belli	Sage sparrow	X			X
Oreoscoptes montanus	Sage thrasher	X			X
Grus Canadensis	Sandhill crane	X	X		
Passerculus sandwichensis	Savannah sparrow	X			X
Sayornis saya	Say’s phoebe	X			X
Accipiter striatus	Sharp-shinned hawk	X	X		X
Asio flammeus	Short-eared owl	X			X
Tringa solitaria	Solitary sandpiper	X		X	
Porzana carolina	Sora	X	X	X	
Pipilo erythrophthalmus	Spotted towhee	X	X		X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Actitis macularia	Spotted sandpiper	X		X	
Buteo swainsoni	Swainson's hawk	X			X
Myadestes townsendi	Townsend's solitaire	X	X		X
Dendroica townsendi	Townsend's warbler	X	X		
Tachycineta bicolor	Tree swallow	X	X	X	
Cygnus columbianus	Tundra (Whistling) swan	X		X	
Ixoreus naevius	Varied thrush	X	X		X
Pooecetes gramineus affinis	Vesper sparrow	X			X
Tachycineta thalassina	Violet-green swallow	X	X		X
Rallus limicola	Virginia rail	X	X	X	
Vireo gilvus	Warbling vireo	X	X		X
Sialia Mexicana	Western bluebird	X			X
Aechmophorus occidentalis	Western grebe	X		X	
Tyrannus verticalis	Western kingbird	X	X		X
Sturnella neglecta	Western meadowlark	X	X		X
Calidris mauri	Western sandpiper	X		X	
Piranga ludoviciana	Western tanager	X	X		X
Contopus sordidulus	Western wood-pewee	X	X		X
Zonotrichia leucophrys	White-crowned sparrow	X	X		X
Wilsonia pusilla	Wilson's warbler	X	X		X
Troglodytes hiemalis	Winter wren	X	X		X
Aix sponsa	Wood duck	X		X	
Dendroica petechia	Yellow warbler	X	X		X
Icteria virens	Yellow-breasted chat	X	X		
Xanthocephalus xanthocephalus	Yellow-headed blackbird	X	X		X
Dendroica coronata	Yellow-rumped warbler	X	X		X
Benthic Biota					
Pacifasticus leniusculus	Crayfish	X		X	
Anodonta californiensis	California floater (mussel)			X	
Anodonta kennerlyi	Western floater (mussel)			X	

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Anodonta kennerlyi	Winged floater (mussel)			X	
Anodonta oregonensis	Oregon floater (mussel)			X	
Corbicula fluminea	Asiatic clam	X		X	
Gonidea angulata	Western ridged mussel			X	
Margaritifera falcate	Western pearlshell mussel			X	
Fisherola nuttalli	Shortface lanx			X	
Fulminicola columbianus	Columbia pebblesnail			X	
Pisidium sp.	Peaclam			X	
Gyraulus sp.	Snail			X	
Limnaea sp.	Snail			X	
Physa sp.	Snail			X	
Radix sp.	Snail			X	
Stagnicola sp.	Pondsnail			X	
Carnivorous Reptiles and Amphibians					
Rana catesbeiana	Bullfrog	X	X		X
Pituophis catenifer deserticola	Great Basin gopher snake	X	X		X
Scaphiopus intermontanus	Great basin spadefoot toad	X			X
Hypsiglena torquata	Night snake				X
Sceloporus graciosus	Northern sagebrush lizard	X			X
Hyla regilla	Pacific tree frog		X		
Chrysemys picta	Painted turtle		X	X	
Pseudacris regilla	Pacific Treefrog		X		
Phrynosoma douglassii	Short-horned lizard				X
Uta stansburiana	Side-blotched lizard	X			X
Charina bottae	Rocky Mountain rubber boa		X		
Ambystoma tigrinum	Tiger salamander			X	
Crotalus viridis	Western rattlesnake	X			X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Thamnophis sirtalis	Western terrestrial garter snake		X	X	
Coluber constrictor	Western yellow-bellied racer	X	X		X
Bufo woodhousei	Woodhouse's toad	X	X		X
Fish Herbivore					
Cyprinus carpio	Common carp	X		X	
Catostomus columbianus	Bridgelip sucker			X	
Catostomus macrocheilus	Largescale sucker			X	
Fish Predator					
Alosa sapidissima	American shad			X	
Ameiurus melas	Black bullhead			X	
Pomoxis nigromaculatus	Black crappie			X	
Ictalurus furcatus	Blue catfish			X	
Lepomis macrochirus	Bluegill	X		X	
Ameiurus nebulosus	Brown bullhead	X		X	
Salvelinus confluentus	Bull trout			X	
Lota lota	Burbot			X	
Ictalurus punctatus	Channel catfish			X	
Oncorhynchus tshawytscha	Chinook salmon	X		X	
Acrocheilus alutaceus	Chiselmouth	X		X	
Oncorhynchus kisutch	Coho salmon	X		X	
Oncorhynchus clarkia	Cutthroat trout			X	
Salvelinus malma	Dolly Varden			X	
Coregonus clupeaformis	Lake whitefish			X	
Micropterus salmoides	Largemouth bass			X	
Rhinichthys falcatus	Leopard dace			X	
Rhinichthys cataractae	Longnose dace			X	
Gambusia affinis	Western mosquitofish			X	
Cottus bairdii	Mottled sculpin			X	
Prosopium williamsoni	Mountain whitefish	X		X	
Catostomus platyrhynchus	Mountain sucker			X	

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Pungitius pungitius	Nine spine stickleback			X	
Ptychocheilus oregonensis	Northern pikeminnow	X		X	
Lampetra tridentata	Pacific lamprey	X		X	
Mylocheilus caurinus	Peamouth	X		X	
Cottus beldingii	Piute sculpin			X	
Cottus asper	Prickly sculpin	X		X	
Lepomis gibbosus	Pumpkinseed	X		X	
Oncorhynchus mykiss	Rainbow trout (steelhead)			X	
Richardsonius balteatus	Redside shiner	X		X	
Cottus perplexus	Reticulate sculpin			X	
Lampetra ayresii	River lamprey			X	
Percopsis transmontana	Sand roller			X	
Micropterus dolomieu	Smallmouth bass	X		X	
Oncorhynchus nerka	Sockeye salmon	X		X	
Rhinichthys osculus	Speckled (Spotted) dace	X		X	
Gasterosteus aculeatus	Threespine stickleback	X		X	
Cottus rhotheus	Torrent sculpin			X	
Sander vitreus	Walleye	X		X	
Pomoxis annularis	White crappie			X	
Acipenser transmontanus	White sturgeon			X	
Ameiurus natalis	Yellow bullhead			X	
Perca flavescens	Yellow perch	X		X	
Mammal Herbivore					
Castor canadensis	Beaver		X	X	
Lepus californicus	Black-tailed jackrabbit	X			X
Neotoma cinerea	Bushy-tailed woodrat	X			X
Cervus elaphus	Rocky Mountain elk	X	X		X
Perognathus parvus	Great Basin pocket mouse	X	X		X
Tamias minimus	Least chipmunk				X
Microtus montanus	Montane vole	X			X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Odocoileus hemionus	Mule deer	X	X		X
Ondatra zibethica	Muskrat		X	X	
Thomomys talpoides	Northern pocket gopher	X			X
Sylvilagus nuttallii	Nuttall's (or mountain) cottontail	X			X
Erethizon dorsatum	Porcupine		X		
Lemmiscus curtatus	Sagebrush vole	X			X
Urocitellus townsendii (formally *Spermophilus townsendii*)	Townsend's ground squirrel	X			X
Urocitellus washingtoni (formally *Spermophilus washingtoni*)	Washington ground squirrel				X
Reithrodontomys megalotis	Western harvest mouse	X	X		X
Odocoileus virginianus	White-tailed deer		X		
Lepus townsendii	White-tailed jackrabbit				X
Marmota flaviventris	Yellow-bellied marmot				X
Mammal Predator					
Taxidea taxus	Badger				X
Eptesicus fuscus	Big brown bat	X	X		X
Lynx rufus	Bobcat		X		X
Canis latrans	Coyote	X			X
Peromyscus maniculatus	Deer mouse	X	X		X
Lasiurus cinereus	Hoary bat	X	X		X
Mus musculus	House mouse	X	X		
Myotis rolans	Long-legged myotis (bat)	X	X		X
Myotis lucifugus	Little brown myotis (bat)	X	X		X
Mustela frenata	Long-tailed weasel		X		
Sorex merriami	Merriam's shrew				X
Mustela vison	Mink		X		
Puma concolor	Mountain lion				X
Onychomys leucogaster	Northern grasshopper mouse	X			X

Table H-18. Species Known or Potentially Occurring on the Hanford Site Classified by Primary Functional and Habitat Type

Scientific Name	Common Name	Hanford Location Data	Habitat Type		
			Riparian	Aquatic	Upland
Rattus norvegicus	Norway rat		X		X
Antrozous pallidus	Pallid bat	X	X		X
Procyon lotor	Raccoon		X		
Lutra canadensis	River otter		X	X	
Mustela erminea	Short-tail weasel		X		
Lasionycteris noctivagans	Silver-haired bat	X	X		X
Mephitis mephitis	Striped skunk		X		
Sorex vagrans	Vagrant shrew		X		
Pipistrellus Hesperus	Western pipistrelle (bat)	X	X		X
Myotis leibii	Western small-footed myotis (bat)	X			X
Myotis yumanensis	Yuma myotis (bat)	X	X		X

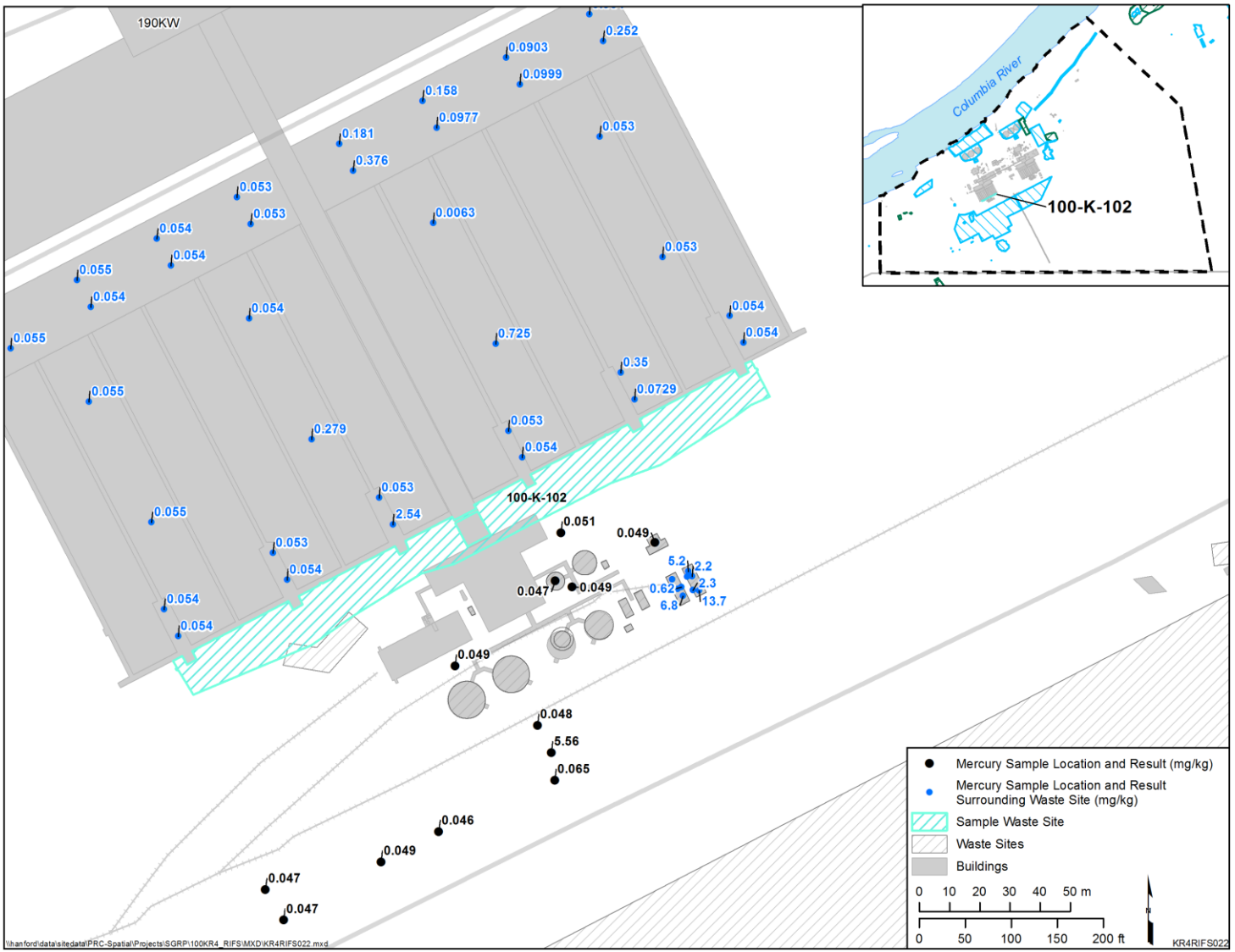


Figure H-1. French Drains and Mercury Stained Soils near the 183KW Sedimentation Basin (100-K-102_Shallow_1) Sampling Locations and Associated Mercury Results

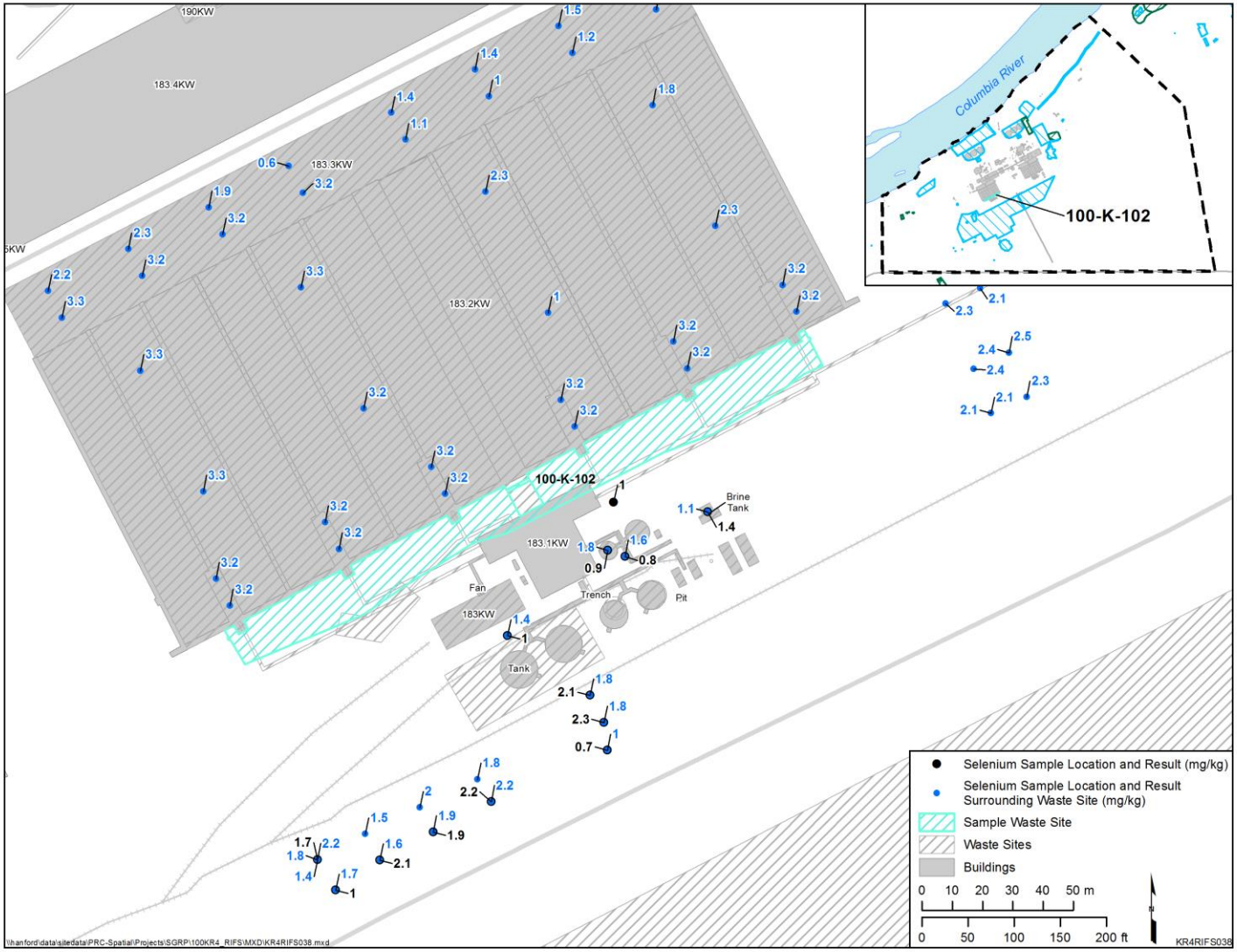
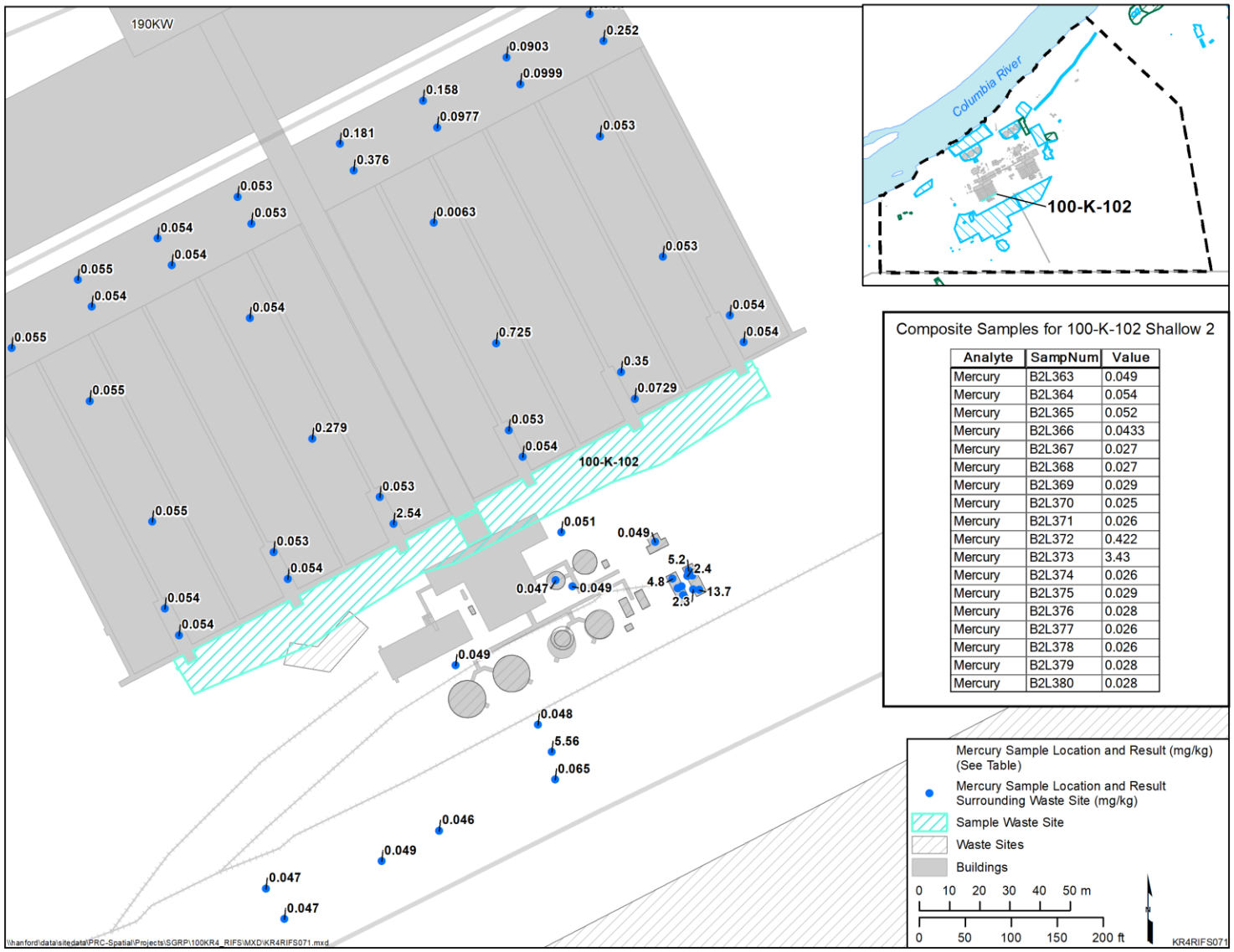


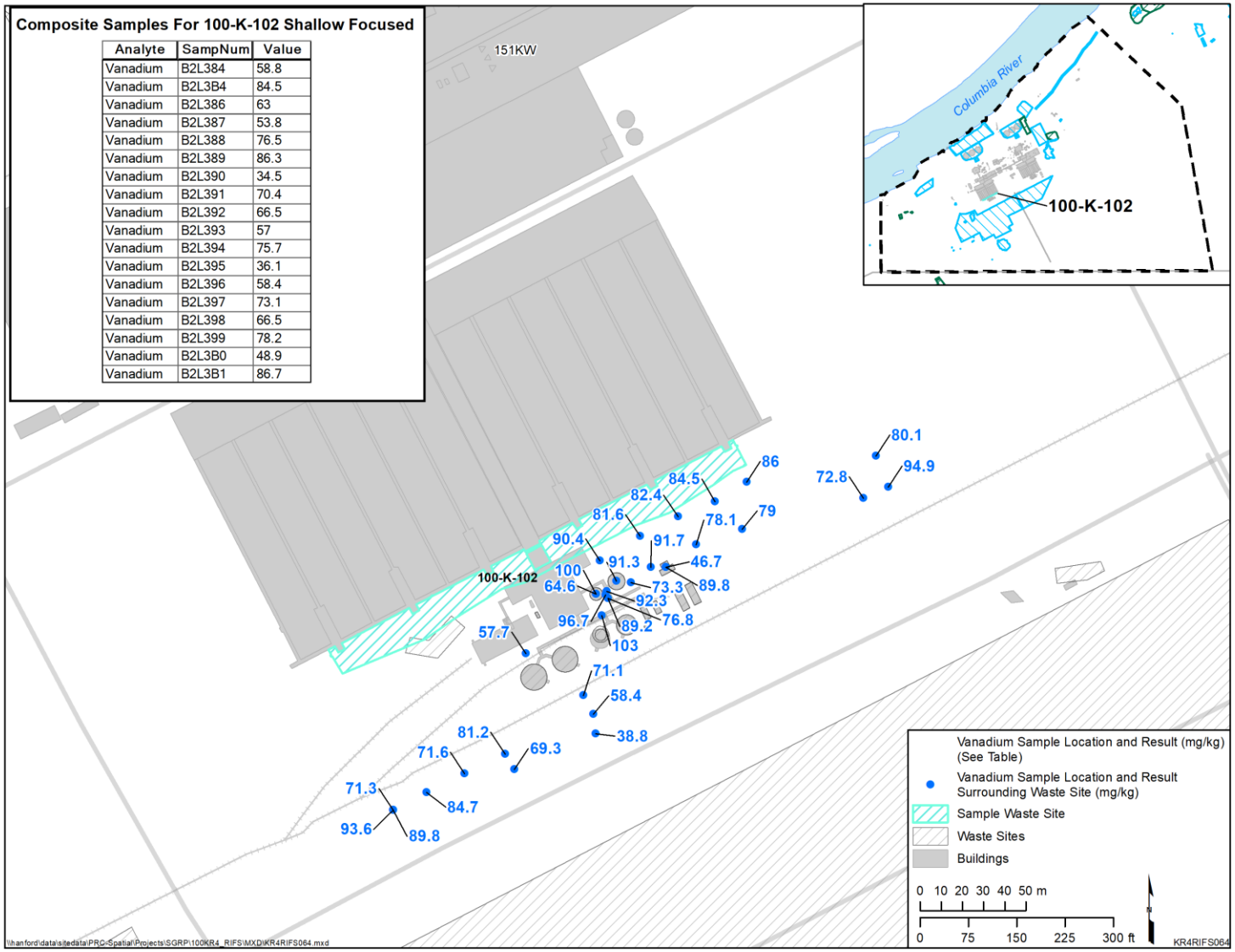
Figure H-2. French Drains and Mercury Stained Soils near the 183KW Sedimentation Basin (100-K-102_Shallow_1) Sampling Locations and Associated Selenium Results



Composite Samples for 100-K-102 Shallow 2

Analyte	SampNum	Value
Mercury	B2L363	0.049
Mercury	B2L364	0.054
Mercury	B2L365	0.052
Mercury	B2L366	0.0433
Mercury	B2L367	0.027
Mercury	B2L368	0.027
Mercury	B2L369	0.029
Mercury	B2L370	0.025
Mercury	B2L371	0.026
Mercury	B2L372	0.422
Mercury	B2L373	3.43
Mercury	B2L374	0.026
Mercury	B2L375	0.029
Mercury	B2L376	0.028
Mercury	B2L377	0.026
Mercury	B2L378	0.026
Mercury	B2L379	0.028
Mercury	B2L380	0.028

Figure H-3. French Drains and Mercury Stained Soils near the 183KW Sedimentation Basin (100-K-102_Shallow_2) Sampling Locations and Associated Mercury Results



Composite Samples For 100-K-102 Shallow Focused

Analyte	SampNum	Value
Vanadium	B2L384	58.8
Vanadium	B2L3B4	84.5
Vanadium	B2L386	63
Vanadium	B2L387	53.8
Vanadium	B2L388	76.5
Vanadium	B2L389	86.3
Vanadium	B2L390	34.5
Vanadium	B2L391	70.4
Vanadium	B2L392	66.5
Vanadium	B2L393	57
Vanadium	B2L394	75.7
Vanadium	B2L395	36.1
Vanadium	B2L396	58.4
Vanadium	B2L397	73.1
Vanadium	B2L398	66.5
Vanadium	B2L399	78.2
Vanadium	B2L3B0	48.9
Vanadium	B2L3B1	86.7

Figure H-4. French Drains and Mercury Stained Soils near the 183KW Sedimentation Basin (100-K-102_Shallow_2) Sampling Locations and Associated Vanadium Results

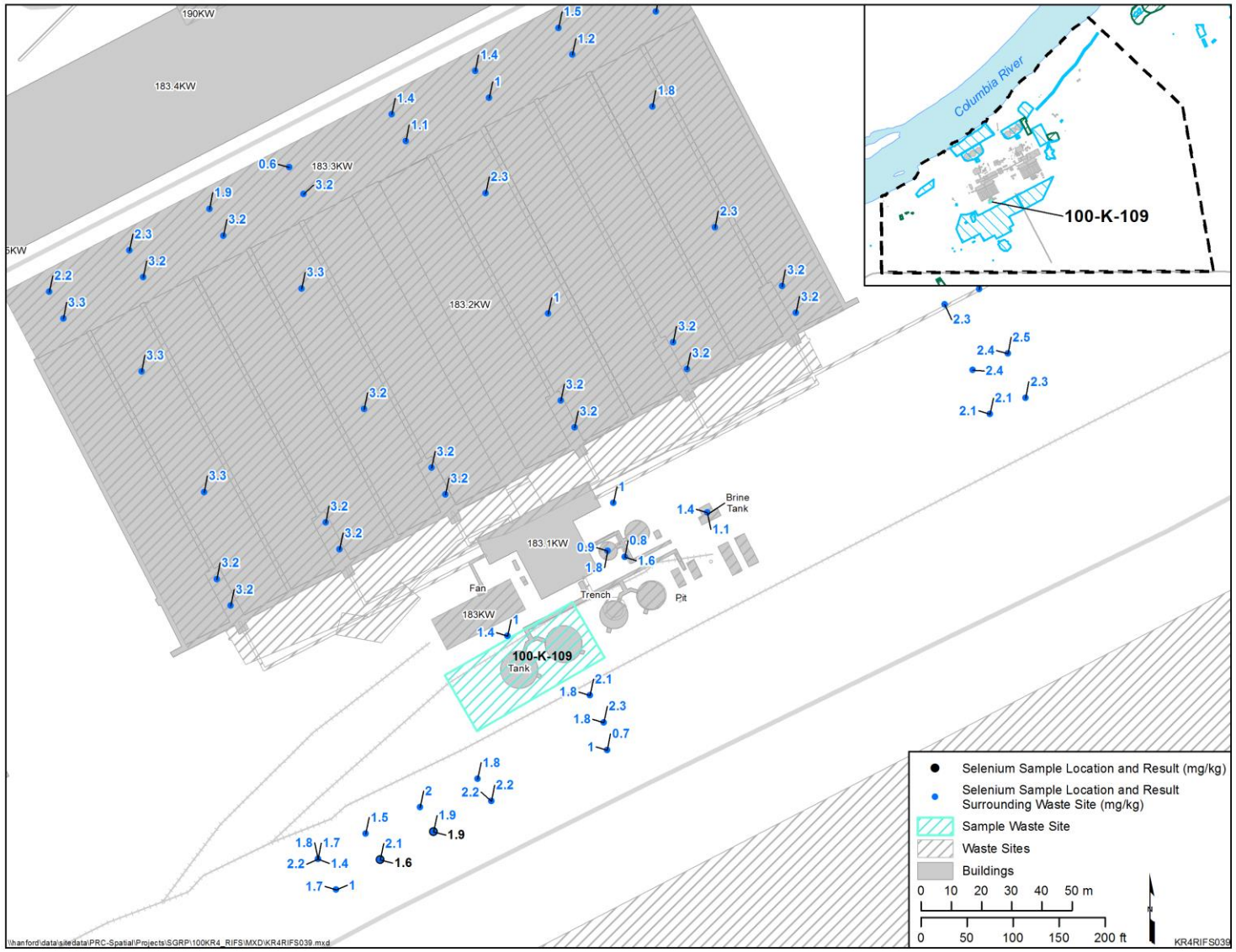


Figure H-5. Unplanned Chemical Release near 183.1KW Head House (100-K-109_Shallow_Focused) Sampling Locations and Associated Selenium Results

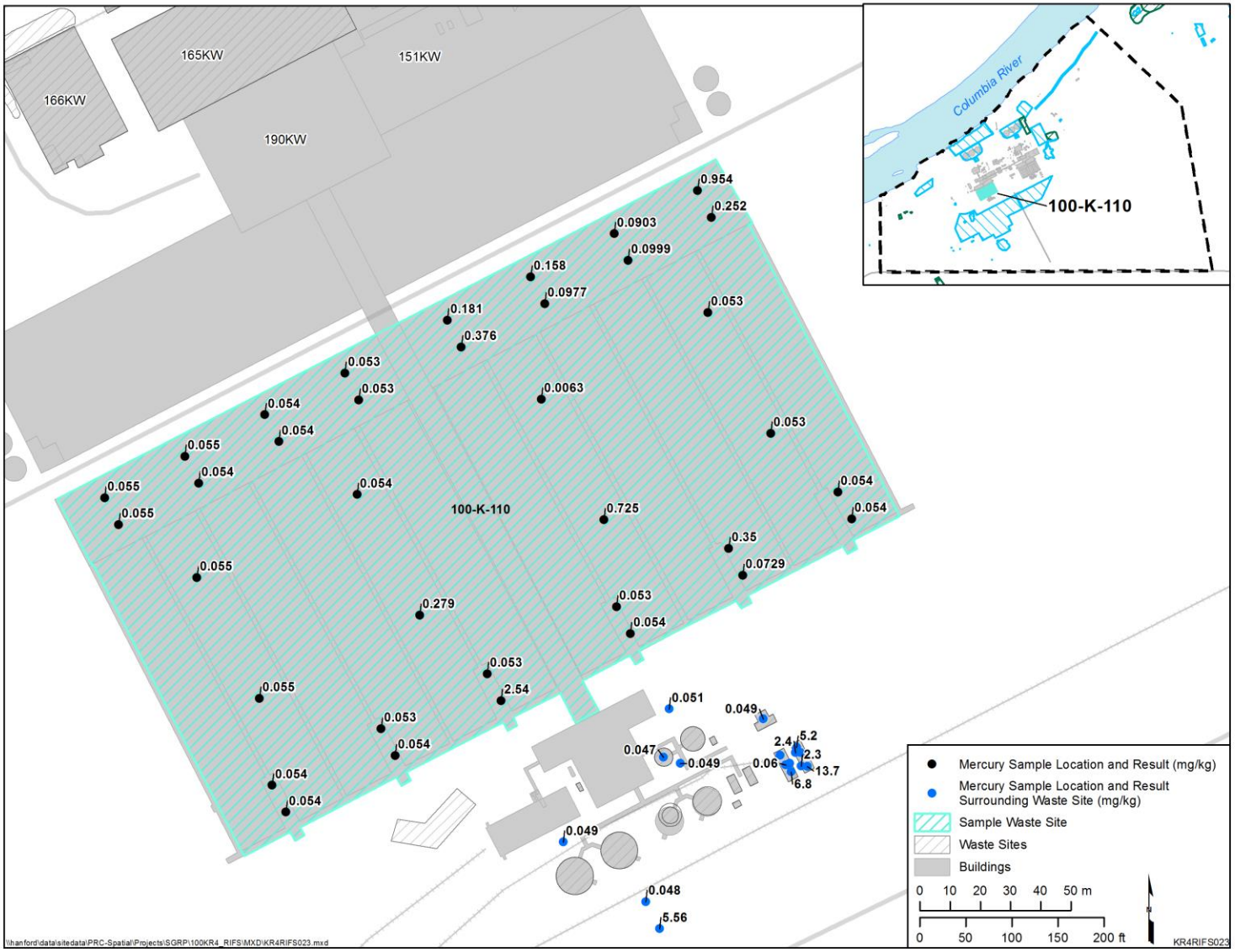


Figure H-6. Soil Beneath 183.2-KW Flocculation and Sedimentation Basins; the 183.3-KW Sand Filter Basins (100-K-110_Shallow) Sampling Locations and Associated Mercury Results

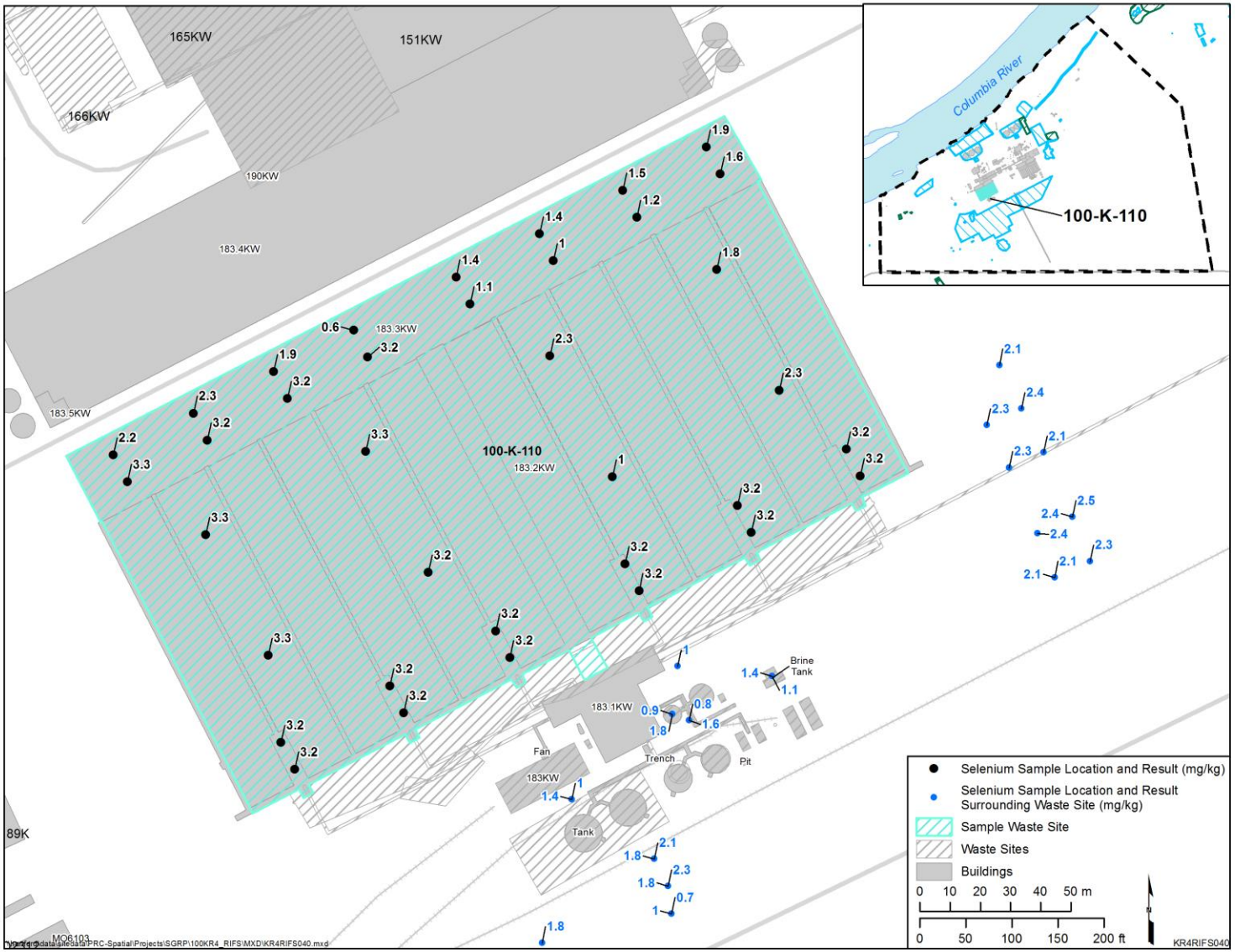


Figure H-7. Soil Beneath 183.2-KW Flocculation and Sedimentation Basins; the 183.3-KW Sand Filter Basins (100-K-110_Shallow) Sampling Locations and Associated Selenium Results

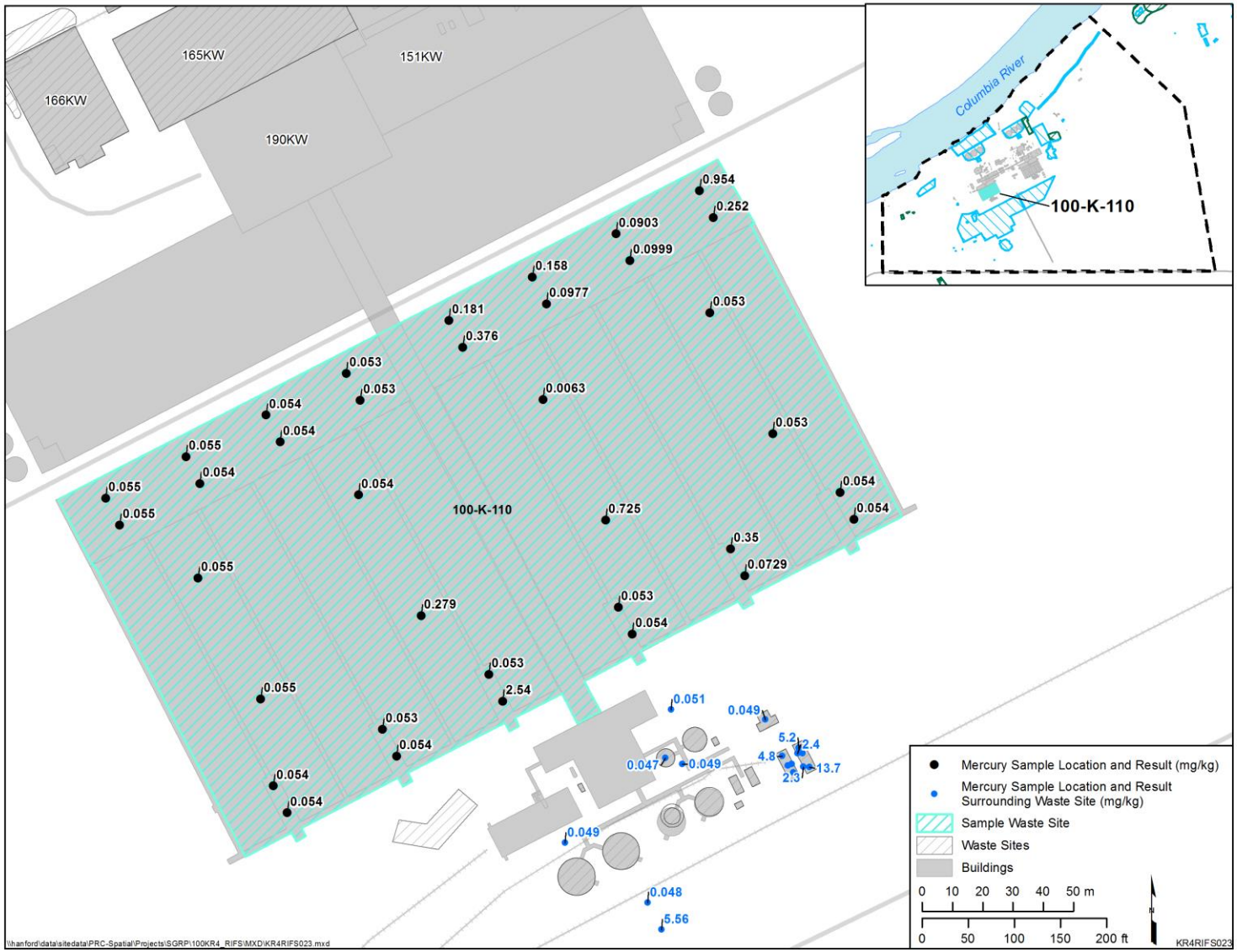


Figure H-8. 183-KE Acid Neutralization Pit, Overflow French Drain, and Liquid Alum Storage Tank (100-K-14, 126-KE-2_Shallow) Sampling Locations and Associated Mercury Results

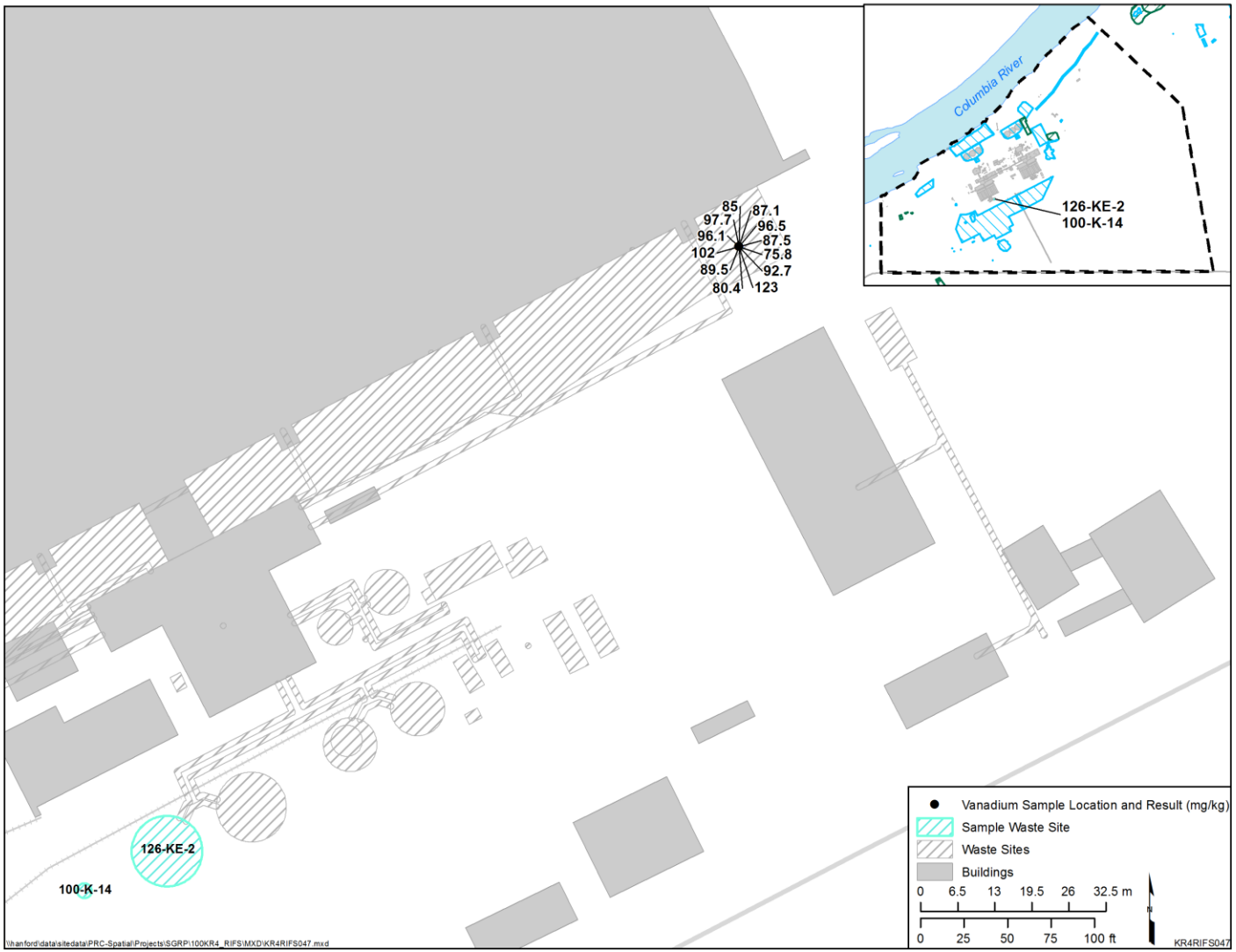


Figure H-9.183-KE Acid Neutralization Pit, Overflow French Drain, and Liquid Alum Storage Tank (100-K-14, 126-KE-2_Shallow) Sampling Locations and Associated Vanadium Results

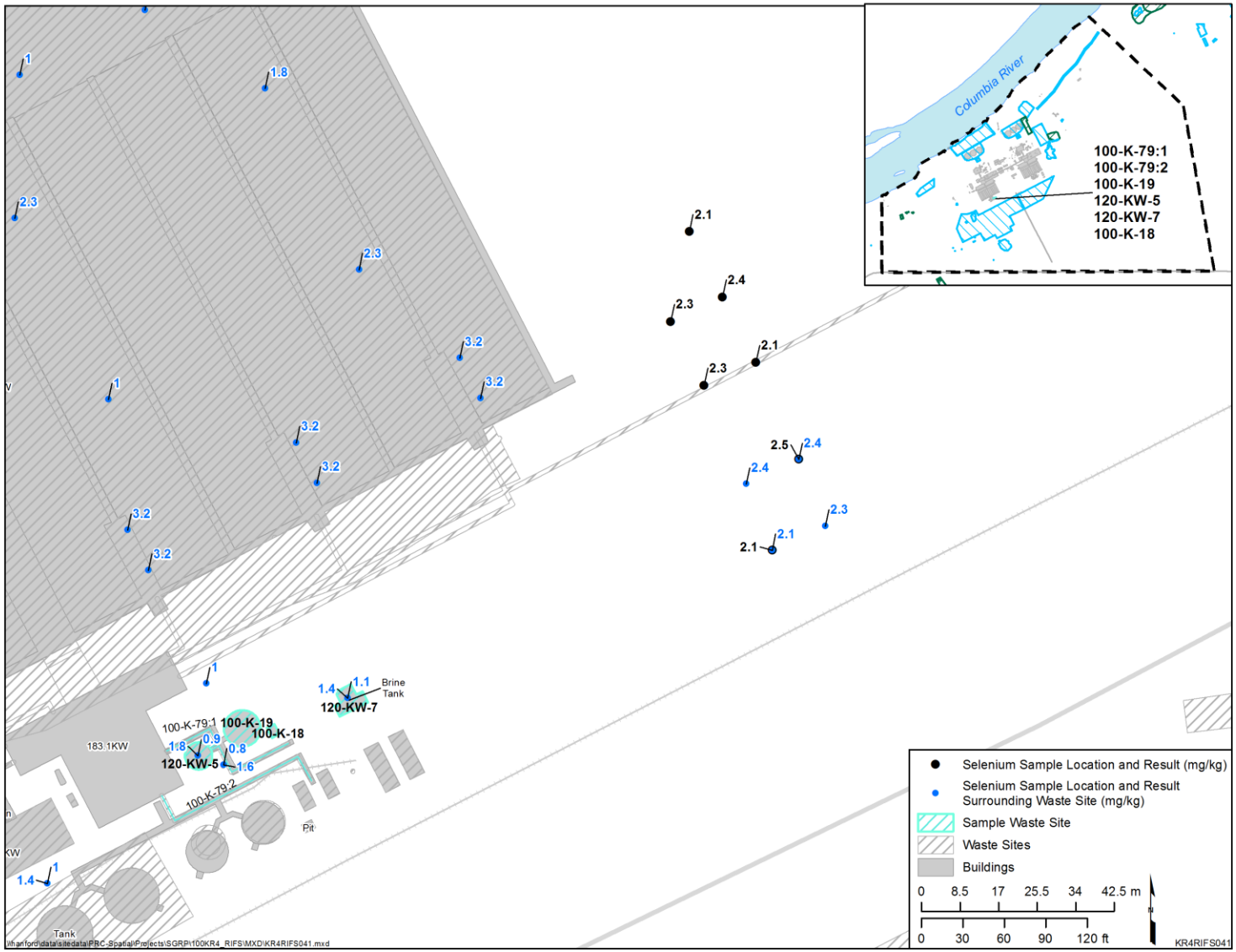


Figure H-10. Sites around the 183.1-KW Water Treatment Plant Headhouse (100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5N) Sampling Locations and Associated Selenium Results

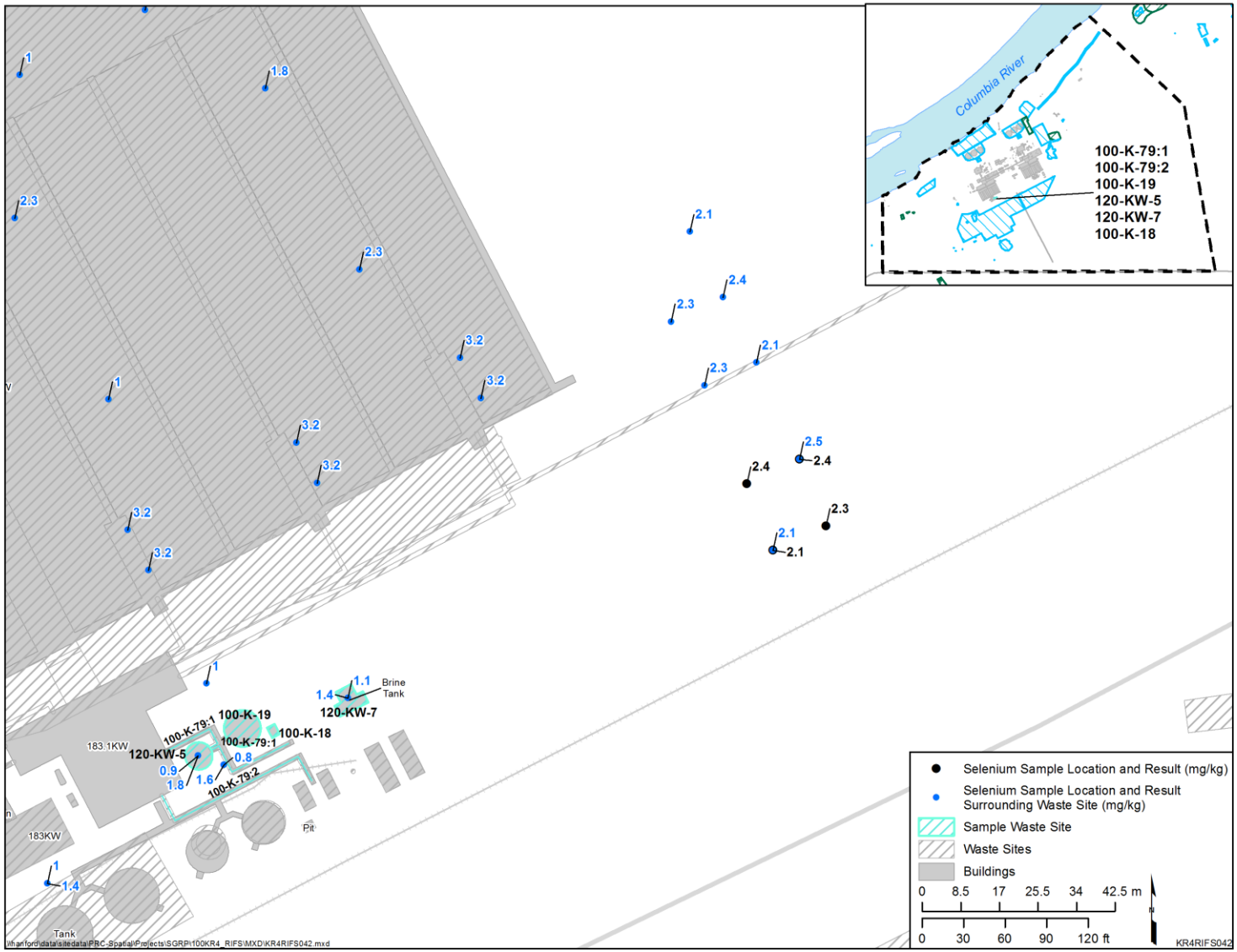


Figure H-11. Sites around the 183.1-KW Water Treatment Plant Headhouse (100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5S) Sampling Locations and Associated Selenium Results

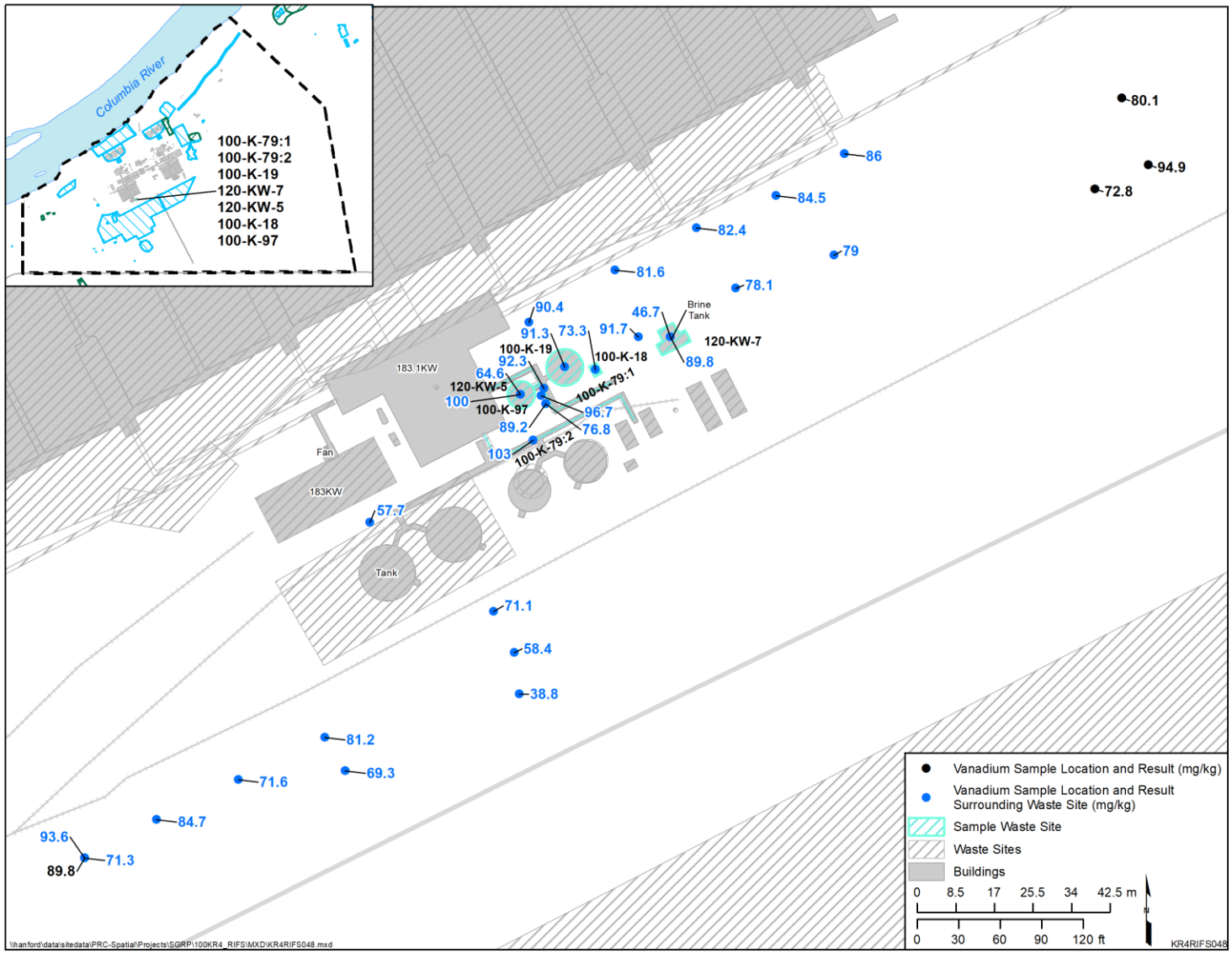


Figure H-12. Sites around the 183.1-KW Water Treatment Plant Headhouse (100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Overburden_5S) Sampling Locations and Associated Vanadium Results

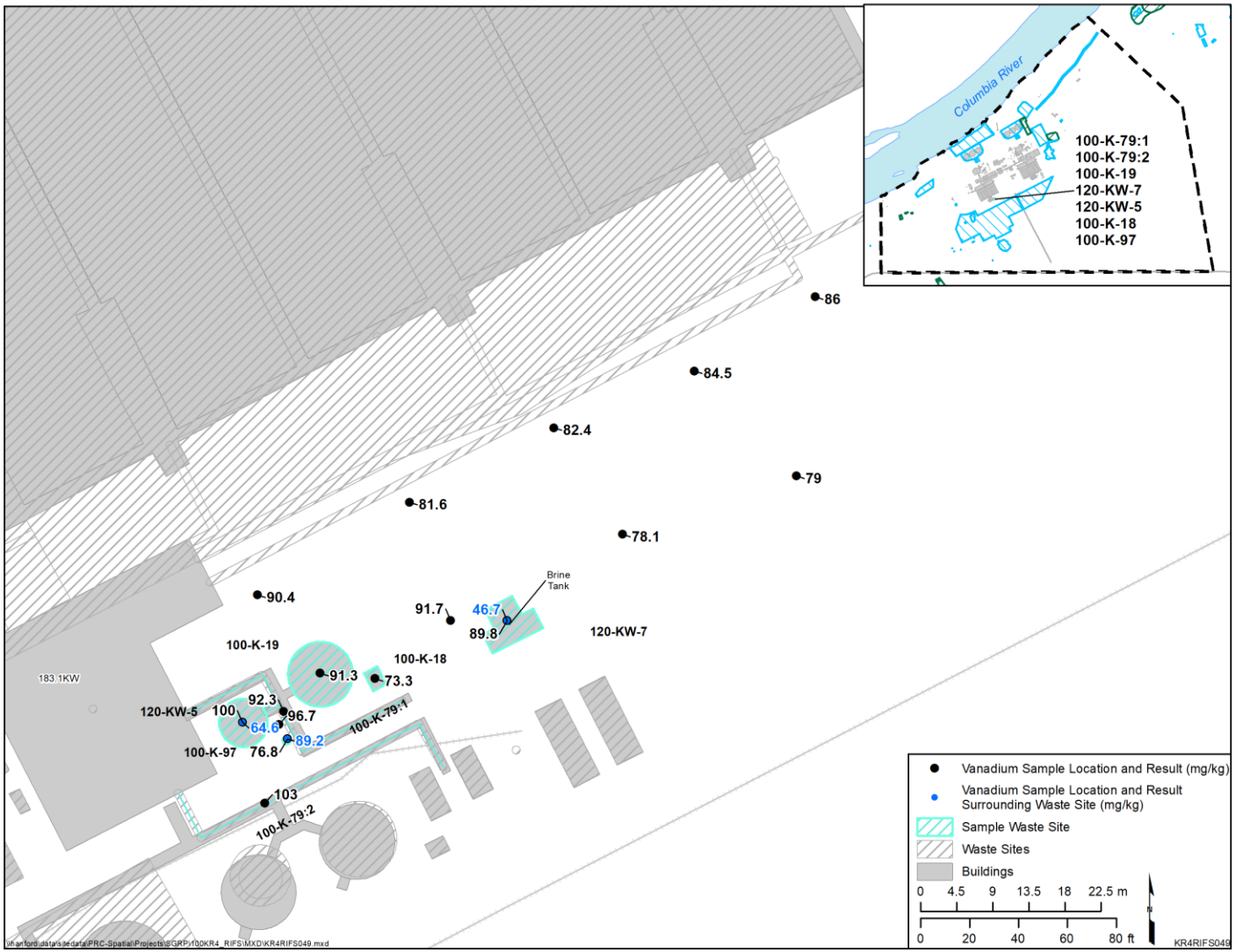


Figure H-13. Sites around the 183.1-KW Water Treatment Plant Headhouse (100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow) Sampling Locations and Associated Vanadium Results

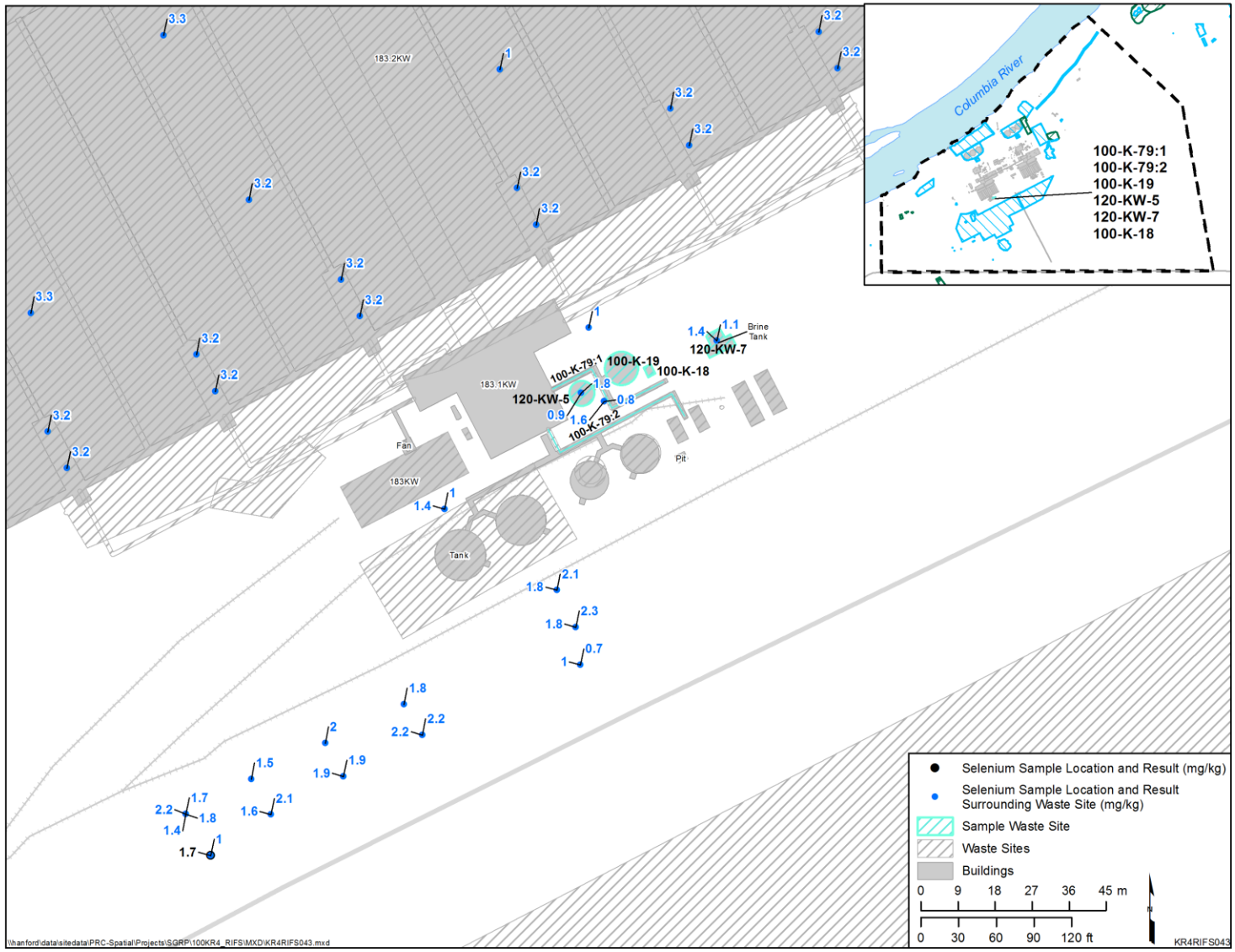


Figure H-14. Sites around the 183.1-KW Water Treatment Plant Headhouse (100-K-18, 100-K-19, 100-K-79:1, 100-K-79:2, 100-K-97, 120-KW-5, 120-KW-7_Shallow_Focused) Sampling Locations and Associated Selenium Results

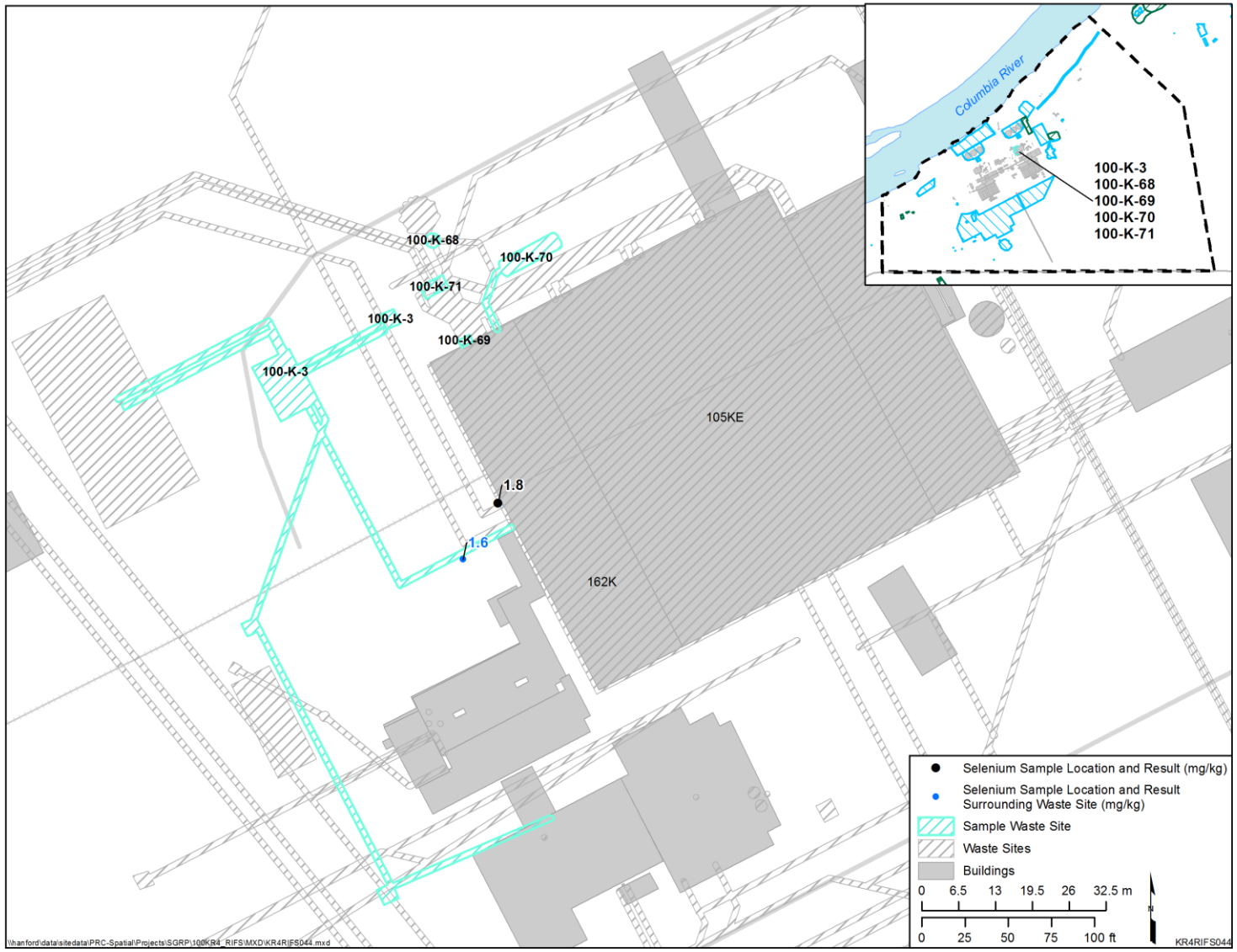


Figure H-15. Process Sewer Sites on the Northwestern side of the 105-KE Reactor (100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_2) Sampling Locations and Associated Selenium Results

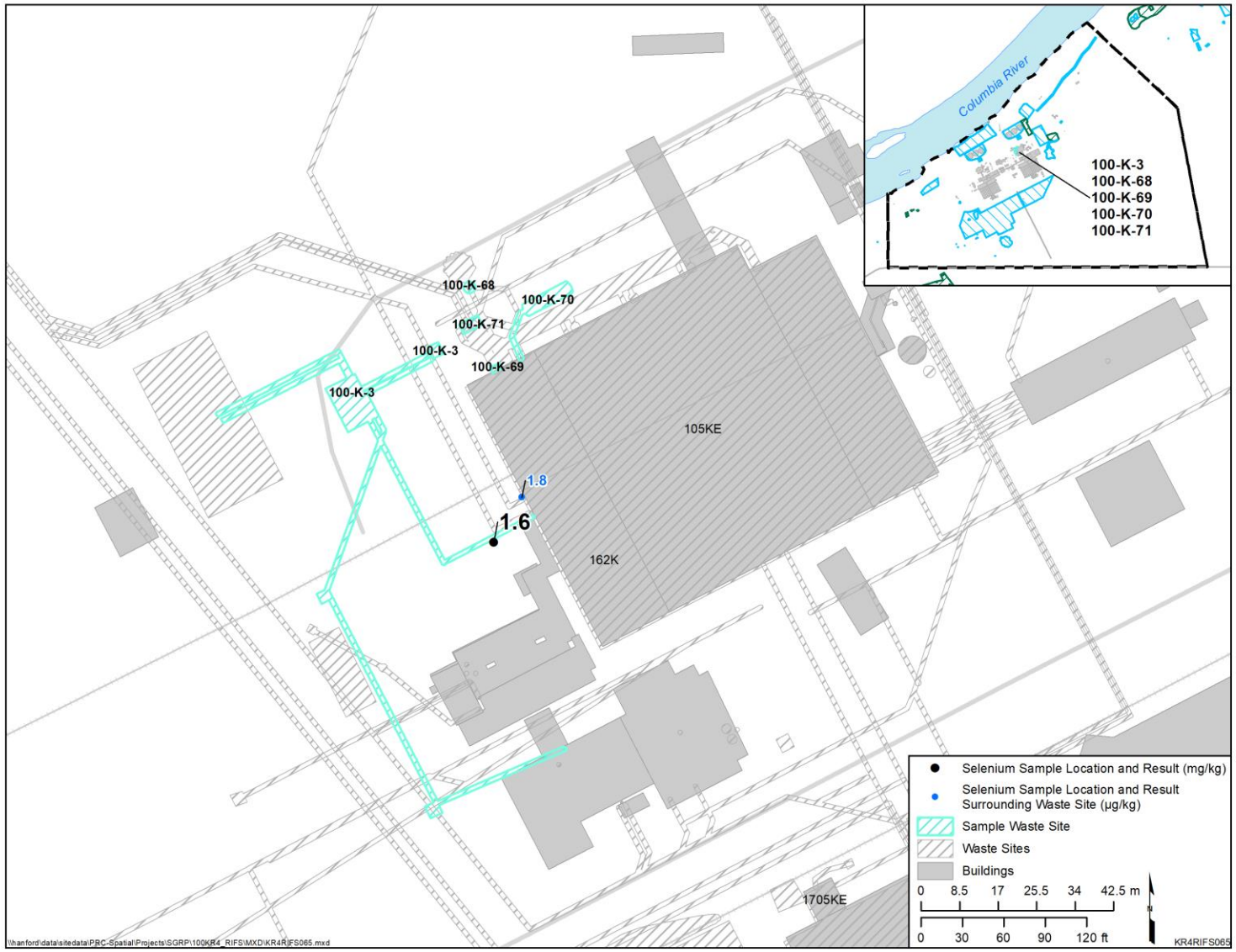


Figure H-16. Process Sewer Sites on the Northwestern side of the 105-KE Reactor (100-K-3, 100-K-68, 100-K-69, 100-K-70, 100-K-71_Shallow_Focused_3) Sampling Locations and Associated Selenium Results

Figure H-17. 183-KE Sulfuric Acid Tank Bases West Tank (100-K-30_Shallow_Focused) and 183-KE Sulfuric Acid Tank Bases East Tank (100-K-31_Shallow_Focused) Sampling Locations and Associated Mercury Results

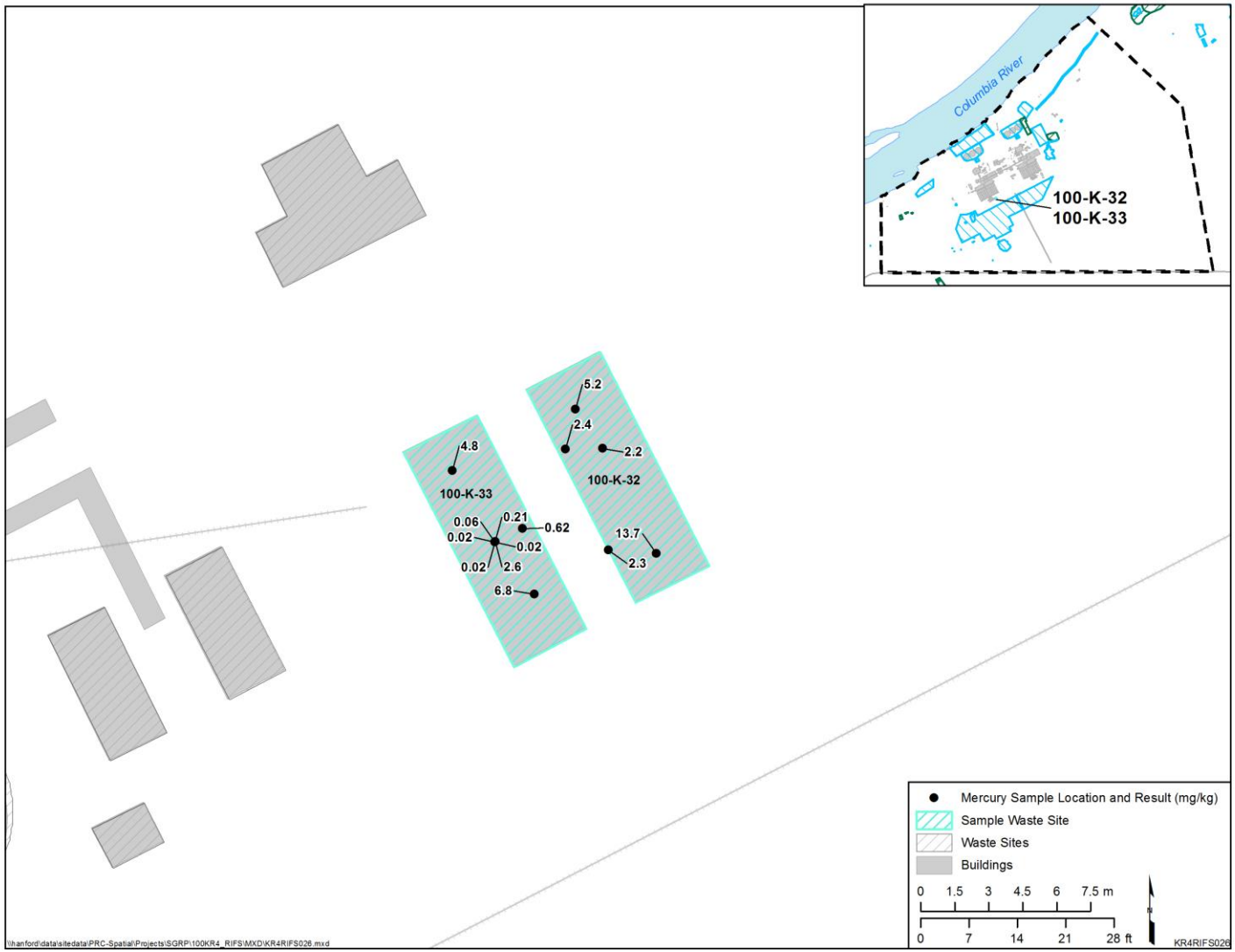


Figure H-18. 183-KW Sulfuric Acid Tank Bases East Tank (100-K-32_Shallow_Focused) and 183-KW Sulfuric Acid Tank Bases West Tank (100-K-33_Shallow_Focused) Sampling Locations and Associated Mercury Results

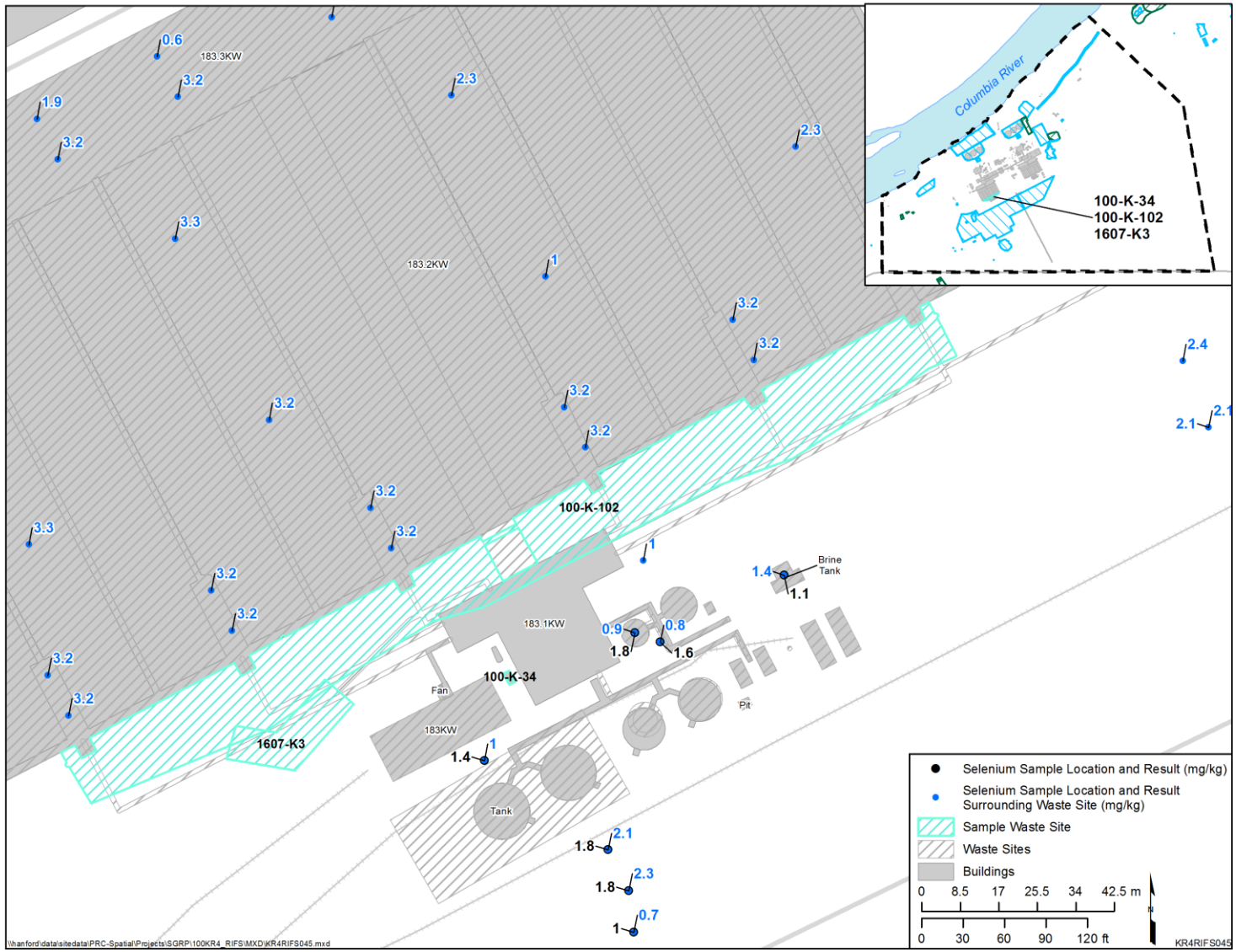


Figure H-19. Acid Neutralization Pit, French Drains, and Septic System at the 183-KW Water Treatment Plant (100-K-34, 100-K-102, 1607-K3_Shallow_Focused) Sampling Locations and Associated Selenium Results

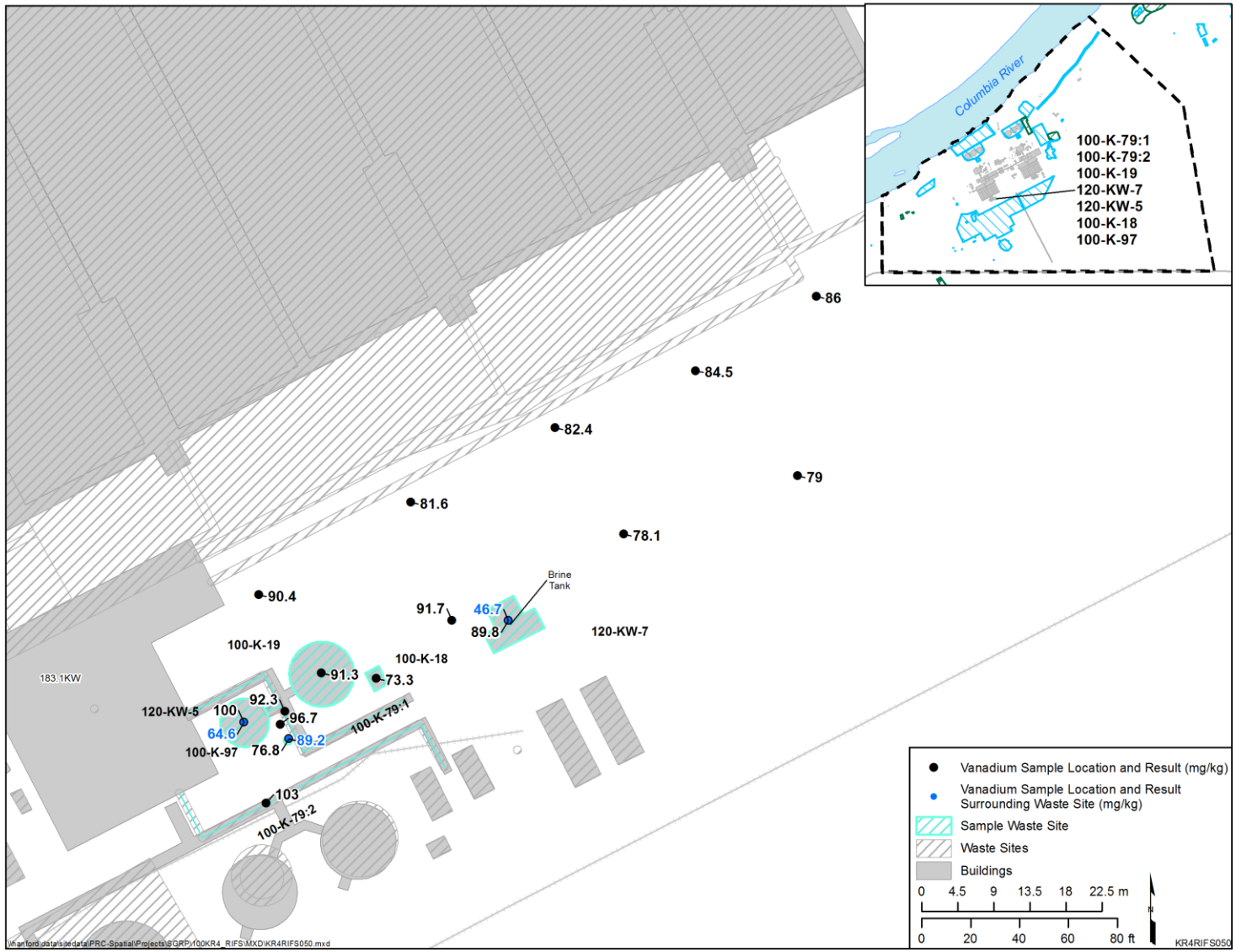


Figure H-20. Acid Neutralization Pit, French Drains, and Septic System at the 183-KW Water Treatment Plant (100-K-34, 100-K-102, 1607-K3_Shallow_Focused) Sampling Locations and Associated Vanadium Results

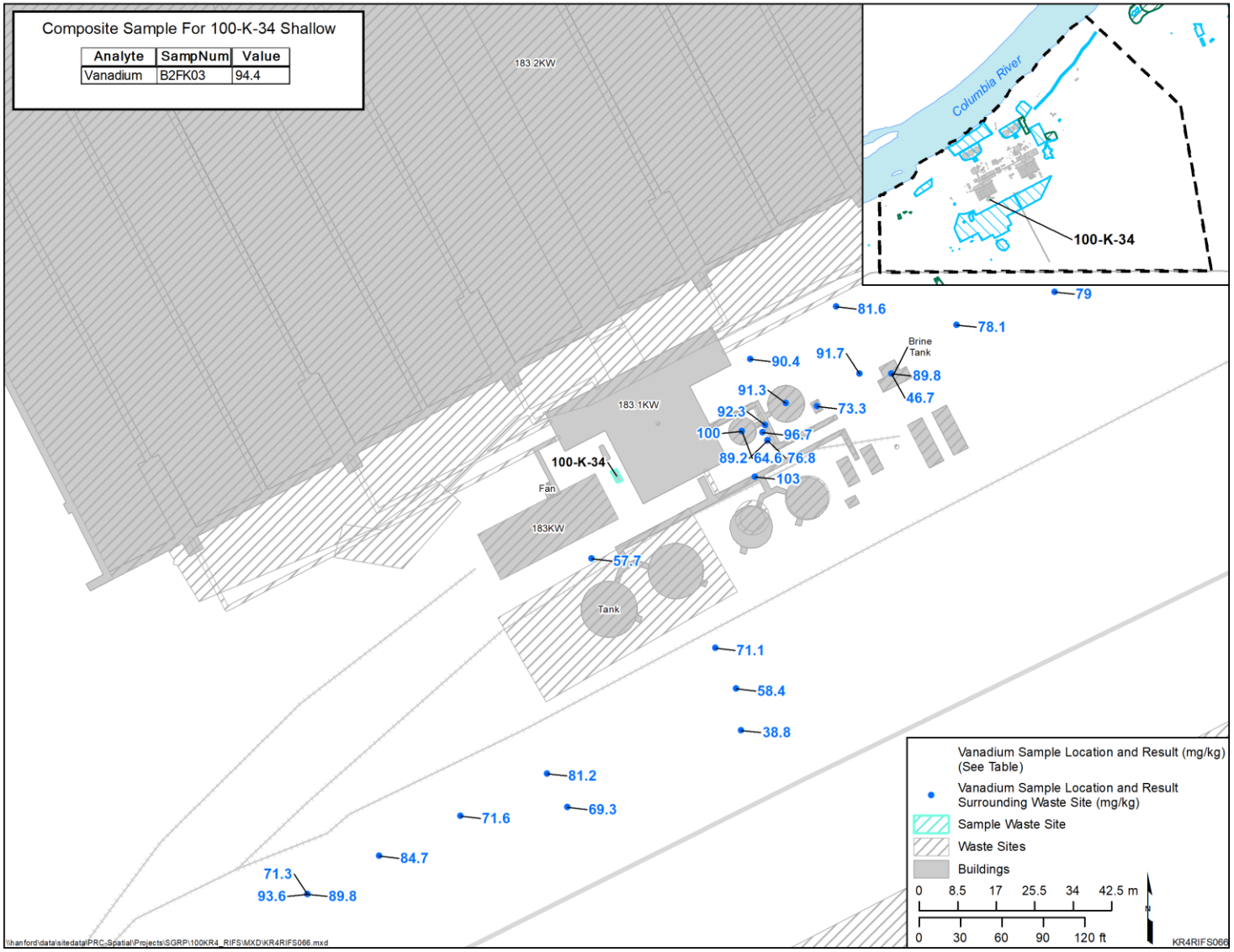


Figure H-21. 183-KW Acid Neutralization Pit (100-K-34_Shallow) Sampling Locations and Associated Vanadium Results

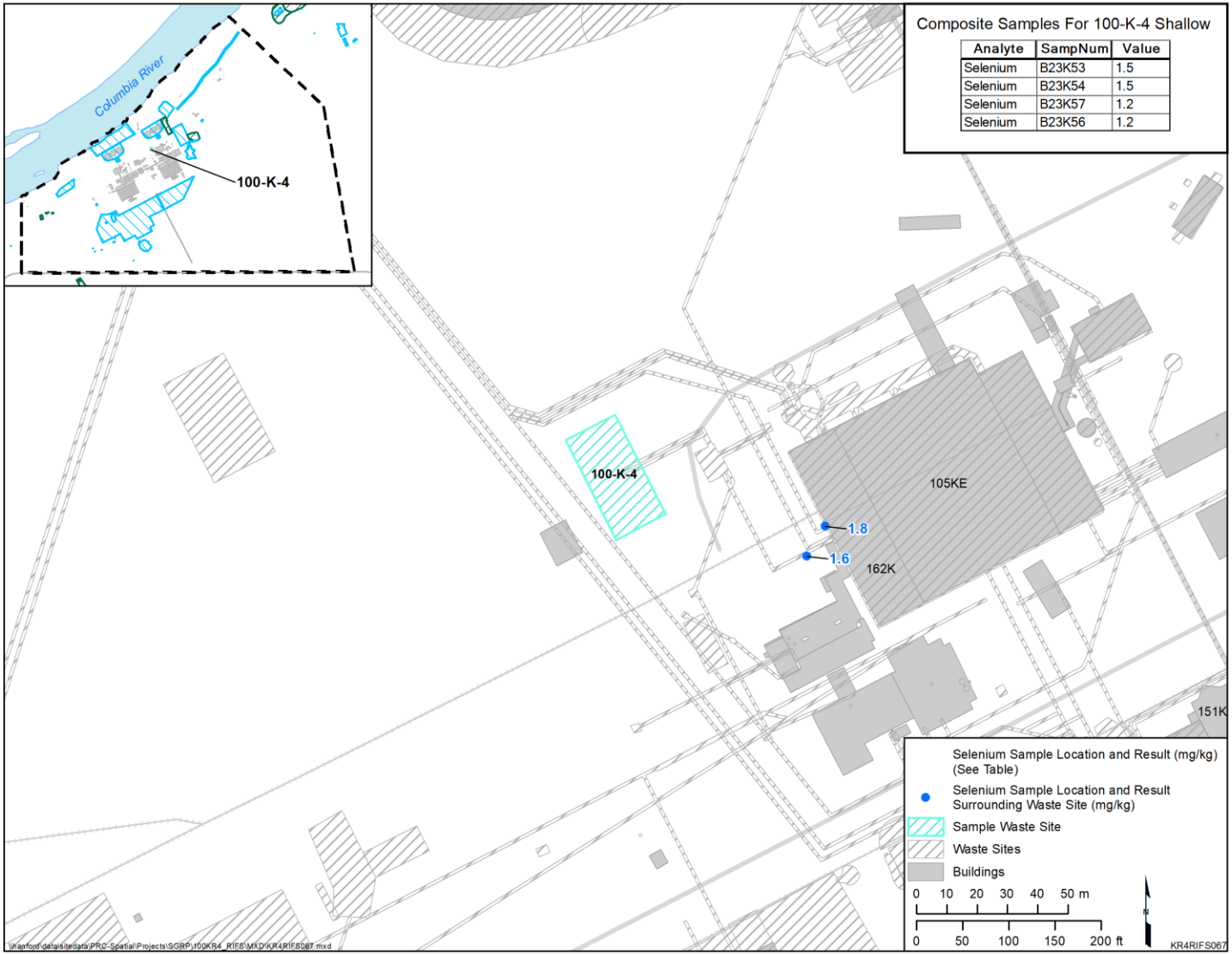


Figure H-22. 1706-KE Wet Fish Studies Ponds and Valve Pit (100-K-4_Shallow) Sampling Locations and Associated Selenium Results

Composite Samples For 100-K-6, 100-K-46, 100-K-62, 132-KE-1 Overburden

Analyte	SampNum	Value
Selenium	B298H8	1.4
Selenium	B298J2	1.8
Selenium	B298J6	1.9
Selenium	B298K0	1.3
Selenium	B298K3	0.9
Selenium	B298K6	2.2
Selenium	B298L2	2.4
Selenium	B298L6	2
Selenium	B298M0	2.2
Selenium	B298M4	2
Selenium	B2BV27	1.3
Selenium	B2BV28	1.3
Selenium	B2BV31	1.3
Selenium	B2BV29	1.2
Selenium	B2BV32	0.8

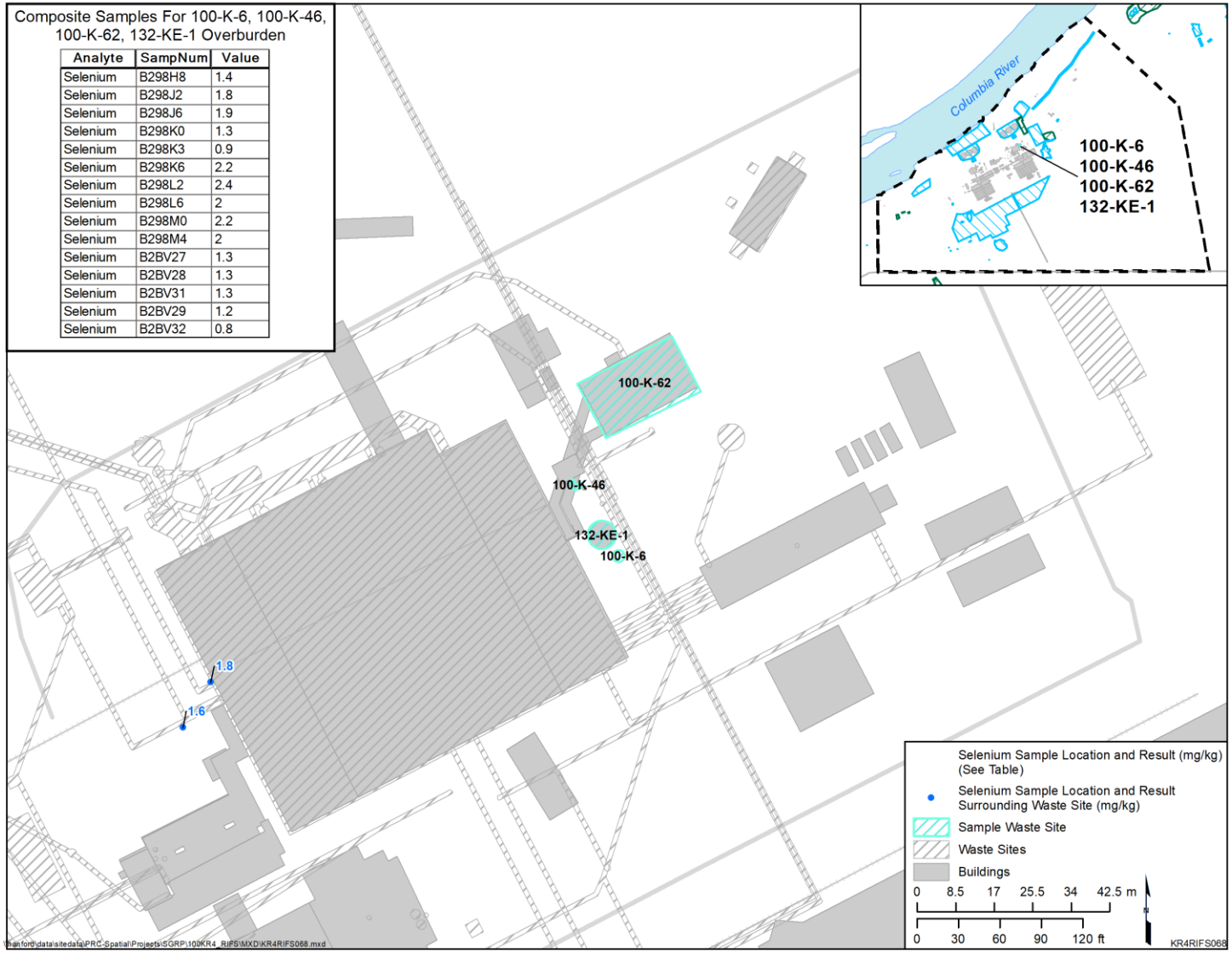


Figure H-23. Sites on the Western Side of the 105-KE Reactor (100-K-6, 100-K-46, 100-K-62, 132-KE-1_Overburden) Sampling Locations and Associated Selenium Results

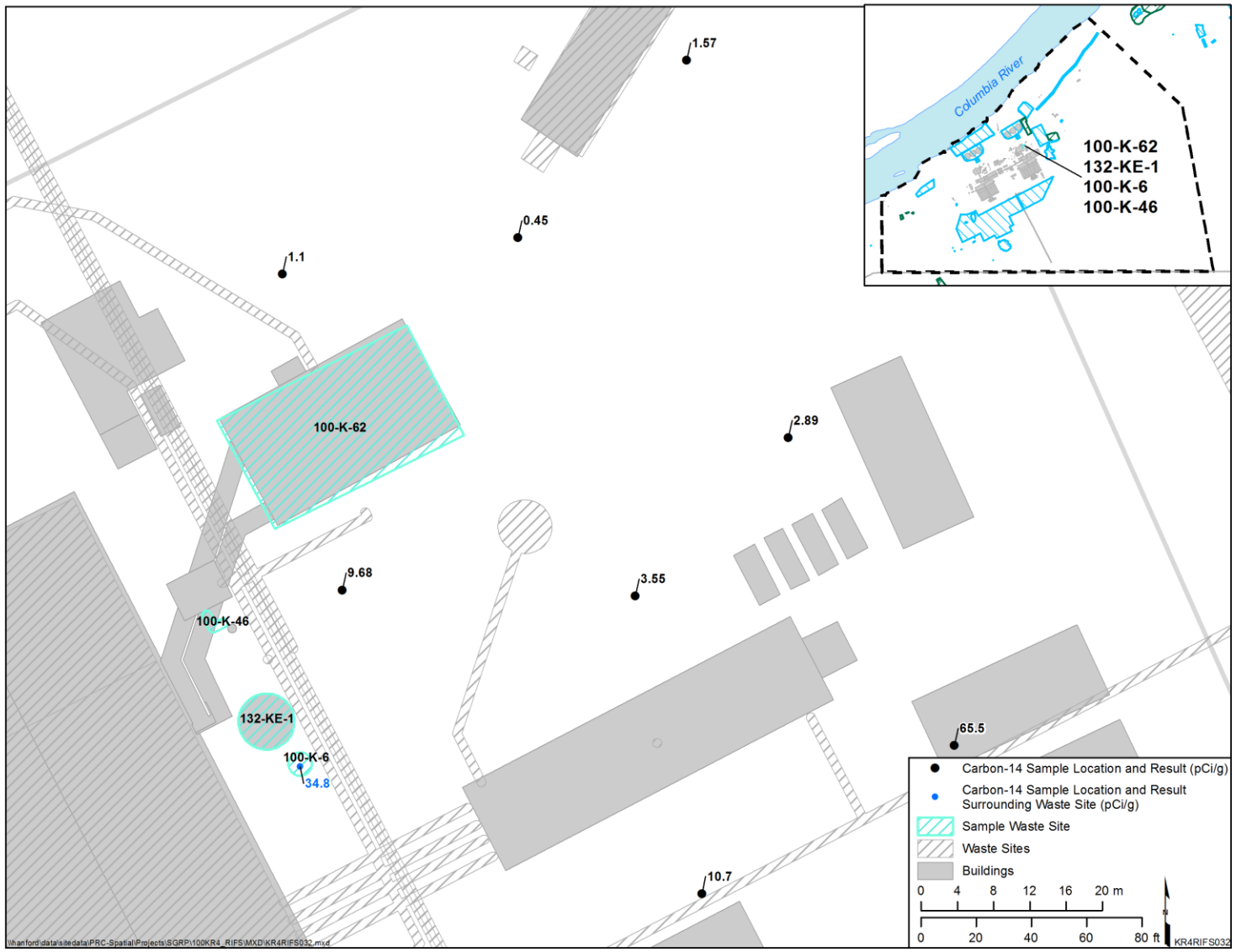


Figure H-24. Sites on the Western Side of the 105-KE Reactor (100-K-6, 100-K-46, 100-K-62, 132-KE-1_Shallow_1) Sampling Locations and Associated Carbon-14/Rads SOF Results

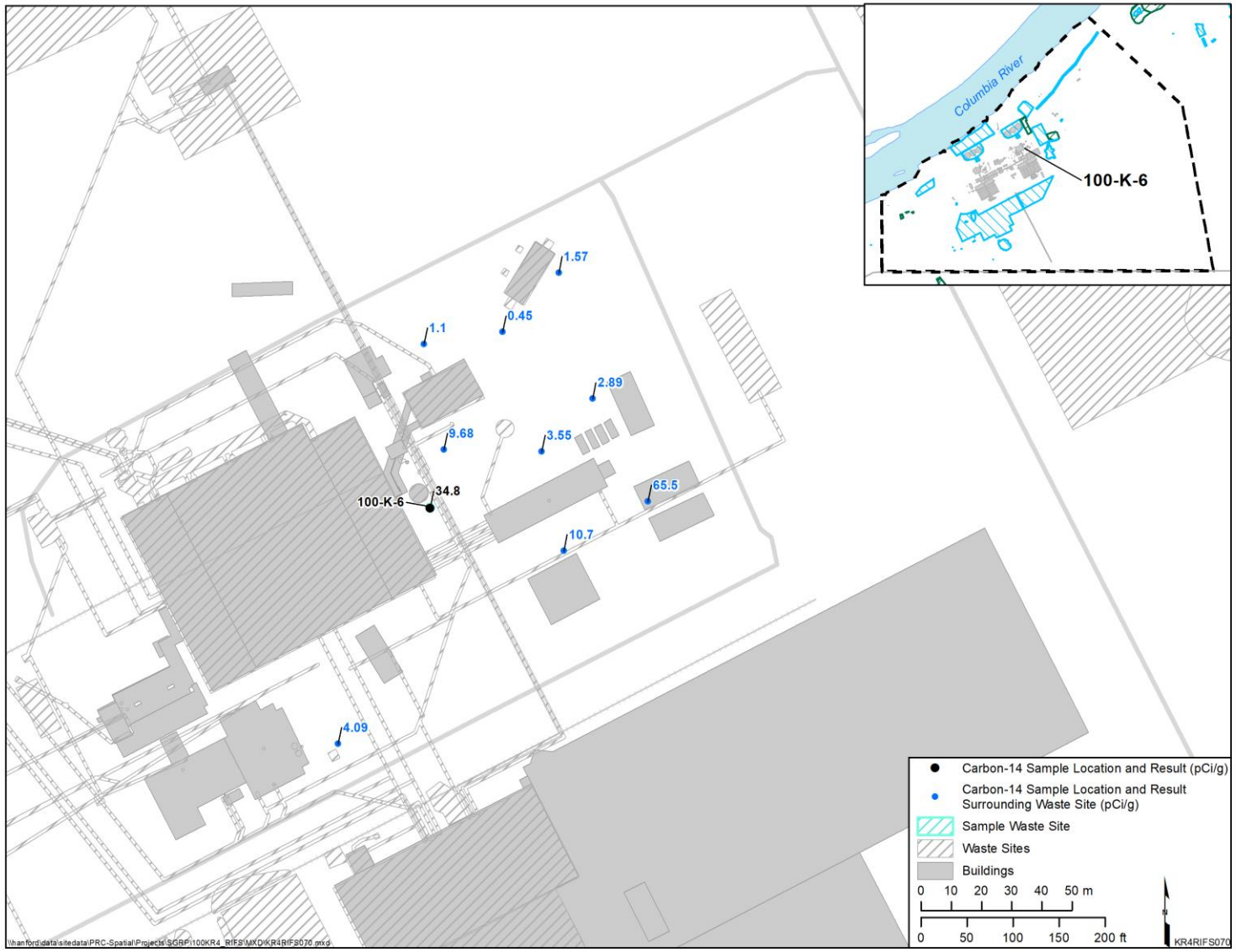


Figure H-25. 105-KE Vacuum Pit (100-K-6_Shallow) Sampling Locations and Associated Carbon-14/Rads SOF Results

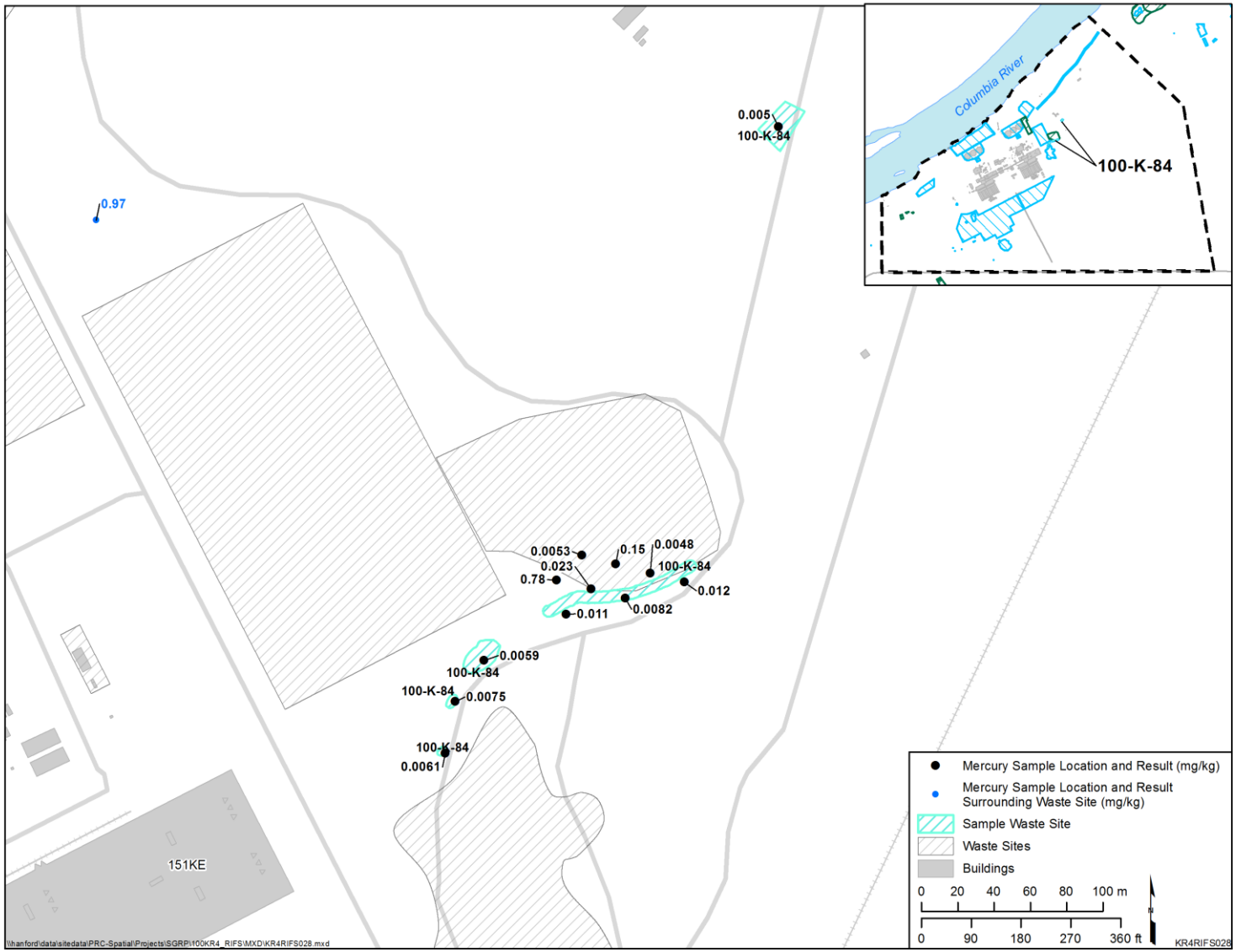


Figure H-26. Red Soil Found Southwest of 118-K-1 (100-K-84_Shallow) Sampling Locations and Associated Mercury Results

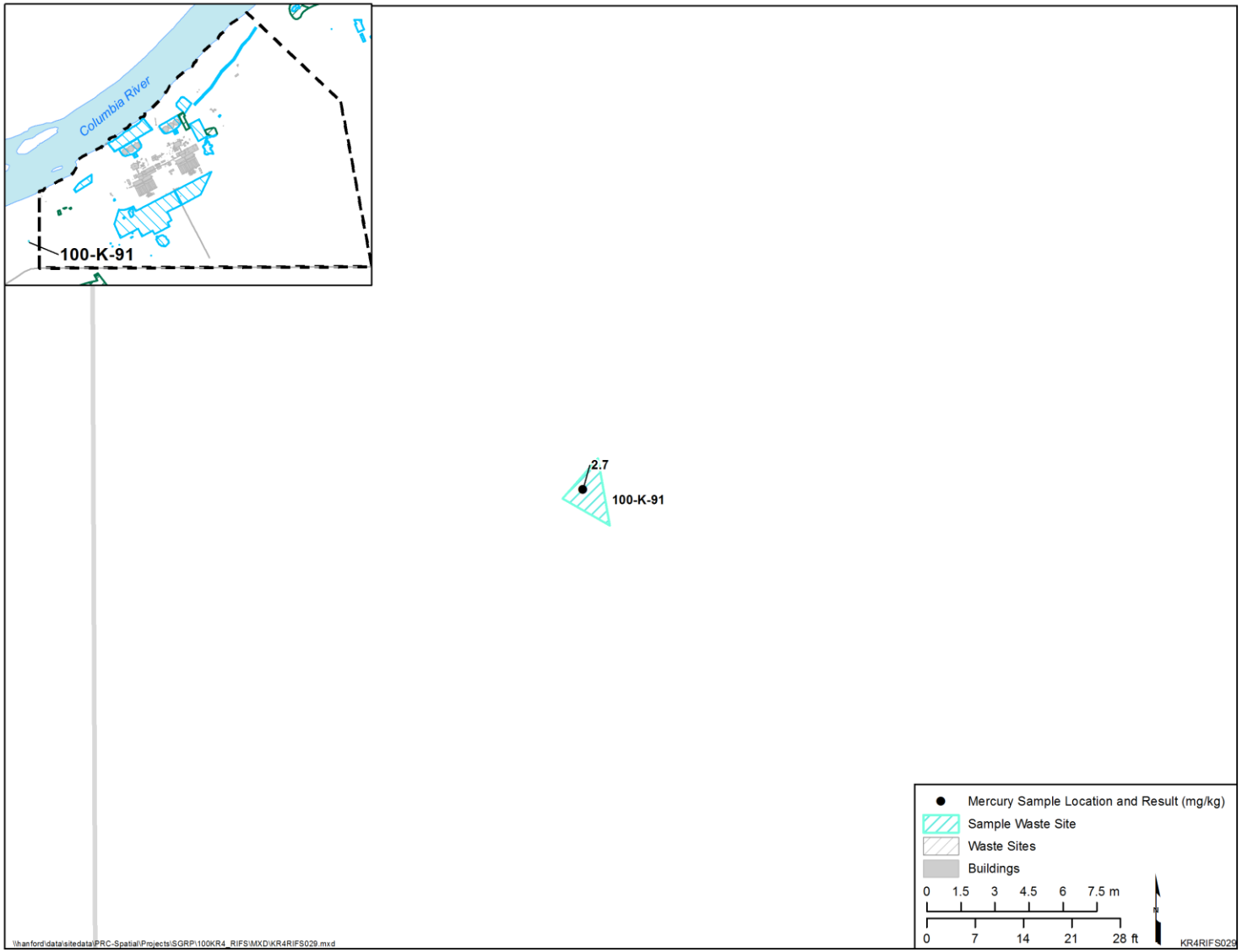
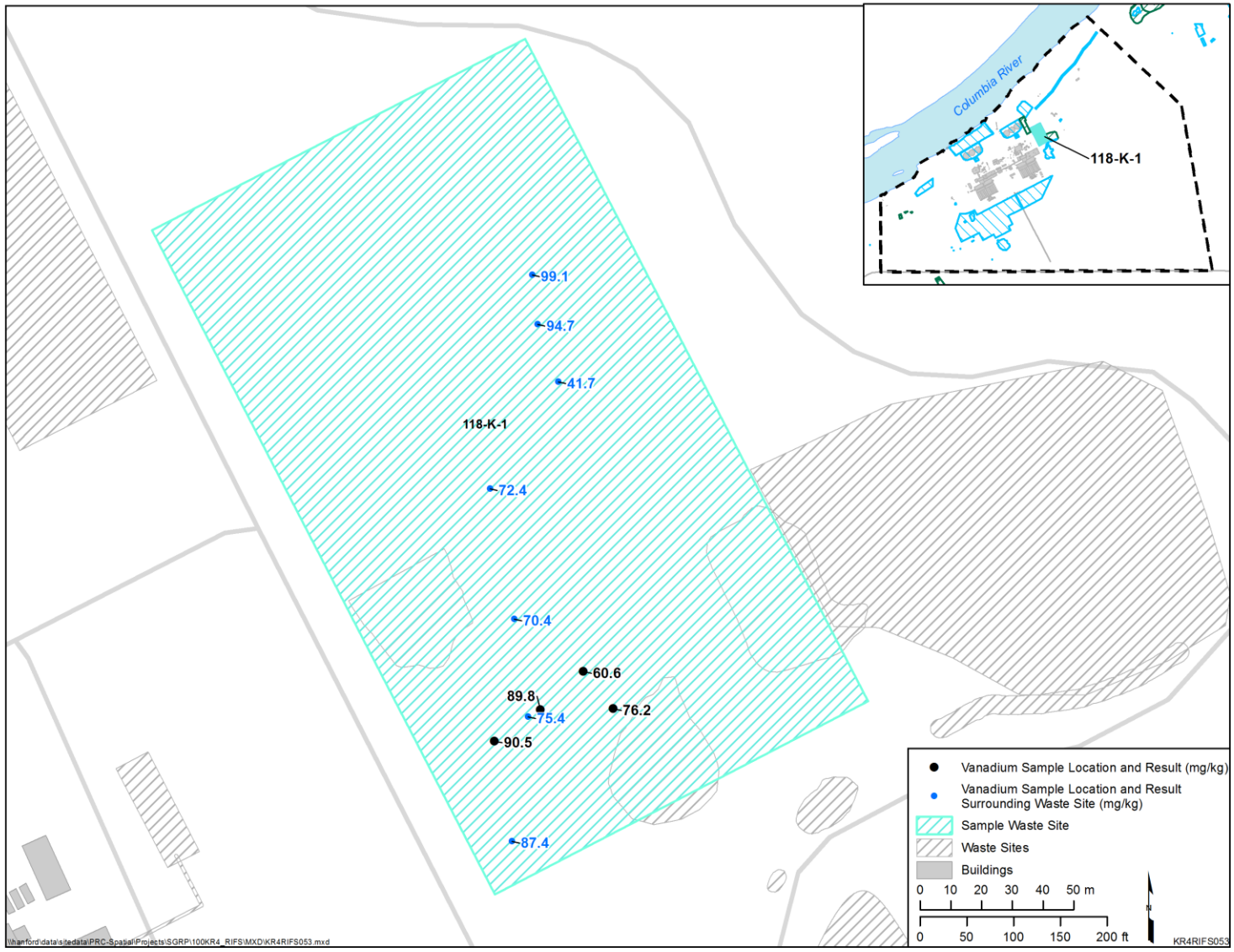


Figure H-27. 100-K Battery (100-K-91_Shallow_Focused) Sampling Locations and Associated Mercury Results



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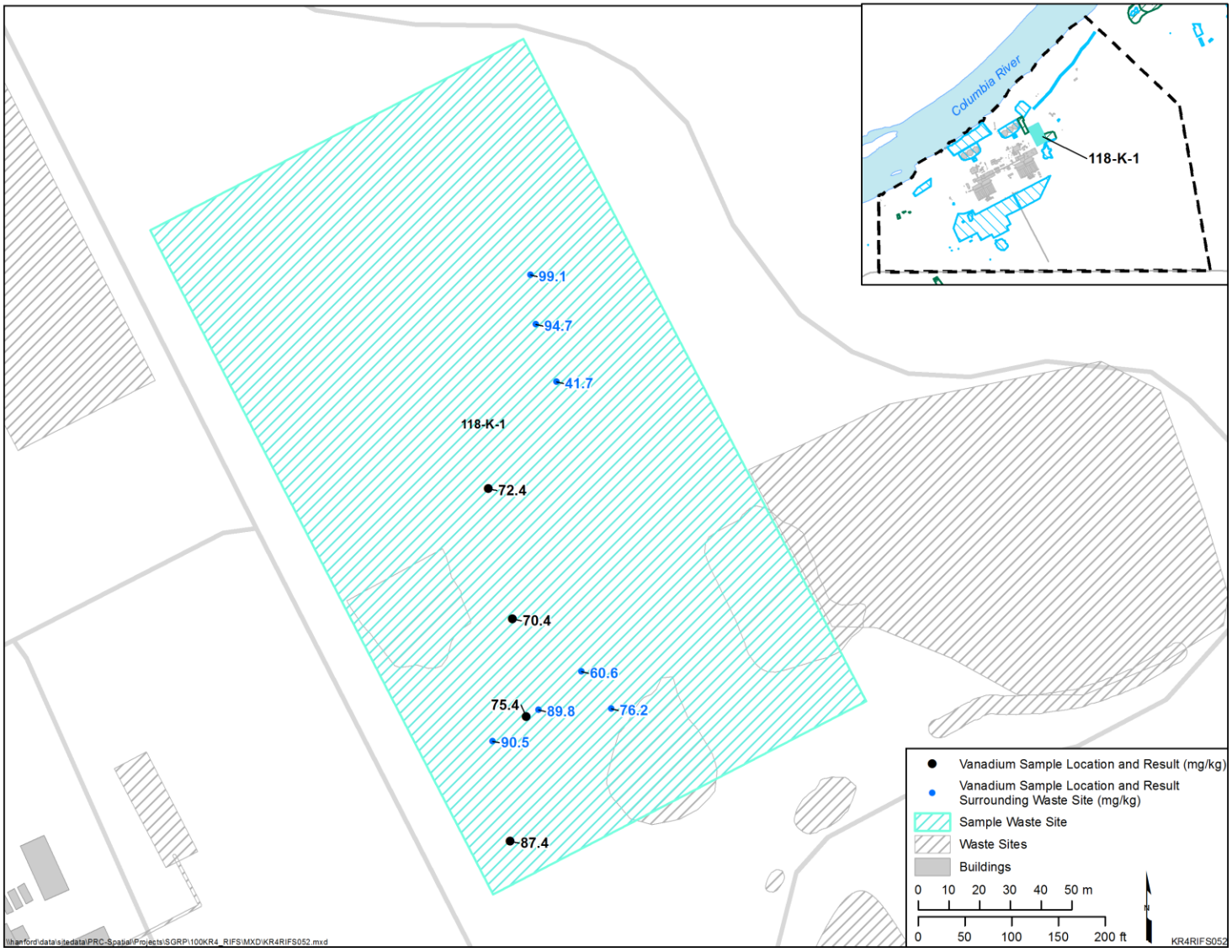

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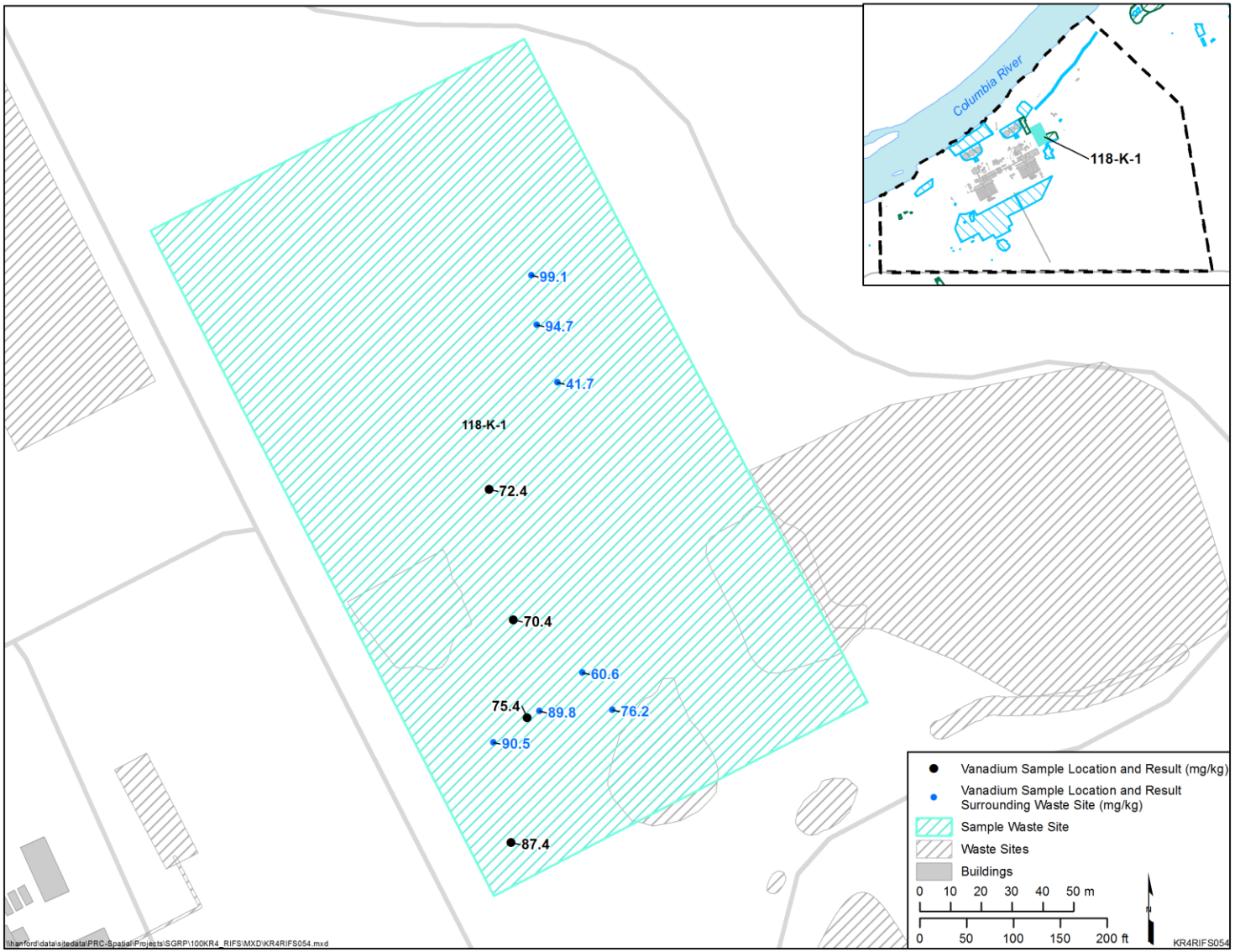

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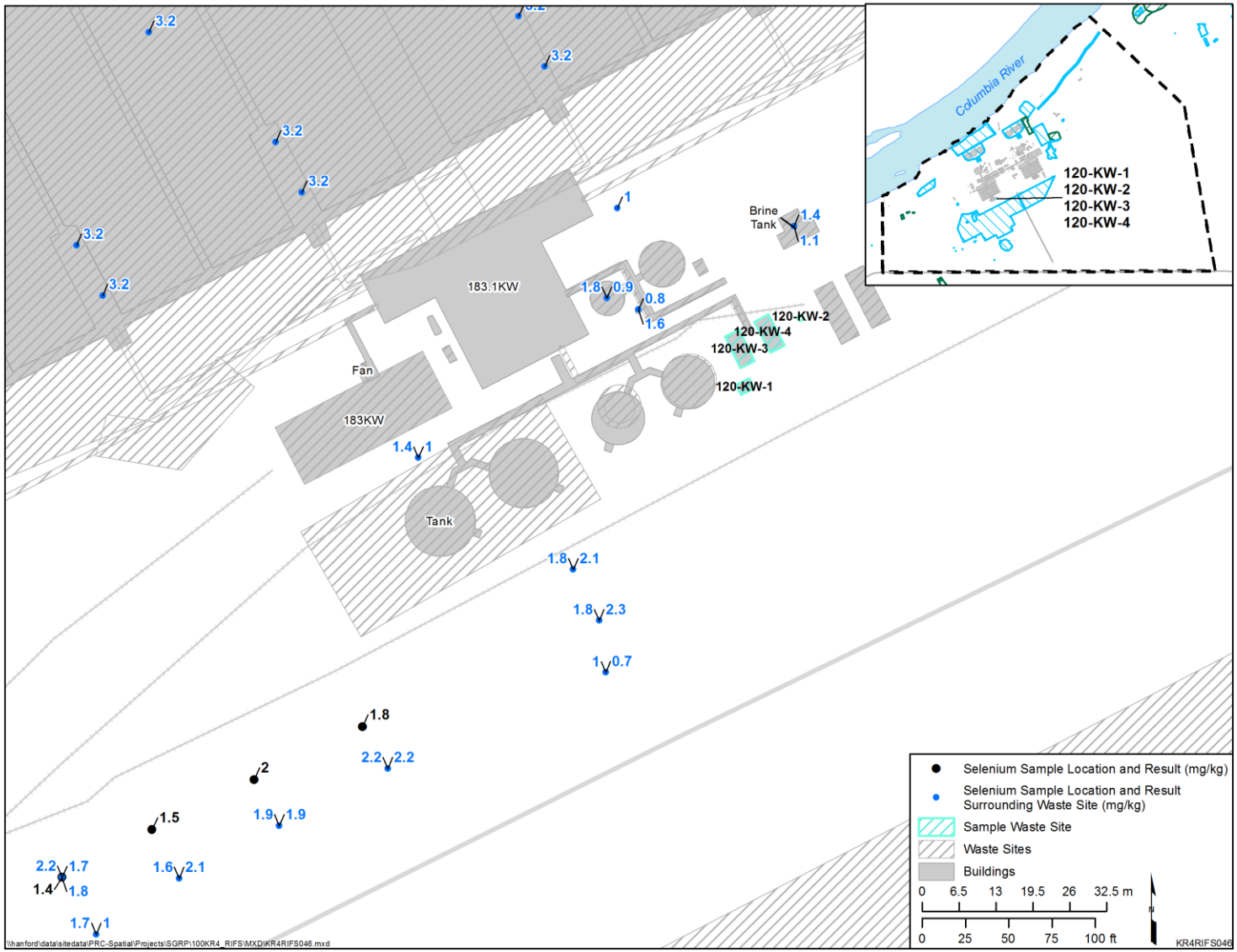

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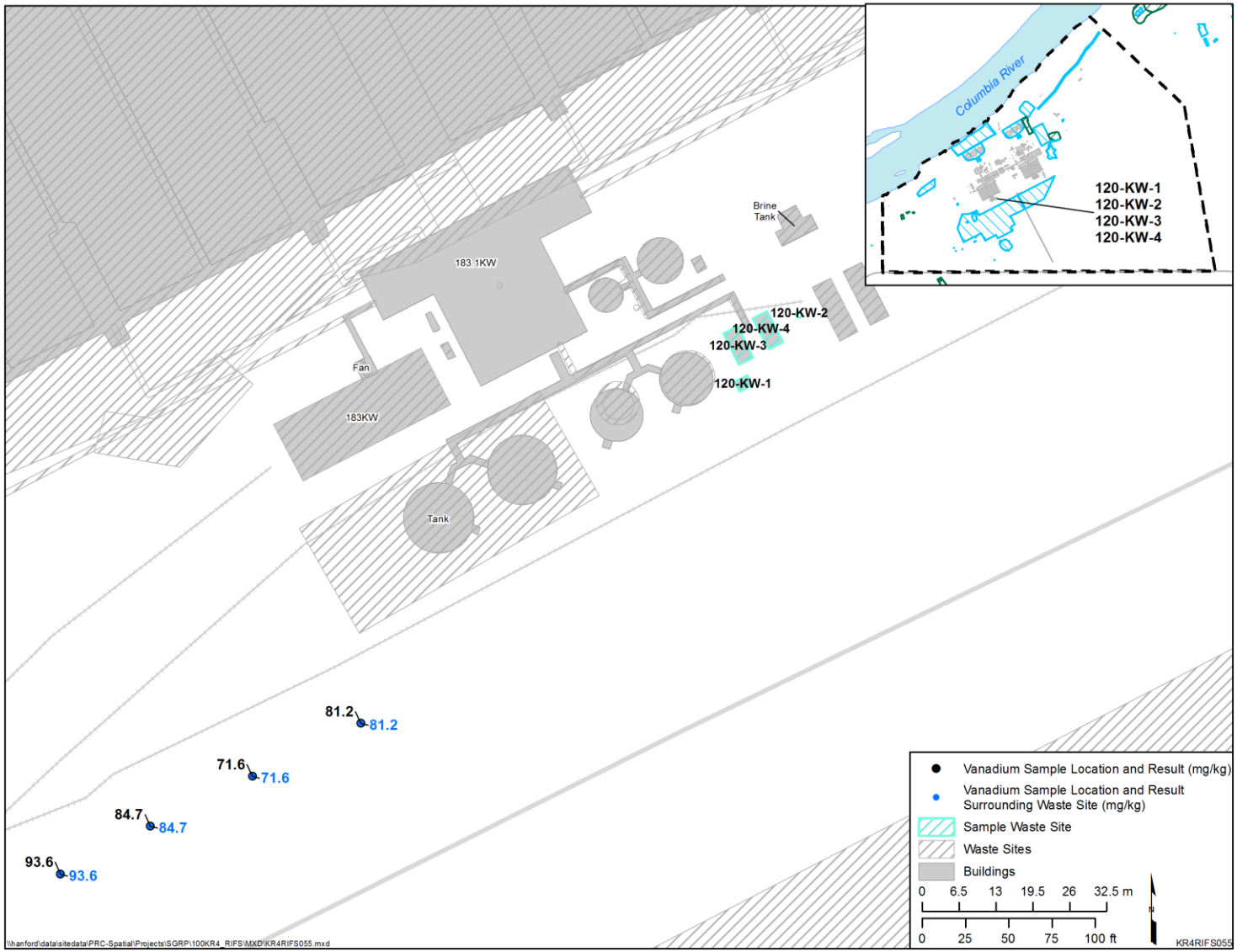

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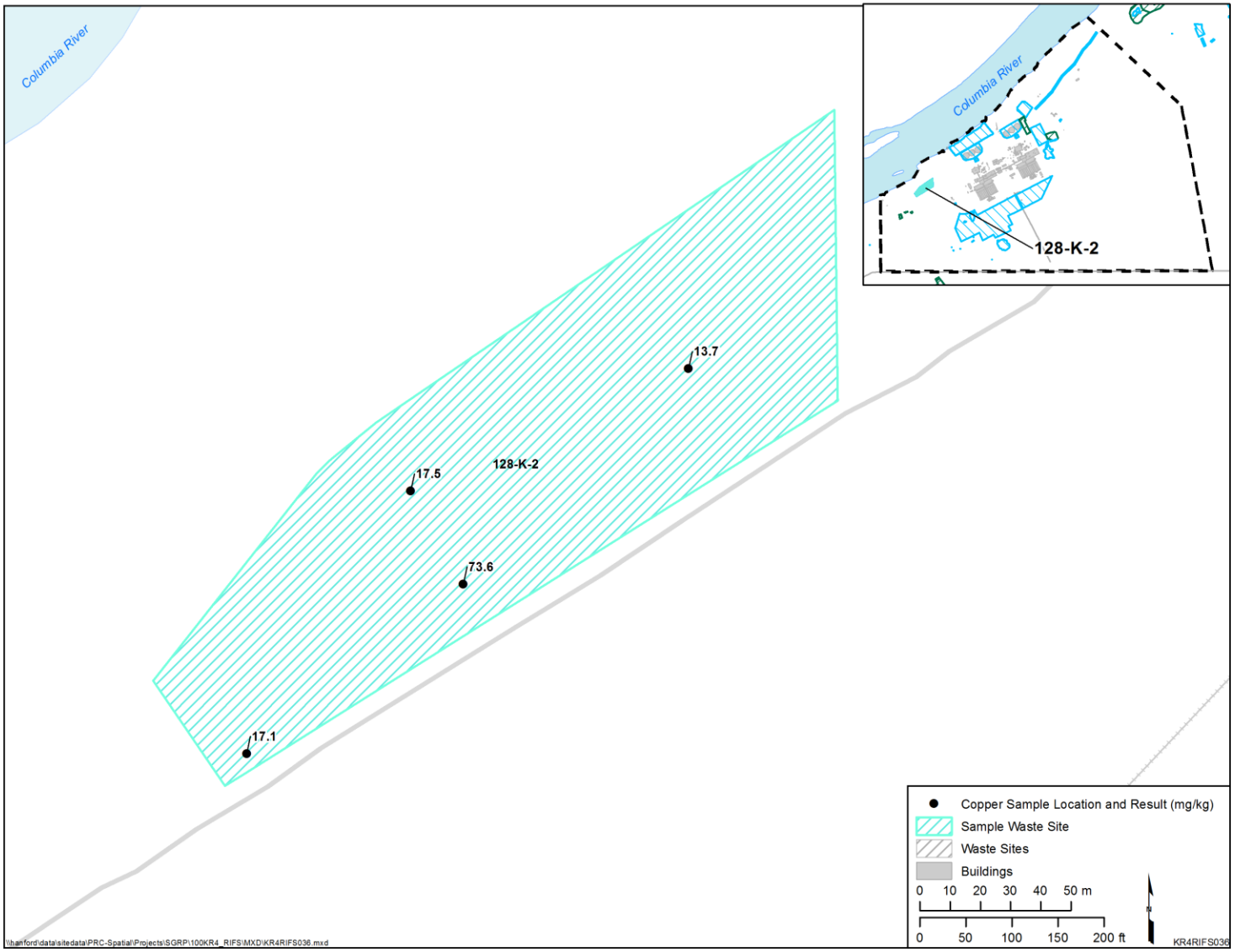

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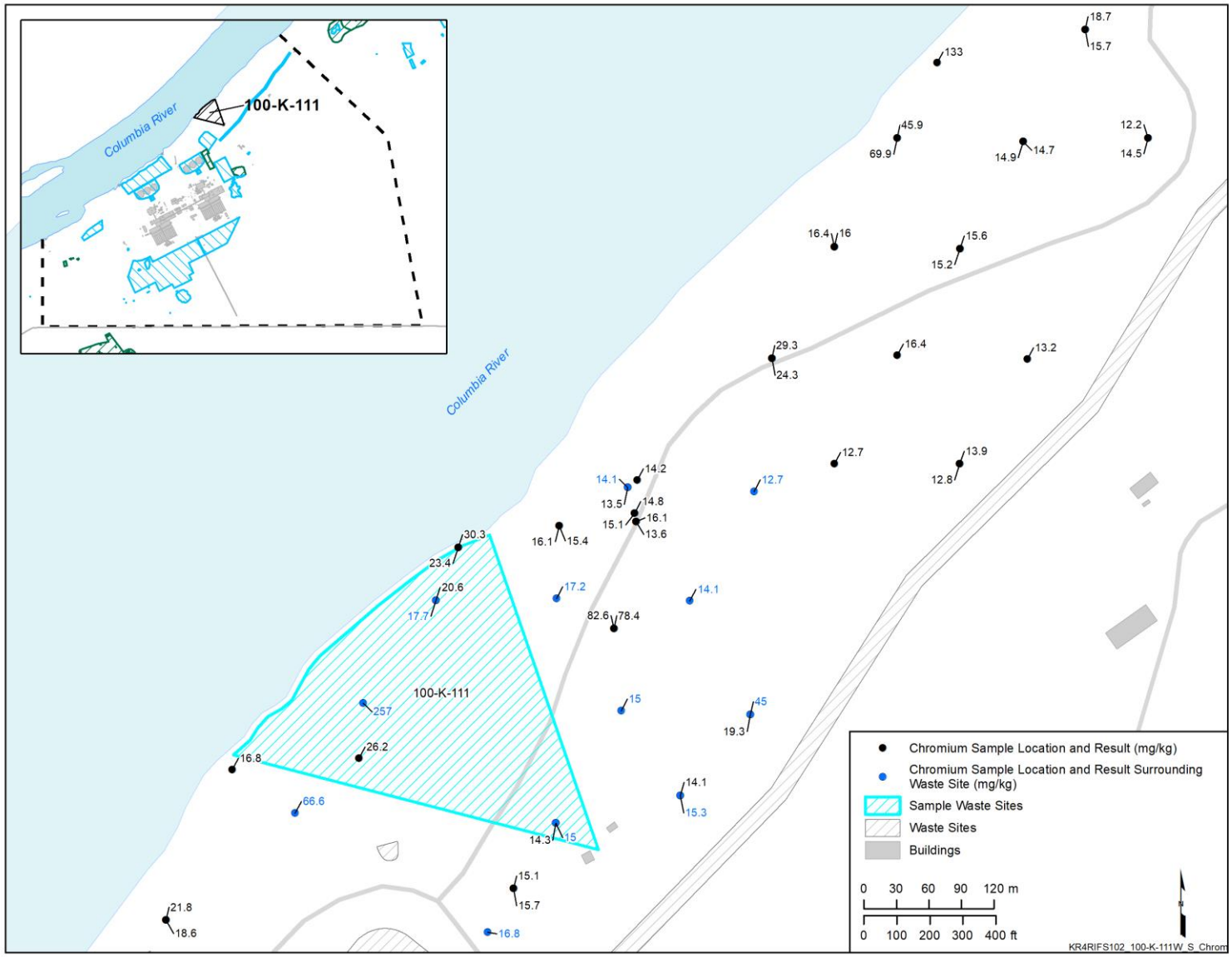

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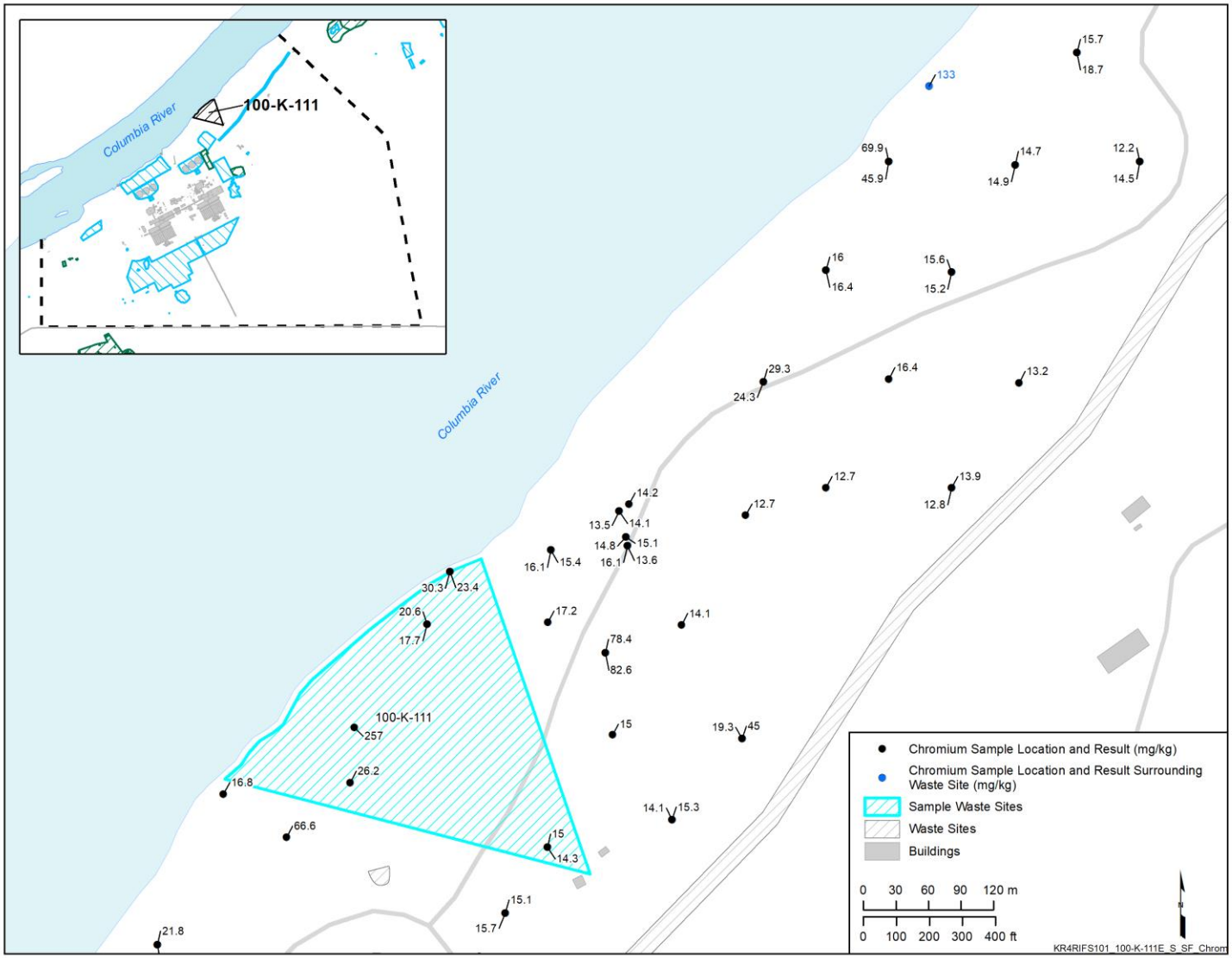

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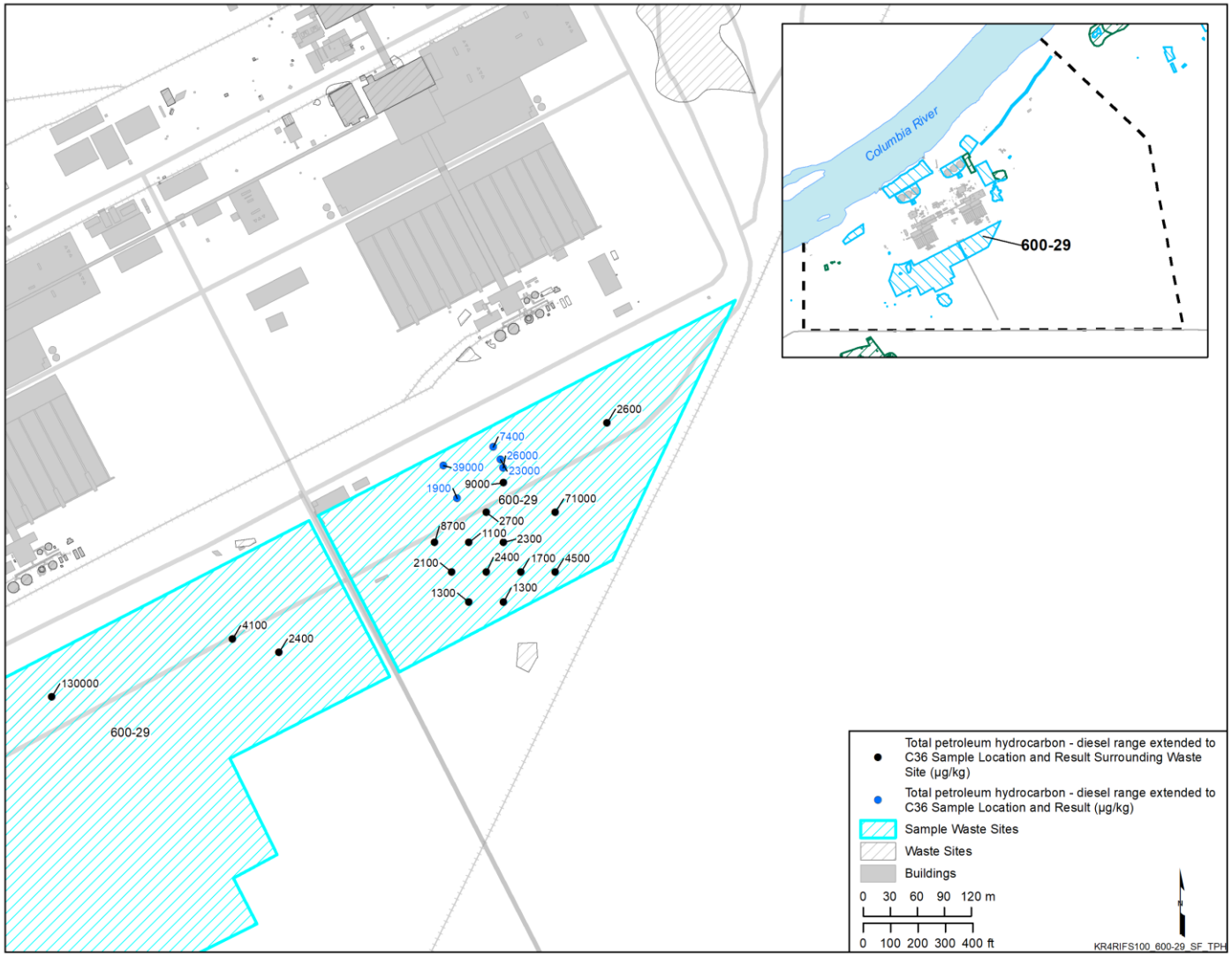

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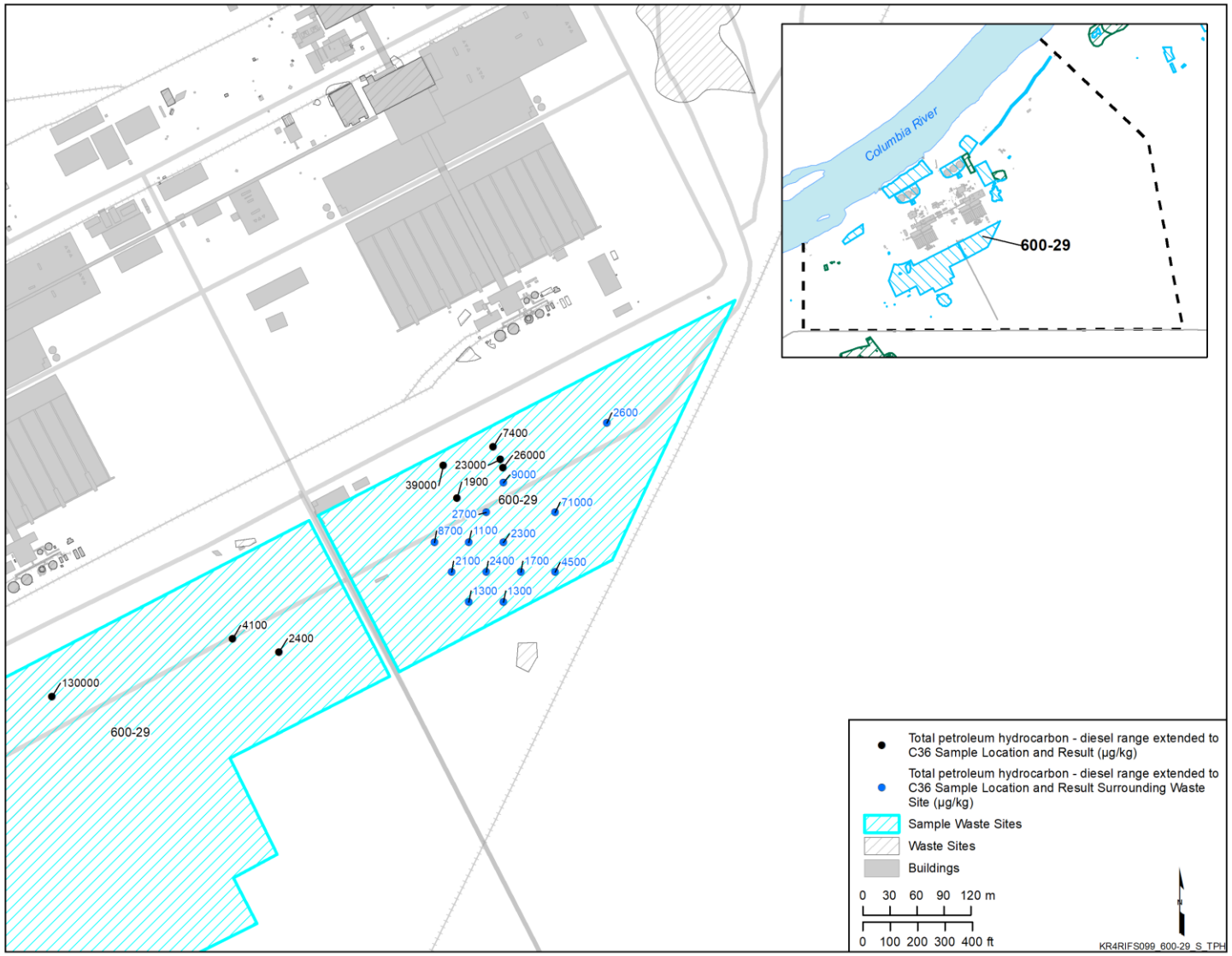

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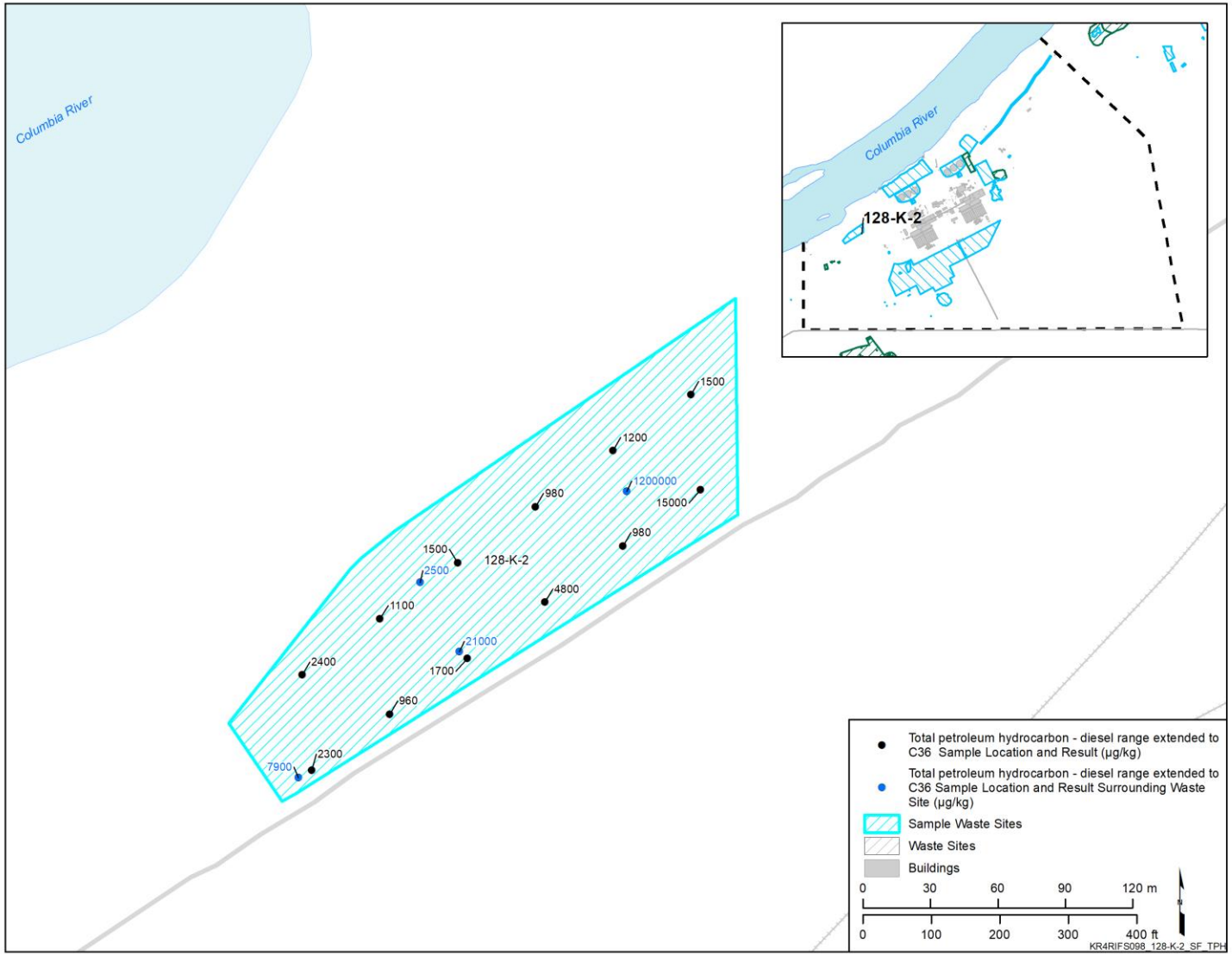

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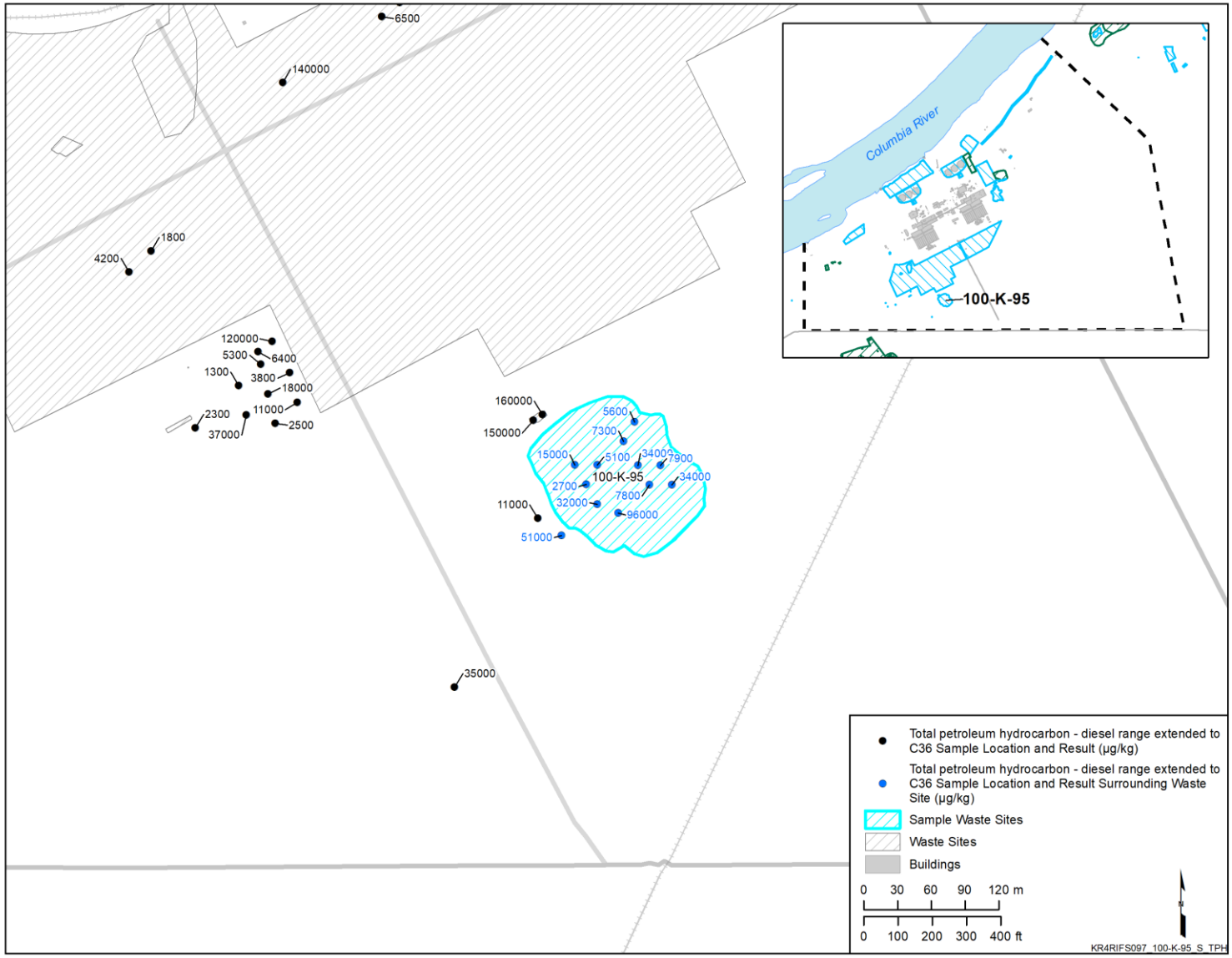

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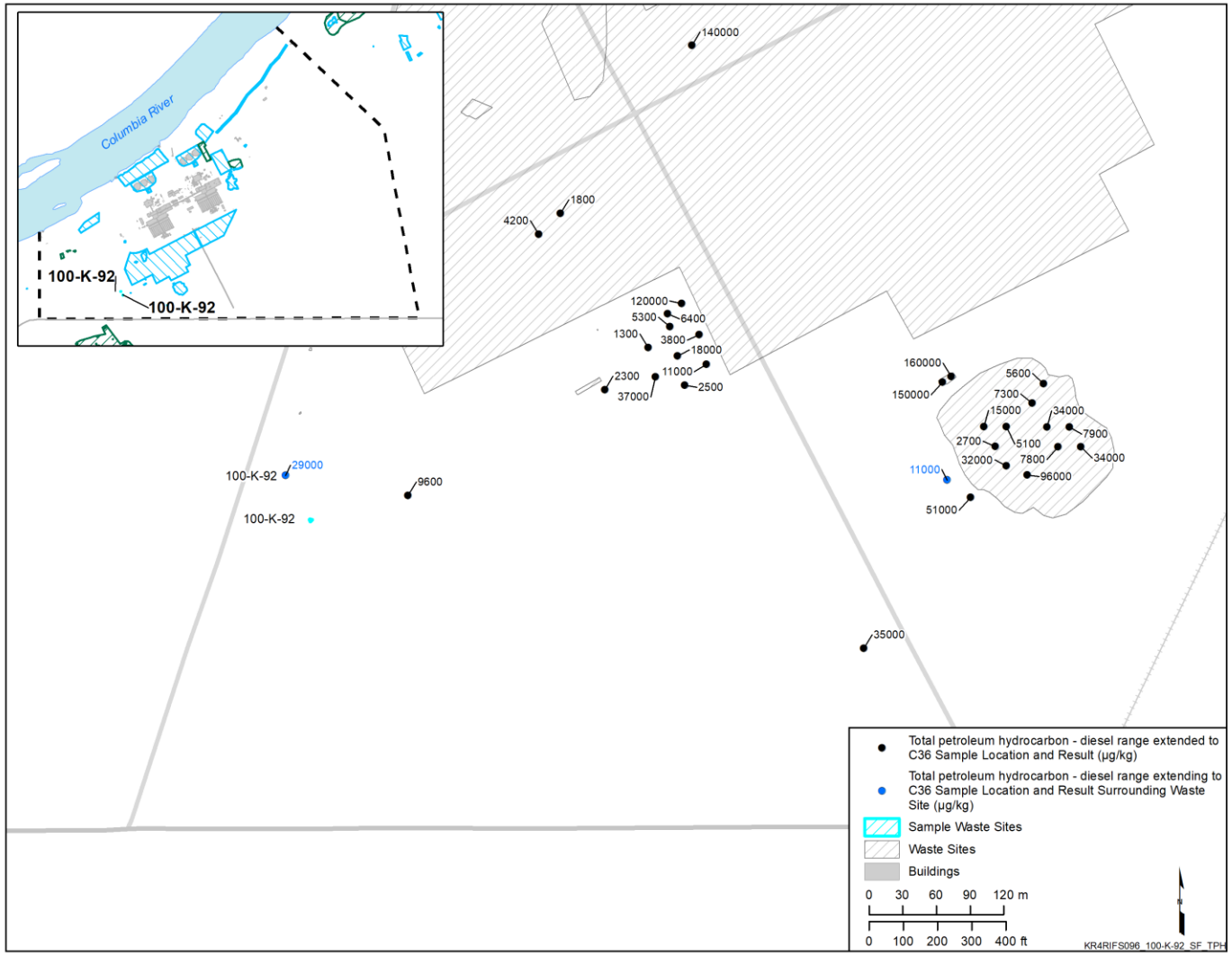

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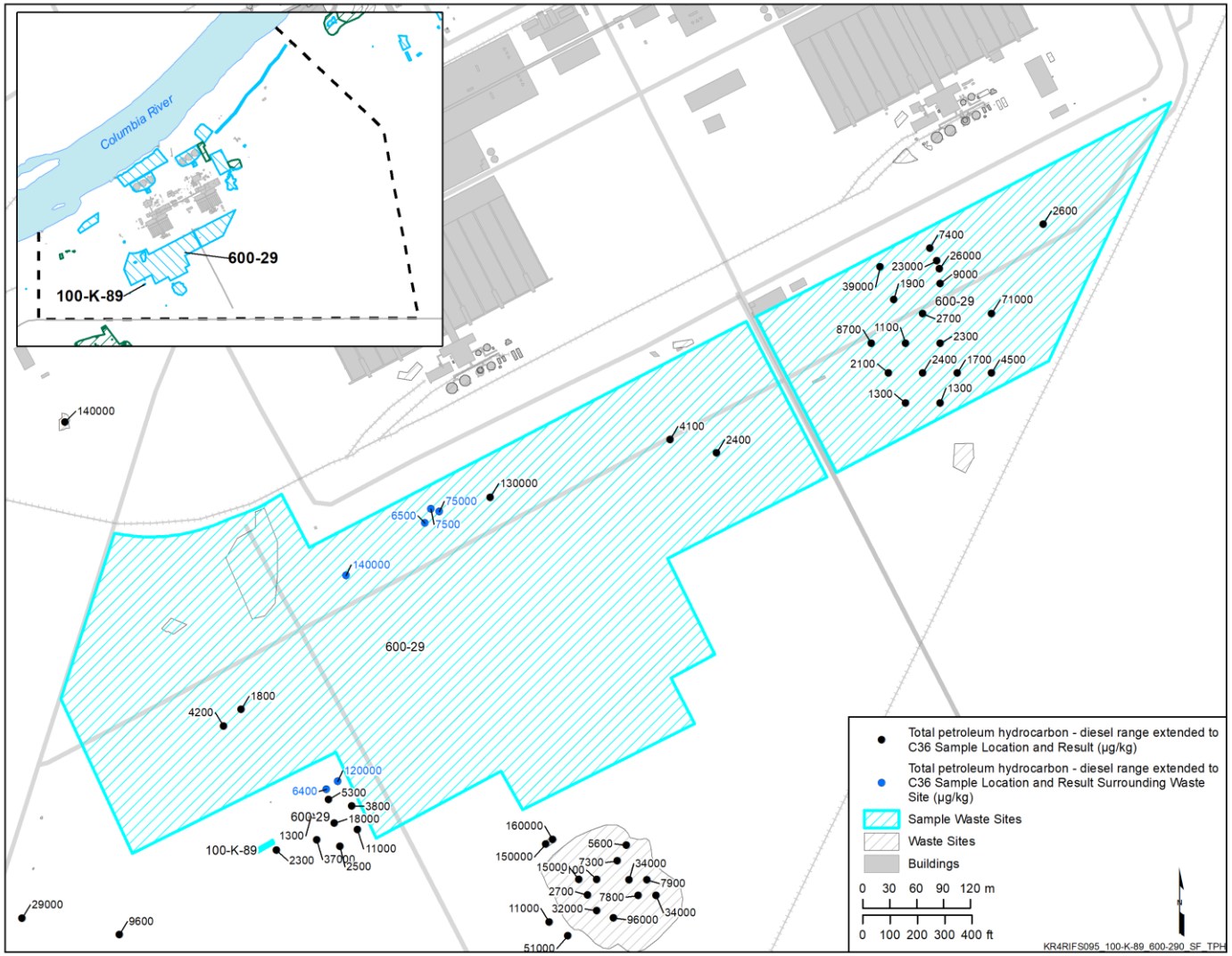

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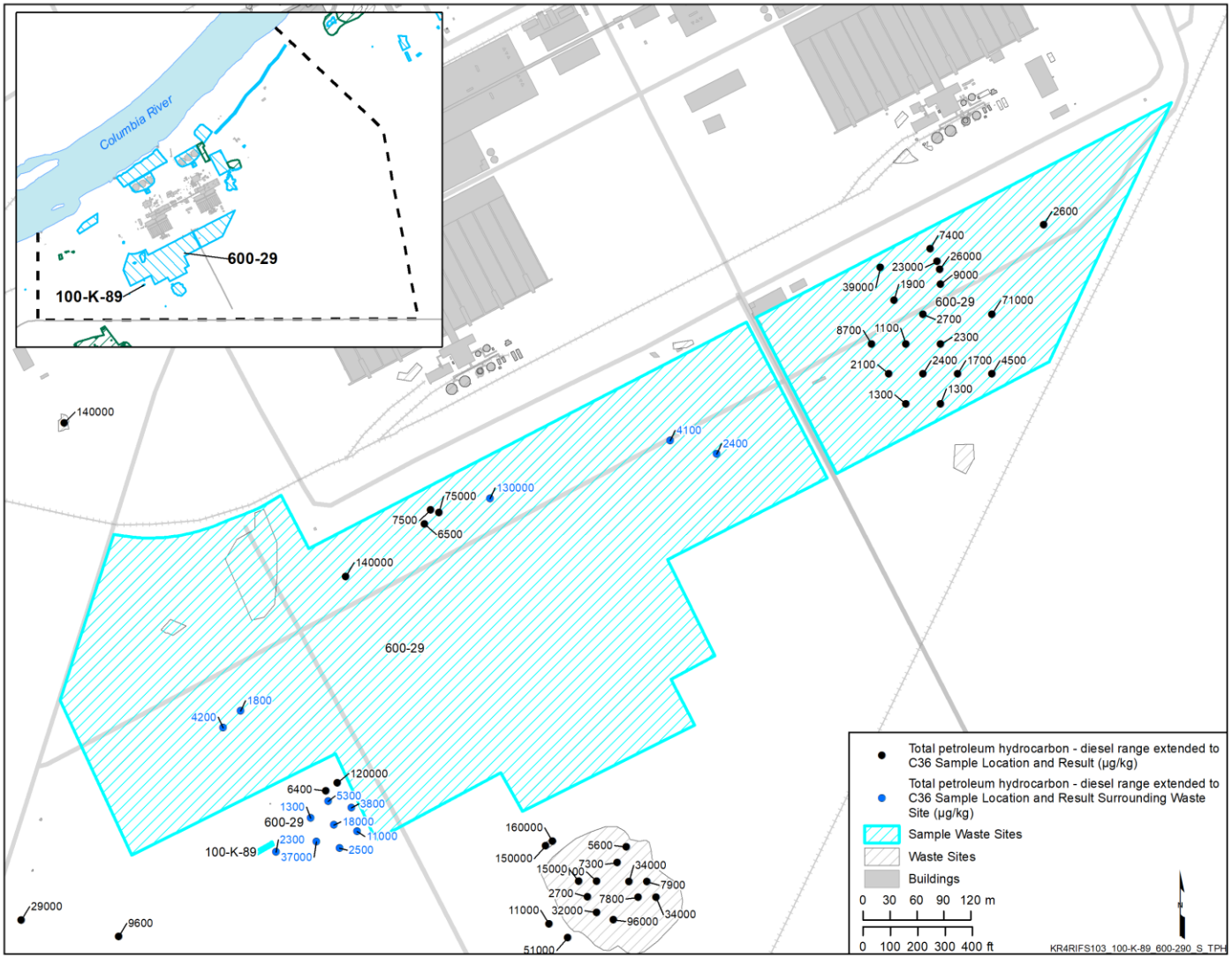

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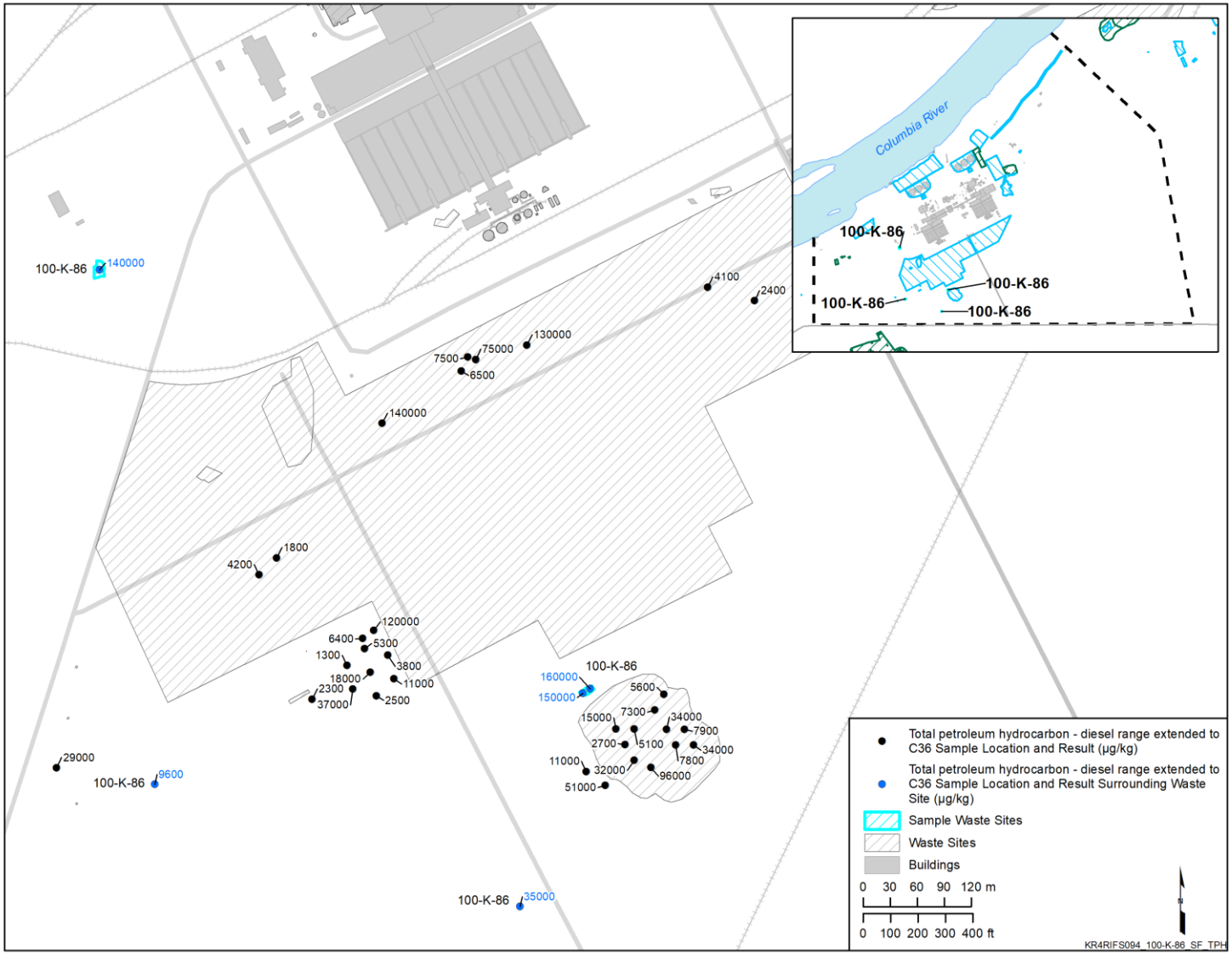

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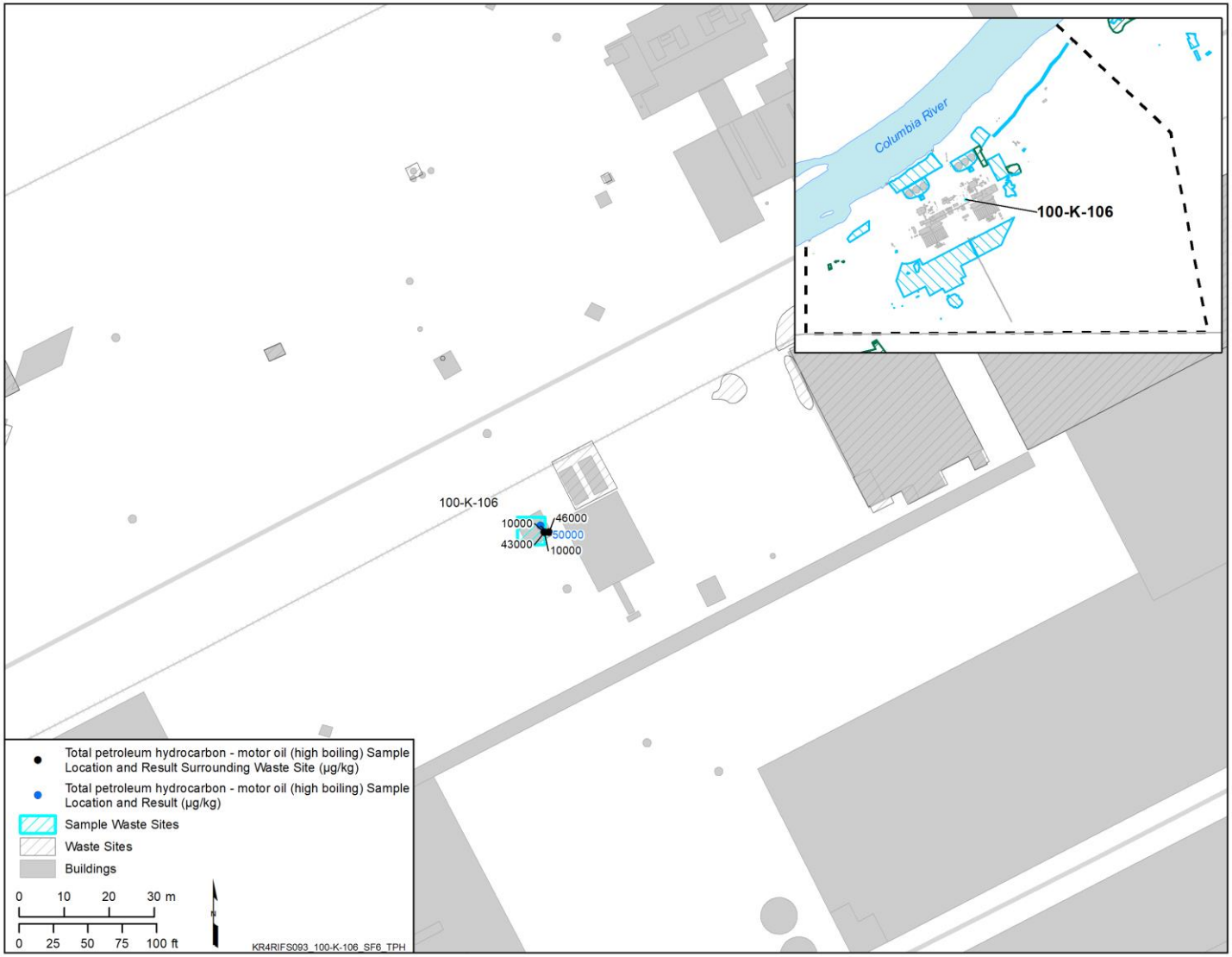

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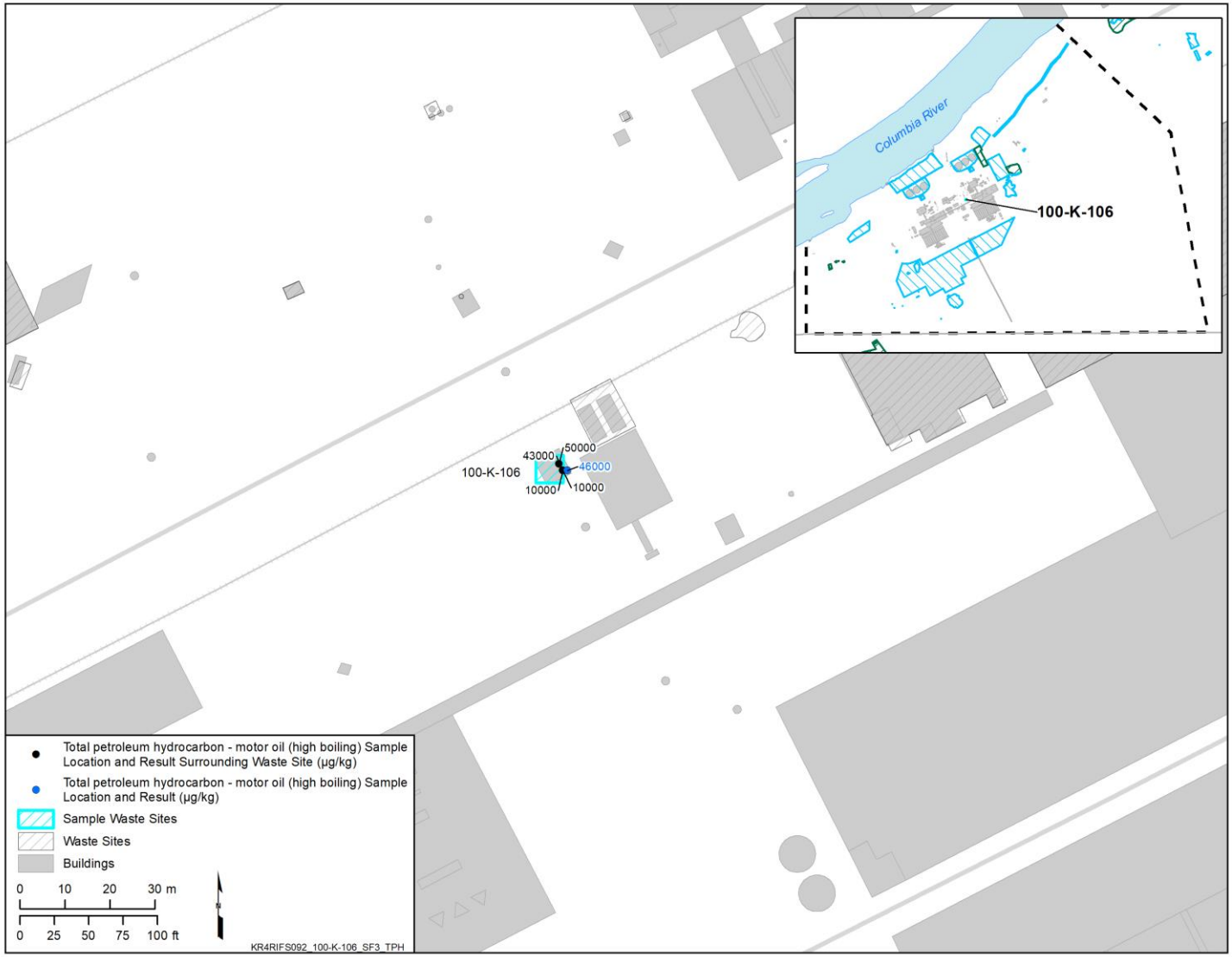

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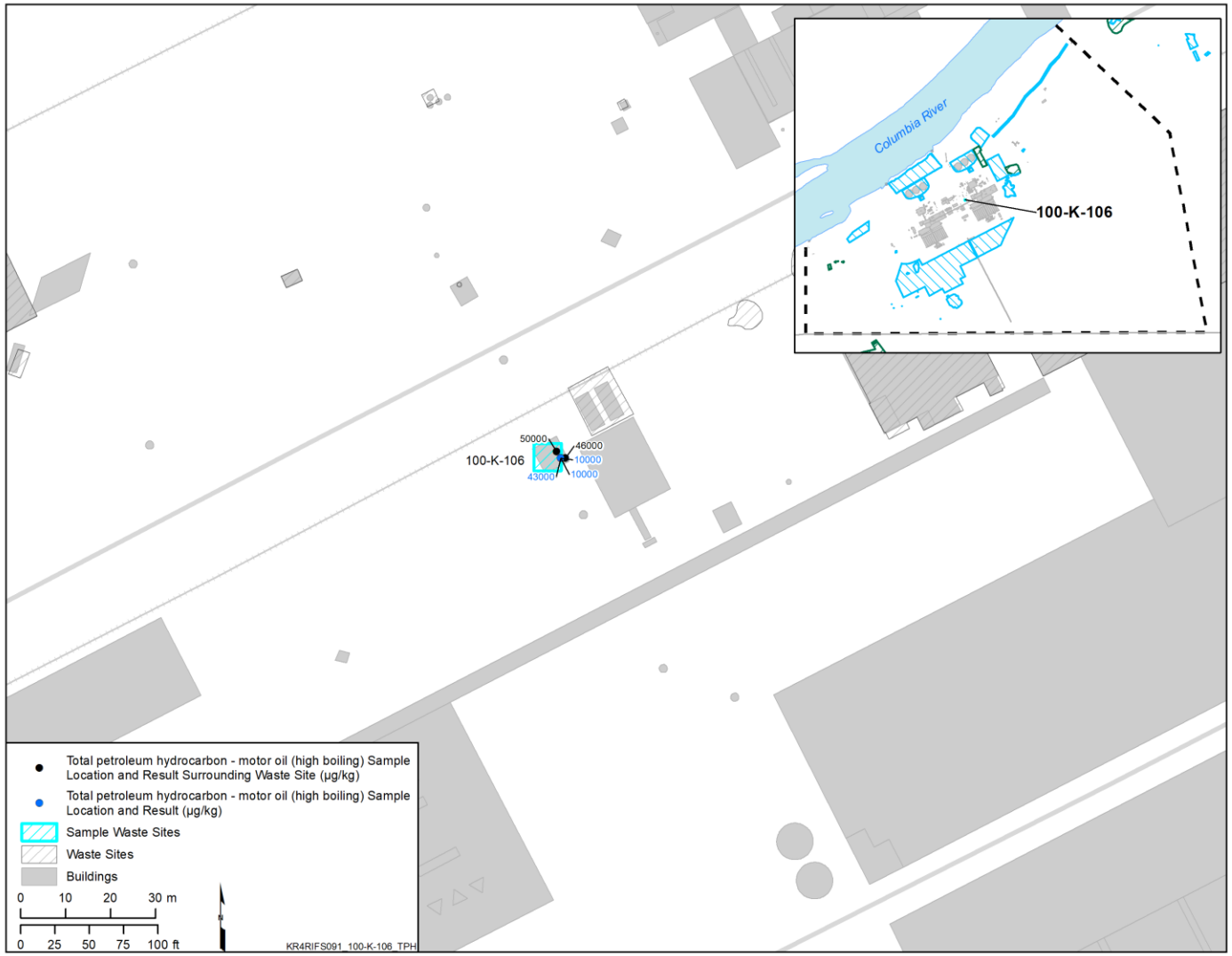

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Appendix I

Nonoperational Area Evaluation

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Terms

BCCA	BC Control Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
FS	Feasibility Study
GPS	global positioning system
HEDR	Hanford Environmental Dose Reconstruction
LiDAR	Light Detection and Ranging
NP	nonoperational property
NPE	nonoperational property evaluation
NPL	National Priorities List
OSE	Orphan Sites Evaluation
OU	Operable Unit
PM_{10}	particulate matter less than 10 micrometers in diameter
RI	Remedial Investigation
SESP	Surface Environmental Surveillance Program
WIDS	Waste Information Data System

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I1 Introduction

This appendix presents information that supports the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) Remedial Investigation/Feasibility Study (RI/FS) conducted for 100-K (DOE/RL-2010-97). Most of the waste sites in 100-K are located near former industrial facilities. Large land areas (beyond the reactors and their associated facilities and waste sites) have little or no subsurface infrastructure or indication of past or present releases of hazardous constituents. This land is referred to as nonoperational property (NP). This appendix presents the nonoperational property evaluation (NPE) specific to 100-K.

I1.1 Scope of the Nonoperational Property Evaluation

This NPE is not directly part of the CERCLA RI/FS process in that it has no role in determining the basis for remedial action or in evaluating remedial alternatives for contaminated soils or groundwater. 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," requires that the nature and extent of contamination be evaluated and appropriate remedial actions taken. Two important outputs from the NPE are evidence that effort has been taken to identify where waste may be present outside of operational areas and, where appropriate, the inclusion of NPE waste sites that may warrant further consideration as part of the RI/FS. The NPE also documents nonoperational conditions for use in risk communication and stakeholder information.

There are fate and transport mechanisms that could potentially distribute contaminants to nonoperational areas. The most credible are human disposal, wind-blown dust dispersion, air emissions from stacks during active operations, overland flow, and biological vectors (intrusion by plants and animals). Multiple lines of evidence have been developed to assess these fate and transport mechanisms and the potential for contamination to exist outside known operational areas. The following areas of focus were used in developing the lines of evidence:

- **Review of existing programs, data, and information with a nonoperational area focus:** Decades of environmental monitoring and surveillance have been conducted and reported at the Hanford Site. In addition to general (routine) monitoring that has included nonoperational areas, special studies have been commissioned and conducted that assess broad-area evidence of emissions and releases from facilities and waste sites.

- **Results of Orphan Sites Evaluations:** The Orphan Sites Evaluation (OSE) is a program that is has been designed primarily to support cleanup and long-term stewardship activities in the River Corridor. It provides a detailed understanding of disturbed areas (contaminated or not). Review of historical records and imagery, combined with on-the-ground walkdowns and field investigations, provide a comprehensive evaluation of current conditions in nonoperational areas.

- **Statistical analyses:** Two statistical analyses were conducted as adjuncts to environmental monitoring, data review, and field investigations. The first was developed and applied to enhance efforts to systematically and rigorously locate potential waste disposal sites. The second evaluated radionuclide distribution (based on available soil concentration data and aerial radiological surveys) to quantify and understand relationships with known waste sites and examine the potential for unidentified sites to exist outside operational areas.

I1.2 100-K Description

100-K covers an area of approximately 9.0 km^2 (3.5 mi^2) and includes the 100-KR-1 and 100-KR-2 Source operable units (OUs), the 100-KR-4 groundwater OU, and nonoperational area. It is situated on

relatively flat and level ground, except near the Columbia River where the land surface changes to gentle, low-relief slopes.

A perimeter fence surrounds a 3.1 km^2 (1.2 mi^2) area where most active operations took place. Within the perimeter fence, the ground surface and upper vadose zone have been highly disturbed and reworked by human activities that included agriculture activities, followed by reactor construction and operations, and waste site and groundwater remedial activities (DOE/RL-2008-46-ADD2, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units*; PNNL-SA-41467, *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment*). The natural soils in this area were shallow (15 to 31 cm [6 to 12 in.]) silt loam over river-deposited gravel. The reactor construction activities disturbed the natural soil strata, leaving a surface of sandy gravel and cobbles in the heavily disturbed areas surrounding the facilities. This alteration in soil structure resulted in a change in the plant communities that became established. The sandy-gravel soils tend to favor the native plants, and cheatgrass is not as dominant in these heavily disturbed areas as in the fine-grained soils. An additional disturbed area extends about 1.5 km (0.93 mi) outside of the northeast corner of the perimeter fence, where cooling water was disposed to the 116-K-2 Trench. The trench has been excavated, contaminated soil and debris removed, the excavation backfilled, and the site revegetated with native plants. Otherwise, the area outside of the perimeter fence is relatively undisturbed.

Spatial data show three primary types of vegetation to the east, south, and west of the perimeter fence: Sandberg's bluegrass-cheatgrass, gray rabbitbrush/Sandberg's bluegrass-cheatgrass, and small patches of big sagebrush/Sandberg's bluegrass-cheatgrass. Wildlife species observed in this area are described in the PNNL data summary for the reactor areas along the River Corridor. The riparian environment adjacent to 100-K extends in a strip along the Columbia River to the north and slightly west of the facility. The strip varies in width from 50 to 75 m (165 to 250 ft) north of the eastern end of 100-K to 150 to 200 m (490 to 660 ft) at the westernmost portion of the facility near the river (PNNL-SA-41467).

I2 Nonoperational Property Evaluation Approach

River Corridor cleanup efforts have focused on known waste sites located within operational areas (often within perimeter fences), and on a limited number of known sites outside these boundaries. Where surveillance monitoring or focused investigative activities have identified previously unknown sites, they have been identified and evaluated for inclusion within the scope of the cleanup efforts. Operational areas comprise a small fraction of the total land surface in the River Corridor. Outside of the operational areas is the NP area. For purposes of this appendix, the NP area in the River Corridor is defined as that area beyond the boundaries of waste sites listed in the Waste Information Data System (WIDS) database. The NP area is considered not to be directly associated with a Hanford Site process or operational activity known or suspected to contribute CERCLA hazardous constituents to the environment.

The approach to the nonoperational property for the River Corridor is to develop a conceptual model of the fate and transport mechanisms that could distribute contaminants from Hanford operations that would warrant further evaluation in the nonoperational areas, and then apply multiple lines of evidence to examine the likelihood that such contamination is present. The lines of evidence include results from long-term surveillance and monitoring programs and other studies; results from a spatial model for predicting the location of man-made features (including waste sites) based on proximity to man-made and topographic features; a spatial model for predicting where elevated radionuclide concentrations (specifically cesium-137) are present in soil based on aerial radiological survey results; and results from the OSE program.

Section L2.1 presents a description of potentially significant contaminant transport pathways. Section L2.2 presents descriptions of the key surveillance and monitoring programs and other studies for the nonoperational area in the 100-K Area. Descriptions of statistical analyses are presented in Section L2.3, and Section L2.4 presents a description of the OSE program.

I2.1 Nonoperational Contaminant Transport Pathways

The NP area, having no history of releases of hazardous or radioactive substances, is presumed to have a low likelihood of contamination that would require a response action under CERCLA. The principal objective of this evaluation is to examine multiple lines of evidence to confirm that hazardous or radioactive substance releases are not present in the NP area. An outcome of this evaluation could be the identification of areas where releases, or contaminant transport, may have occurred.

The following is a select set of contaminant release pathways that apply when evaluating the potential for contaminant transport into nonoperational areas:

- **Anthropogenic contaminant sources.** Contaminants from facilities or known waste sites may have been physically transported by human actions to shallow soils outside of waste site boundaries. Several activities and programs at the Hanford Site identify waste sites that have resulted from these types of activities. Section L2.2 presents an overview of these activities and programs.

- **Transport via wind-blown dust.** Hazardous and radioactive substances in surface soils and materials can become suspended into the air, dispersed to downwind locations, and subsequently deposited onto the ground. Approximately 6% of the 1,518 km^2 (586 mi^2) Hanford Site (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or used. Potential fugitive dust emission sources are located in the five operations areas within this actively disturbed area: the 100 Area, 200 East, 200 West, 300 Area, and 400 Area. The potential for fugitive dust emissions from these sources is generally conceived to occur subsequent to disturbance, erosion, or removal of soil covers over waste sites or through plant or animal biointrusion. These events can expose erodible material that contains contamination. Engineering controls (e.g., surface soil stabilization, dust suppression water, work cessation due to wind conditions) can be, and are, applied to mitigate or eliminate this transport pathway. However, contaminated areas posted as Radiologically Controlled Areas or Soil Contamination Areas could contain erodible material that could produce fugitive emissions from resuspension of windblown dust (DOE/RL-2010-17, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2009*). Figure I-1 depicts a conceptual model of wind-blown dust transport.

- **Emissions from facility stacks.** Hazardous and radioactive substances emitted into the air from former and currently operating facility stacks and vents can be dispersed to downwind locations and subsequently deposited onto the ground. Three groups of sources of Hanford Site stack air emissions had the potential to affect the River Corridor by air deposition. Two of the groups, which represent by far the greatest potential contributors, are stack emissions that occurred during active operations between 1944 and 1972. The two groups are examined separately based on their physical location and type of contamination. Group one is stack emissions from 200 Area operations that separated plutonium and uranium from irradiated reactor fuel. The second group is stacks in the 100 Area that exhausted ventilation air from the working areas of the nine production reactor facilities.
  The 100 Area sources were minor emissions compared with those from 200 Area facilities. The third group is nonradionuclide emissions resulting from coal-fired power plants used to generate steam for heating and process operations. There were large two power plants in the 200 Area that operated until the mid-1990s: 284-E Power Plant in the 200 East Area and 284-W Power Plant in the 200 West Area (WHC-EP-0472, *Facility Effluent Monitoring Plan for the 284-E and 284-W Power Plants*).

Nonradionuclide toxic air pollutants that could be emitted from coal-fired power plants are principally trace metals, but also include traces of volatile organic compounds such as formaldehyde, and polycyclic organic matter. The polycyclic aromatic organic matter and certain trace metals, in particular arsenic, cadmium, lead, and antimony, adhere to the fine particulate matter emitted from a power plant stack. Figure I-2 presents the conceptual model of transport from stack emissions.

- **Overland transport.** Hazardous and radioactive substances in surface materials can be transported away from facilities or known waste sites by surface runoff (overland flow). This could conceivably occur following precipitation events or, as has been documented, from releases (or "spillage") of process liquid waste that had been discharged to liquid waste disposal sites. Overland flow potentially results in the transport of contaminated sediments or water away from a waste site. Factors that affect overland flow include slope of the ground surface, soil texture, vegetative cover, and frequency of precipitation.

  The Hanford Site is in a semiarid region where precipitation is more than balanced by evaporation and transpiration such that substantial overland flow from precipitation is an unlikely occurrence. A more likely source for overland flow is spills or releases from liquid waste disposal facilities during historical active operations. In general, these leaks were infrequent and documented through written and photographic records. Most resulted in localized contamination in and around the disposal sites. A number of these sites have been remediated under the interim action records of decision.

- **Biointrusion.** Hazardous and radioactive substances in shallow soil can be transported to plants at ground surface through their roots, or disturbed and transported to the soil surface by burrowing animals or insects. Plants extend roots into the soil to extract nutrients and water. Most of the mass of plant roots is concentrated within the shallow soil; however, some deep-rooted plant species are found at the Hanford Site. Unless actively managed and controlled, deep-rooted vegetation (e.g., tumbleweeds, sagebrush) growing over underground sources of contamination may selectively uptake contaminants, particularly radionuclides, into their tissues. When radionuclides are transported from roots to aerial portions of the plant, surface contamination may result. Desert animals and insects burrow for shelter from the heat, cold, or predators; reproduction; feeding; and water conservation. Most wildlife burrow no more than a few feet in depth; however, some macroinvertebrates (harvester ants) have been reported to burrow to depths of up to 2.4 m (8 ft) in soil at the Hanford Site. Animals that burrow into contaminated soil could unearth contaminants and disperse them on the soil surface. The conceptual model of biointrusion is depicted on Figures I-3 and I-4.

I2.2 Surveillance and Monitoring Programs

Several programs at the Hanford Site collect environmental surveillance and monitoring data. Many of these programs collect data to address regulatory requirements for emissions, effluent discharges, or U.S. Department of Energy Orders regarding radiological control. Other programs perform environmental monitoring of soil, water, air, or vegetation. Most of these programs are summarized in the annual environmental report for the Hanford Site (e.g., DOE/RL-2017-74, *Hanford Site Environmental Report for Calendar Year 2016*).

Fifteen Hanford Site programs that identify waste sites and/or collect environmental monitoring and surveillance data are listed in Table I-1. Table I-1 also identifies five other sources of information and data applicable to a nonoperational area evaluation. Information and data from these programs were evaluated to identify trends in how hazardous substances or radionuclides may have been transported from operational areas or waste sites to nonoperational areas within the River Corridor. Information from the programs involved with soil, air, or vegetation monitoring, or with radiological control, were of most use in the NPE. The evaluation of the 100-K Area results from these programs is summarized in Section L3.1.

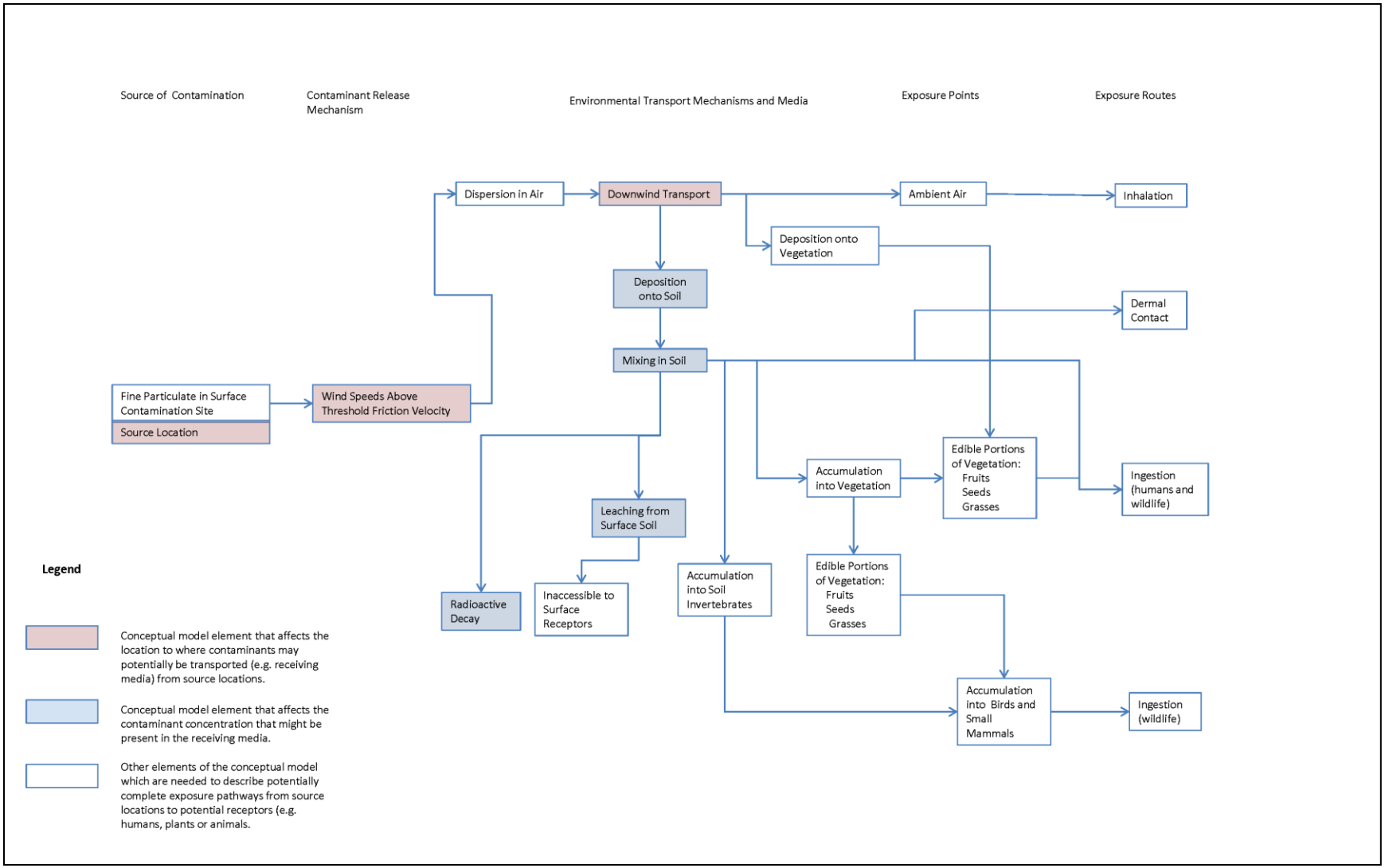

Figure I-1. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport of Windblown Dust

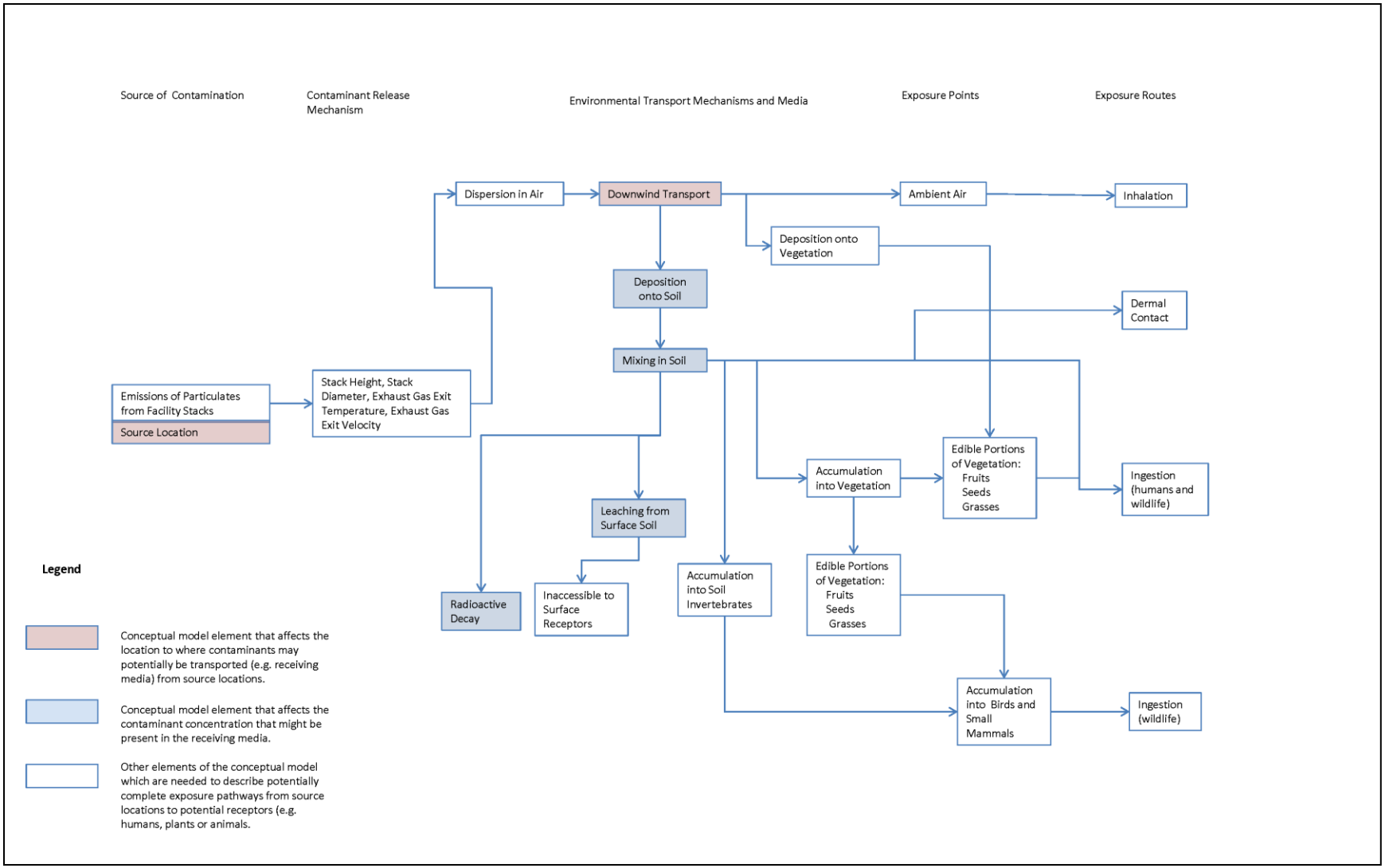

Figure I-2. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Emissions from Facility Stacks

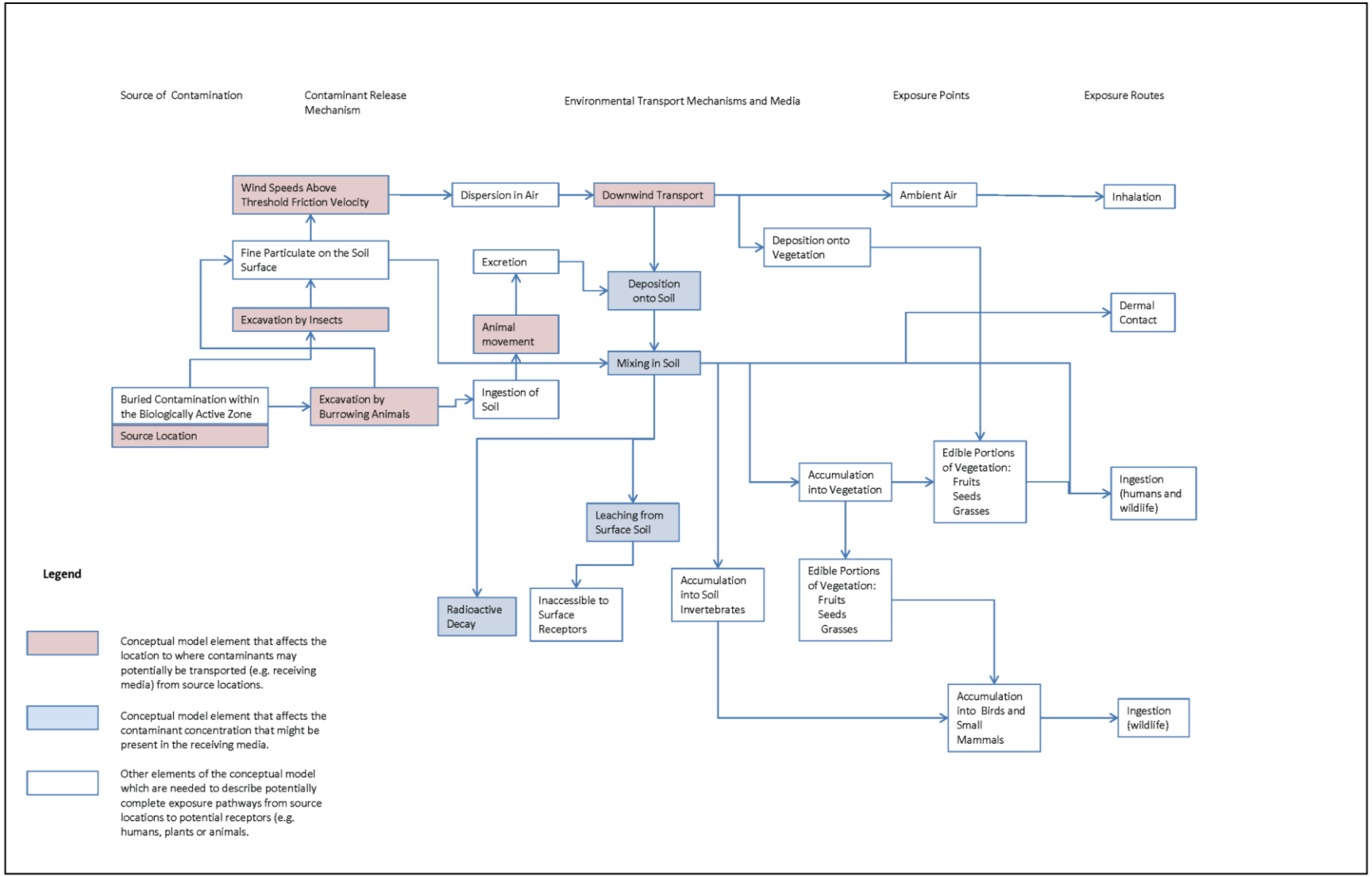

Figure I-3. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Animal Intrusion of Buried Contaminants

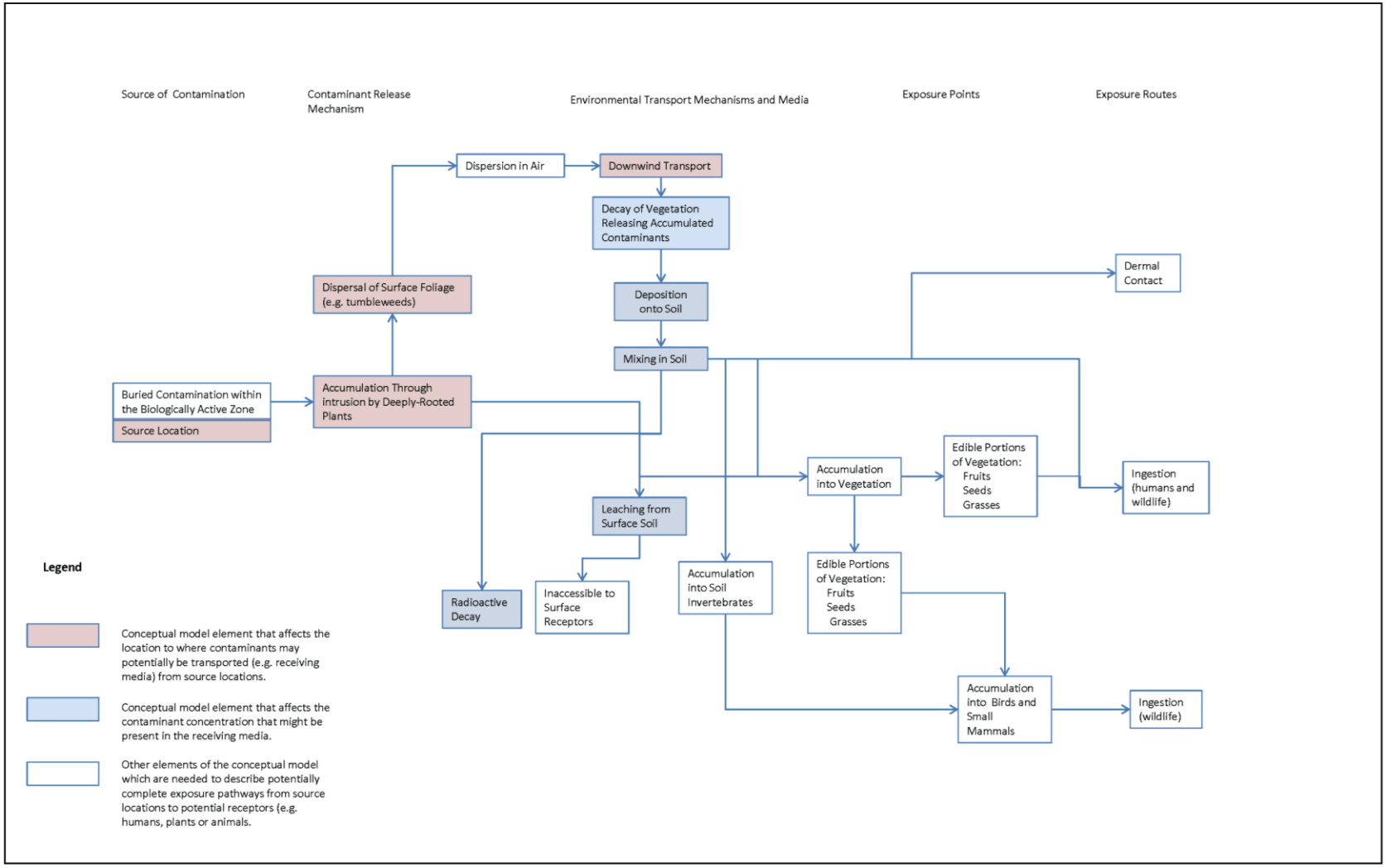

Figure I-4. Nonoperational Area Conceptual Model of Contaminant Fate and Transport Pathways—Transport via Intrusion of Deep-Rooted Plants

Table I-1. Existing Hanford Site Programs Related to Environmental Data and Monitoring

Ongoing Hanford Site Programs	
Air Emissions Monitoring	Liquid Effluent Monitoring
Ambient Air Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Ambient Air Monitoring
Soil Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Soil Monitoring
Vegetation Monitoring Near Hanford Site Facilities and Operations	Sitewide and Offsite Vegetation Monitoring
Radiological Dose Measurement Near Hanford Site Facilities and Operations	Radiological Surface Surveys Near Hanford Site Facilities and Operations
Groundwater Monitoring	Radiation Area Remedial Action Project
Waste Information Data System	Spill and Release Reporting
Vegetation Control Activities	
Additional Information and Data Sources	
Aerial Radiological Surveys	*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* (DOE/RL-2007-21)
Aerial Photography (includes Light Detection and Ranging)	Emissions estimation and dose assessments conducted as part of the Hanford Environmental Dose Reconstruction Project.
Hanford Site background studies	

I2.3 Statistical Analyses

The statistical analyses focused on:

- Developing and applying a predictive model for waste site locations
- Establishing association between cesium-137 measured directly in soil and high resolution aerial survey results
- Developing a sitewide model of soil cesium-137 using lower resolution sitewide aerial surveys

The results of these analyses were used to model the likelihood of finding previously undiscovered waste sites in the nonoperational areas as a function of man-made and topographic features, and model the potential for radionuclide concentrations (specifically cesium-137) in surface soil to be higher than selected threshold concentrations.

These lines of investigation are described below. Section L3.2 discusses the results from these analyses.

I2.3.1 Predictive Modeling of Waste Site Locations

The predictive model is based on the conceptual model that waste sites are located in proximity to anthropogenic features such as roads or existing operational areas, or flat or low-lying topography. The distributions of these geographic variables, measured at WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A quantitative model was developed to show the probability of a waste site being located at any unsampled location within the Hanford Site as a function of these geographic measures. Factors considered in developing geographic variables for known waste sites and sources included distance to operational areas; distance to roads, railroad grades, utility rights of way (e.g., power lines); and topography, including slope aspect elevation and curvature. These models were used to rank areas based on the relative probability that a previously undiscovered waste site might exist.

I2.3.2 Aerial Surveys and Soil Radionuclides

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive aerial radiological surveys. Soil measurements were expressed as activities per unit mass (pCi/g), suitable for estimation of exposure for risk assessment, whereas data obtained from aerial surveys were expressed as gross counts for gamma emitting radionuclides. Aerial survey data could be used to estimate exposure if it could be calibrated with soil cesium-137 activity data. Predictive models and maps of the probability that cesium-137 levels would be expected to exceed screening levels could be prepared based on the statistical relationship between soil activity measurements and aerial survey gross counts.

A detailed investigation in the BC Control Area (BCCA), which included collecting high-resolution aerial survey data and relatively high-density soil sampling, provided data to perform a detailed geostatistical analysis. The analysis of the BCCA data supported development of a sitewide model based on less resolved, but more laterally extensive, aerial surveys of all of the Hanford Site. The results of the site-wide model were used to draw conclusions specific to the River Corridor. The results of both analyses support the utility of aerial radiological surveys for estimating concentrations in soil for unsampled areas.

I2.4 Orphan Sites Evaluation

The OSE is a systematic approach to evaluate land parcels in the River Corridor to ensure that all waste sites or releases requiring characterization and cleanup have been identified. Information collected through these evaluations also supports elements of the CERCLA Section 120(h)(4), “Federal Property Real Disposal Process,” requirements for review and identification of uncontaminated property at federal facilities. The OSE supplemented past systematic efforts that identified source waste sites, including the Tri-Party Agreement management procedures (TPA MP-14) (RL-TPA-90-0001, *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, “Maintenance of the Waste Information Data System (WIDS)”) discovery process for identifying known and potential waste sites and the CERCLA hazard ranking conducted in 1985 and 1986 to place the Hanford Site on the National Priorities List (40 CFR 300, Appendix B, “National Priorities List”).

Two of the key elements of an OSE include a historical review and a field investigation. Review of historical information was conducted to identify potential orphan sites and to target areas for further evaluation during the course of conducting the associated field investigation. Historical research focused on identifying specific items or features typically associated with a waste site. The most common features associated with a waste site in reactor areas include drains, cribs, drywells/french drains, burial grounds, pipelines, aboveground and belowground storage tanks, septic systems, drain fields, burn pits, trenches,

ditches, pits, spills, sumps, vaults, ash pits, disposal areas, pumps, and buildings and facilities that contain chemicals and radiological contaminants. Information obtained and used in the historical review included the following resource types:

- Maps
- Construction and operations drawings
- Technical and operations documents
- Construction and operations photographs
- Aerial photographs
- Geophysical survey results
- Cleanup verification packages
- Sampling logbooks
- Personnel interviews

Field investigation activities were used to provide another level of assurance by conducting systematic walking surveys to document potential orphan sites and to follow up on potential orphan sites identified from historical review. Three primary tools provided the media to record the information observed in the field including hand-held Trimble GeoXT™ global positioning system (GPS) units, digital cameras, and field logbooks. Geophysical survey instrumentation was used to supplement these tools in selected areas of suspect subsurface features identified during the historical review or field investigation.

To ensure a systematic approach for area coverage, standardized 30×30 m (100×100 ft) conceptual grids were established over the investigation areas. The grid and existing known features in the areas were loaded onto the GeoXT GPS units, which were used in the field to monitor progress and record information. Walking surveys were typically performed in pairs with approximately 15 m (50 ft) spacing between individuals. Features encountered during this investigation were recorded using the GPS unit, digital camera, and field logbook.

The field investigation for regions of the River Corridor used a graded approach. High resolution, four-band (red, green, blue, and near-infrared) orthophotography imagery and Light Detection and Ranging (LiDAR) topography data were collected for approximately 57,468 ha (142,000 ac) of the River Corridor in April 2008. The data were collected in the early spring when foliage and undergrowth obscuring the ground surface was at a minimum. The orthophotography and LiDAR data were used to conduct “virtual walkdowns” of the areas. Based on results of these “virtual walkdowns,” areas were selected to conduct walking surveys (30×30 m [100×100 ft] reference grid system). Vehicle surveys along accessible roads and utility easements were also part of the field investigation. In addition, standard walking surveys were conducted throughout the River Corridor along the Columbia River, based on the level of interest in the shoreline area and its inclusion as part of the Hanford Reach National Monument (65 FR 37253, “Establishment of the Hanford Reach National Monument”).

I3 Evaluation Results

This section summarizes the results of the NPE in 100-K of the River Corridor based on the approach presented in Section L2. The NPE is based on multiple lines of evidence, including the results from surveillance and monitoring programs, and other studies conducted in the River Corridor; the results from

™Trimble GeoXT is a trademarked product of Trimble Navigation Limited, Sunnyvale, California.

statistical analyses performed to identify the potential presence of waste sites and to evaluate the spatial distribution of selected radionuclides in soil; and the results from the OSE.

I3.1 Results from Surveillance and Monitoring Programs

Hanford Site programs, which provided information characterizing conditions in the nonoperational areas in and around 100-K, included the soil, air, and vegetation sampling conducted as part of the Near Facility Monitoring program and the Surface Environmental Surveillance Program (SESP). The radiological control program with emphasis on radiological surveys and activities for identifying and controlling biological vectors (biointrusion from plants and animals), and external radiation monitoring conducted as part of the SESP.

Other activities that contribute to characterizing conditions in the nonoperational areas include the waste site discovery process under TPA-MP-14, which results in identified waste sites being inventoried in WIDS and, as discussed in Section L3.3, the OSE. Historically, interim actions conducted under the Radiation Area Remedial Action project contributed to stabilizing and controlling releases from waste sites. The results from these programs have been discussed using the framework of the conceptual model described in Section L2.1.

I3.1.1 Anthropogenic Disposal Activities

Past and present investigation activities provide confidence that waste site locations within the River Corridor are known. Waste site identification activities in the River Corridor fall into two categories: systematic and observational. Various systematic programs have been conducted at different times since the beginning of Hanford Site transition from production to cleanup in the 1980s, with the most recent being the OSE program that was initiated in 2004 (Section L3.3). An inventory of known and potential waste sites has been maintained in the WIDS database since the early 1980s, and is continually maintained through the TPA-MP-14 discovery process. Between 1985 and 1988, preliminary assessment/site inspection activities were completed to identify waste sites and prioritize the relative hazards. Waste disposal information was collected through exhaustive reviews of literature and maps, employee interviews, and visual inspection of all sites and unplanned releases. Results were organized and sites were ranked with respect to potential environmental impacts in accordance with a slightly modified version of the CERCLA hazard ranking system. The results from this process provided information to support addition of the 100 and 300 Areas to the National Priorities List (40 CFR 300, Appendix B) and subsequent listing of waste sites in Appendix C of Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*.

A variety of activities conducted as part of the RI/FS process has further characterized potential release and disposal activities in the 100 Area. These historical activities are summarized in DOE/RL-2008-46-ADD2.

I3.1.2 Windblown Dust Emissions

Emission sources, which could release contaminants through wind-blown dust, are described variously as “fugitive,” “diffuse,” or “nonpoint” emissions sources (DOE/RL-2010-17). The Hanford Site consists of 1,520 km^2 (580 mi^2) of semiarid shrub-steppe land, of which approximately 6% (about 83 km^2 [32 mi^2], or 8,909 ha [20,000 ac]) has been actively disturbed or actively used. This 6% of land is distributed into large operational and support areas where almost all fugitive emission sources are located: the 100, 200 (which includes 200 East and 200 West), 300, and 400 Areas.

The potential for fugitive dust emissions from waste sites (prior to their cleanup) is generally characterized as occurring subsequent to erosion of soil covers or plant or animal biointrusion, which may

expose erodible material containing concentrations of radionuclides. Contaminated areas posted as Radiologically Controlled Areas or Soil Contamination Areas also could contain erodible material that is radiologically contaminated, and that could produce fugitive emissions from resuspension of windblown dust (DOE/RL-2010-17).

The Radiation Area Remedial Action program is responsible for the interim stabilization, surveillance, and maintenance of the inactive waste sites at the Hanford Site. Interim stabilization measures to control fugitive dust have historically been performed on inactive waste sites prior to their cleanup. Stabilization measures included consolidation of surface contamination within the waste site from which it originated, then covering the waste with a layer of soil or other material (such as cobbles). Waste sites were then revegetated or treated as needed with a nonselective herbicide. Quarterly surveillance, annual radiological surveys, annual herbicide applications, removal of deep-rooted vegetation, and occasional corrective action for small areas of surface contamination continued following stabilization. Interim stabilization reduced sources of windblown dust potentially originating from contaminated soils.

The potential magnitude of windblown dust transport can be evaluated from the frequency of restrictions to visibility and ambient air monitoring for particulate matter and radionuclides in air. Dust, blowing dust, and smoke from field burning are described as phenomena causing restrictions to visibility (i.e., visibility less than or equal to 9.6 km [6 mi]). Reportedly, there are few such days at Hanford (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*). Particulate air monitoring shows that annual average PM_{10} (particulate matter finer than 10 micrometers [µm] in diameter) concentrations at the Hanford Meteorological Station are similar to PM_{10} concentrations at the Benton Clean Air Authority station located in Kennewick.

I3.1.3 Stack Emissions

Radionuclide emissions formerly produced from stacks in the 200 Area and the 100 Area had the potential to affect the River Corridor through deposition from the air. Based on studies conducted as part of the Hanford Environmental Dose Reconstruction (HEDR) project, most of the emissions occurred between 1944 and 1972 from facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel (PNWD-2222 HEDR, *Radionuclide Releases to the Atmosphere from Hanford Operations*). The largest releases from these facilities occurred in 1945, before effective collection devices were installed ahead of the stacks to prevent the discharge of volatile and particulate radionuclides. Most of the inventory emitted consisted of gaseous and/or short-lived radionuclides, which would be unlikely to result in measurable concentrations in soil in Hanford Site nonoperational areas. The nine production nuclear reactors in the 100 Area had stacks to exhaust ventilation air from the working areas of the reactor facilities. These were minor sources of emissions compared to the 200 Area facilities. No significant stack releases from 300 Area operations were reported in the documents that evaluated soil sampling and monitoring. The 300 Area primarily supported fuel fabrication processes and research activities that were not expected to have contributed to radioactive airborne emissions released on the Hanford Site (DOE/RL-2005-49, *RCBRA Stack Air Emissions Deposition Scoping Document*).

Releases of long-lived radionuclides, including americium-241, cesium-137, iodine-129, strontium-90, plutonium-238, plutonium-239/240, and plutonium-241, from the 200 East and the 200 West Area major stacks, were a very small fraction of the total inventory emitted into the air. A review of dose reconstruction information indicates that most of the total releases of long-lived radionuclides consist of cesium-137 and strontium-90 with a minor contribution of the other radionuclides.

Potential long-term impacts from these emissions within the Hanford Site have been assessed through air and soil sampling conducted as part of the Near Facility Monitoring and SESP programs (PNNL-19455, *Hanford Site Environmental Report for Calendar Year 2009*). Air sampling at 100-K is performed at a

sampling station located south of the fence line of the operational area. Particulate sampling for gross alpha and beta radiation, conducted at this station since 1991, shows either a flat or a declining trend in concentrations. Direct measurements of gamma dose made at this station since 1970 have shown background levels of radioactivity, with the exception of an elevated level measured in 2005. The Annual Environmental Reports describe the general trends in radionuclide concentrations measured in soil. While concentrations at some near-facility sampling locations are higher than offsite locations, average concentrations are low and show no changes in trends over several years (PNNL-19455). In general, concentrations of sampled radionuclides, including cesium-137, strontium-90, plutonium-239/240, uranium-235, and uranium-238, are comparable to Hanford Site background concentrations in soil.

I3.1.4 Overland Flow

Because the Hanford Site is in a semiarid region, January, March, and December are the only months that have always received measurable precipitation, reported from 1946 through 2004. Normal annual precipitation at the Hanford Site is 17.7 cm (6.98 in.) (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*). In the Hanford Site semiarid climate, precipitation is balanced by evaporation, transpiration, and vegetative uptake such that substantial overland flow from precipitation is an unlikely occurrence.

A more likely source for overland flow is historical spills or releases from liquid waste disposal facilities during active operational periods. Liquid effluents generated as a direct result of reactor operations consisted primarily of reactor cooling water, fuel storage basin water, and decontamination solutions.

Cooling water was transferred from the reactor buildings through effluent lines to the retention basins for cooling and thermal decay of short-lived radionuclides. From the retention basins, the water was transferred through large pipes to the outfall structures, then into pipes that discharged to the Columbia River. Overflow from the outfall structures also could discharge directly to the shore of the river through nearby spillways (WHC-SD-EN-TI-239, *100-K Area Technical Baseline Report*). During 1975, sampling was performed of all the retired radioactive liquid waste disposal sites, retention basin systems, and associated diversion trenches in the 100 Area. Sampling was performed of the contaminated fill inside the basins and along and in effluent lines and junction boxes, and through the basin floors. Samples were also collected along the outside of the retention basin walls for understanding overland flow (UNI-946, *Radiological Characterization of the Retired 100 Areas*).

Leaks from the liquid waste disposal sites in the 100 Area that resulted in overland flow are described in the report of the 1975 sampling event (UNI-946). In general, these leaks were infrequent, well-documented, and resulted in localized contamination around the periphery of the disposal sites. The leaks have been characterized historically or as part of the current RI/FS process. The majority have been cleaned up and interim closed out in accordance with the interim action records of decision. The identification of leaks or spills from waste sites also is incorporated into the procedure for maintaining WIDS in accordance with TPA-MP-14 (RL-TPA-90-0001). Based on the available information, overland flows from liquid waste disposal facilities are limited in lateral extent, and unplanned liquid release sites are identified through existing programs such as WIDS. The factors considered in this evaluation indicate that contamination in nonoperational areas through overland transport is unlikely to occur.

I3.1.5 Biointrusion

Radiological surveillance monitoring or vegetation sampling conducted as part of the Near-Facility Monitoring Program (PNNL-19455) has not identified contaminated vegetation episodes around 100-K. Mud dauber wasp nests were identified as a potential animal intrusion concern in 100-K (HNF-SP-0665, *2011, Quarterly Environmental Radiological Survey Summary, Fourth Quarter Calendar Year 2010, 100, 200, 300 and 600 Areas, Rev. 79*).

I3.2 Statistical Evaluations

The statistical evaluations provide estimates of the likelihood of finding previously undiscovered waste sites in the nonoperational property areas and the potential for exposure to cesium-137 exceeding selected threshold concentrations in surface soils.

I3.2.1 Relative Probability of Missing an Existing Waste Site

Known waste sites have largely been located in proximity to anthropogenic features and relatively particular topographic conditions. For example, most waste sites found to date are near roads, in low-lying areas such as ditches or ponds, or proximal to operational areas. The spatial distributions of these geographic variables, measured at known WIDS sites, were compared with the distribution of the same variables calculated at an unbiased set of locations systematically distributed across the Hanford Site. A statistical relationship was established to rank the likelihood that an available location might contain a previously unknown waste site. Logistic regression was used to develop the statistical relationship between waste site locations and geographic variables.

Factors considered in developing geographic variables expected to predict locations of known waste sites and sources included distance to operational areas; distance to roads, railroad grades, lakes, streams, or utility rights-of-way (e.g., power lines); and topography.

The geographic characteristics of the known waste sites were investigated to determine if their locations exhibited predictable spatial patterns. The purpose of this analysis was to develop a quantitative predictive model describing relationships so that areas within the River Corridor could be prioritized based on the relative probability that a previously unidentified waste site might be present. This analysis does not provide an absolute probability that a waste site exists, but rather provides a relative probability that allows locations to be ranked to identify the more likely location for a waste site—after all, there may be no additional waste sites in the River Corridor that have not been found. The predictive model provides direction to the most likely places for a waste site to occur if one exists.

The predictive model was developed based on a set of known waste site locations obtained from WIDS (referred to as a “training set”). The results of this model were used to predict the relative probability of encountering a potential waste site in areas that may not have been investigated in the field. This provided a ranking of locations within the NP that could then be investigated in the field, compared with previous field or desktop investigation results to determine the potential that additional previously undetected waste sites may remain within the NP. In the River Corridor area, the modeled predictions were compared with information generated from the OSE. The modeled predictions were compared with miscellaneous remediation points and waste site points observed during observations of aerial photography and LiDAR imagery, field walkdowns, and vehicular road surveys conducted as part of the OSE. These comparisons provided independent validation of the predictive model.

Predictive models of waste site locations were developed with logistic regression. The relative probability of a waste site is highest within the decision area boundaries and adjacent to smaller local roads. Outside the decision unit boundaries, the relative probabilities are generally less than 2%, with the exception of areas that are proximate to smaller roads that could afford easy access for discarding wastes.

All of the River Corridor area was investigated through the OSE virtual walkdowns, including investigation of high-resolution aerial photography, LiDAR, and other sources of information available in electronic form. In addition, areas were investigated exhaustively through field walkdowns. The field walkdowns provide essentially 100% field coverage for identification of potential waste sites. Generally speaking, field walkdowns coincide with the areas identified statistically to be the most likely to contain

waste sites; that is, areas close to operational facilities, known waste sites, and secondary roads that could afford easy access for dumping waste.

I3.2.2 Spatial Analysis of Soil Radionuclides and Aerial Surveys

Measurements of the presence of radionuclides were available from direct soil measurements, as well as from laterally extensive radiological aerial surveys. Soil measurements were expressed as activities per unit mass (pCi/g) suitable for estimation of exposure for risk assessment, but provide only limited understanding of the spatial distribution of concentrations. Data obtained from aerial surveys interrogates much larger areas, but are expressed as gross counts for gamma-emitting radionuclides. The aerial survey data were not directly applicable to estimation of potential exposure without calibration to directly measured soil concentrations.

For purposes of the NPE, aerial survey data were calibrated against measured soil cesium-137 activity data. Geostatistical methods were used in a preliminary study to develop a spatially explicit relationship between soil activity measurements and aerial survey gross counts within BCCA. Detailed geostatistical analysis was conducted within the BCCA because high-resolution aerial survey data and relatively high-density soil sampling data were available for this area. The preliminary analysis of the BCCA data was used as a pilot study to support determination to proceed with development of a more extensive sitewide model based on less-resolved, but more laterally extensive aerial surveys of all of the Hanford Site. The results of the sitewide model were used to draw conclusions regarding the distribution of cesium-137 (a contaminant of potential concern related to Hanford Site operations) specific to the NP area.

Aerial surveys conducted in 1996 (DOE-0335, *An Aerial Radiological Survey of the Hanford Reservation Richland Washington, Date of Survey: February 29 to March 21, 1996*) and 2009 (SGW-45563, *An Aerial Radiological Survey of the Hanford BC Controlled Area and West Lake Area Survey Data Survey Data – September 22 to 30, 2009*) were combined with ground radiological surveys and soil sampling and analytical data for cesium-137 in the BCCA to establish a relationship to the aerial survey results and measured concentrations in soil. A statistical model of the probability that soil cesium-137 levels exceed selected threshold levels (1.05, 1.5, 3.1, and 6.2 pCi/g) was developed as a function of gross counts of gamma-emitting radionuclides using sitewide aerial survey results. The statistical model was validated against a set of waste sites in the 200-MG-1 OU, where radiological surveys and soil sampling and analysis had been conducted as part of interim remedial actions.

The logistic regression models provide estimates of the probability of exceeding threshold levels, which can be interpreted as estimates of the proportion of an area that would be expected to exceed those levels if one were to sample them. The probabilities that cesium-137 activities exceed 1.05 pCi/g in 100-K are shown in Figure I-5. The highest probabilities are near the reactors and former retention basins. North of these areas there is apparent evidence of cesium-137 levels that exceed 1.05 pCi/g with probabilities in excess of 30% just north of the fence line. Probabilities closer to the Columbia River are generally less than 10%. For areas close to disposal areas and the reactor facilities, it is plausible that these estimates could be a result of elevated soil cesium-137 activities, or they may be related to increased gamma activity from radioactive sources within the operational area. It is anticipated that this uncertainty would be resolved during the RI/FS process associated with confirmation and closure of remedial actions in this area. Other areas outside the fence line at 100-K indicate that the probability of exceeding 1.05 pCi/g is less than 10%. Hanford Site background for cesium-137 is 1.05 pCi/g, which is the 90th percentile of the Hanford background sample data. This indicates soil cesium-137 levels are at or below Hanford background levels in the NP areas near 100-K.

I3.3 Orphan Sites Evaluation

100-K was addressed by a combination of three separate OSE reports including the 100-K OSE, OSR-2008-0003, *100-K Area Orphan Sites Evaluation Report*: parts of Segment 1 OSE, OSR-2009-0002, *100-F/IU-2/IU-6 Area – Segment 1 Orphan Sites Evaluation Report*; and Segment 4 OSE, OSR-2011-0001, *100-F/IU-2/IU-6 Area – Segment 4 Orphan Sites Evaluation Report*. Within 100-K, 22 orphan sites (new discovery sites) that were identified through the OSEs are addressed in the 100-K RI/FS report. Sixteen orphan sites (new discovery sites) were identified through the 100-K OSE, six of which are within the 100-K Exclusion Area. There was concern that the six exclusion area sites were physically separated far enough from their associated facilities that they could potentially be overlooked during facility demolition activities, and therefore were identified as orphan sites. The information on these sites was used for completion of the TPA-MP-14 process. TPA-MP-14 discovery site evaluation checklists were completed for each of the 10 orphan sites located outside the exclusion area.

I4 Conclusions

Multiple lines of evidence were reviewed to evaluate conditions in the 100-K NP area (and the River Corridor more generally) based on potential release and transport mechanisms. Surveillance and monitoring programs, in combination with the OSE, have comprehensively identified all waste sites within 100-K. In addition, the surveillance and monitoring programs, in combination with studies conducted as part of the HEDR, have demonstrated that emissions to the air, either from windblown dust or from stack emissions, have not affected nonoperational area soils with radionuclides. The surveillance and monitoring programs also have verified that biointrusion has not resulted in a spread of contamination into the NP areas.

Statistical analysis of the geographical distribution of waste sites based on man–made features and topography describes the likely locations of waste sites near 100-K. The results from this analysis reinforce the findings from the OSE, which has systematically identified the remaining waste sites within 100-K. Statistical analysis of the distribution of radionuclide concentrations observable from aerial surveys has confirmed that the probability of detecting elevated radionuclide concentrations in nonoperational area soils is very small.

Based on the evaluation of these multiple lines of evidence, the probability of identifying waste sites or contaminant dispersal from Hanford Site operations in 100-K nonoperational areas is considered negligible.

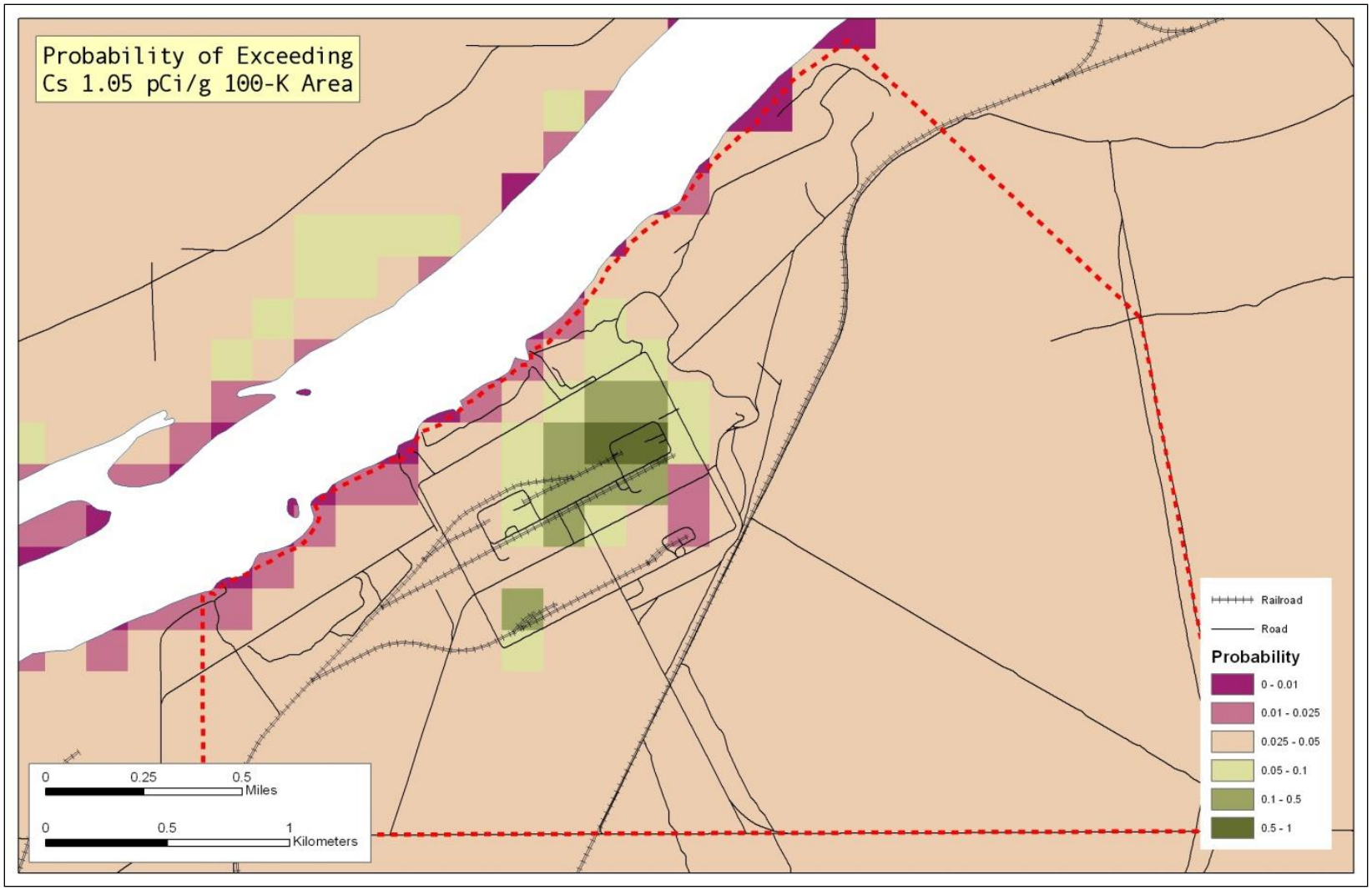

Figure I-5. Modeled Probability that Soil Cesium-137 Exceeds 1.05 pCi/g in the 100-K Area of the Hanford Site

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Appendix J

Riparian/Nearshore Evaluation

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Terms

BEHP	bis(2-ethylhexyl)phthalate
AWQC	Ambient Water Quality Criteria
COI	contaminant of interest
COPEC	contaminant of potential ecological concern
CRC	Columbia River Component
Cr(VI)	hexavalent chromium
FS	feasibility study
HEIS	Hanford Environmental Information System
MDLs	method detection limits
OU	Operable Unit
QC	quality control
RCBRA	River Corridor Baseline Risk Assessment
ROD	record of decision

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J1 Introduction

This appendix presents an evaluation of data from the riparian and nearshore environment along 100-K at the Hanford Site, Washington. The 100-K Area is located along the Columbia River and includes the 100-KR-1 and 100-KR-2 Source Operable Units (OUs), the 100-KR-4 Groundwater OU, and the adjacent surface water, saturated sediment, and aquatic biota. This evaluation of nonradiological substances and radionuclides detected in soil, water, and sediments supports the determination of whether potential transport pathways exist to these media from Hanford Site sources. The analytical data are referenced throughout this appendix by table number (Tables J-1 through J-38) and are found in the associated data tables file recorded on removable media.

J1.1 Sources

In total, 197 waste sites are in the 100-K Area, located principally in the upland zone (Chapter 1, Table 1-5). As described in PNNL-SA-41467, *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment*, the riparian environment immediately adjacent to the 100-K Area is composed of a strip of vegetative zone with varying widths from the shoreline to where the upland vegetation becomes dominant. This strip varies from approximately 50 to 75 m (164 to 246 ft) north of the eastern end of 100-K, and from approximately 150 to 200 m (492 to 656 ft) at the westernmost portion of the facility near the river. A limited number of the 100-K waste sites are of interest regarding the riparian/nearshore. In addition to these waste sites, groundwater in the 100-KR-4 OU is potentially a source of contaminant release to riparian and nearshore media.

J1.1.1 Waste Sites and Soils

The following paragraphs present brief descriptions of waste sites located close to the riparian zone in the 100-KR-1 and 100-KR-2 OUs. The nature and extent of contamination has been characterized or is currently being characterized for these waste sites. Although it is not known if there are potential releases or exposure pathways from these sites, their proximity to the riparian area makes them candidates for consideration as potential sources in this evaluation.

128-K-2. The site is located approximately 0.3 km (0.2 mi) southwest of the 100-K Area perimeter fence along the old Hanford Irrigation Project Canal. This site has not been covered with fill. A single chain-link fence with signs warning of asbestos marks the area. A variety of trash is exposed on the ground surface. There is evidence of burning in many locations. Most of the material on the surface is scrap metal and glass. Office waste, paint, solvents, and laboratory waste have also been found. Additionally, the area is covered with non-friable and friable asbestos. Remediation was performed at this site under an interim action record of decision (ROD) and the site was backfilled (https://pdw.hanford.gov/arpir/pdf.cfm?accession=0091166). The status of this site is interim closed out.

100-K-63. The site is along the Columbia River shoreline, north of the 107-KW retention basins. This site received effluent leaked from the 107-KW basins. The site is a large portion of the floodplain along the shore of the Columbia River, north of 100-K West Reactor Area that is posted as a radiological contamination area. Most of it is posted as an Underground Radioactive Material Area, but two sections remain posted as Soil Contamination Areas. Remediation was performed at this site under an interim action ROD and the site was backfilled (https://pdw.hanford.gov/arpir/pdf.cfm?accession=1209200624). The status of this site is interim closed out.

100-K-64. The site is north of the 107-KE retention basins, along the Columbia River shoreline, just west of the 116-K-1 crib. This site received effluents from the 100-KW basin. The site is the portion of the floodplain along the shore of the Columbia River, north of KE Reactor area. No remediation has been

performed at this site under an interim action ROD, and it is classified as accepted. Characterization sampling was performed at the site, as described in Section 4.2.5.2.

116-K-1. This site was a large crib located northeast of the 107-KE Retention Basins and near to the Columbia River. The crib was intended for disposal of diverted contaminated cooling water, but part of the crib washed out shortly after initial startup, and repairs were made in the area. The crib was abandoned once the 116-K-2 trench was completed, but continued to receive some contaminated effluent from valve leaks in the sewer piping system. Remediation was performed at this site under an interim action ROD and the site was backfilled (http://pdw.hanford.gov/arpir/pdf.cfm?accession=D5235655).

116-K-2. This site was northeast of the 107-KE Retention Basins and ran parallel to the Columbia River. During reactor operation, several washout areas were created along the riverside of the trench from effluent discharge. The washout areas resulted from extensive seepage through the northern side of the trench, which discharged along the ground surface until reaching the river. Remediation was performed at this site under an interim action ROD and the site was backfilled (https://pdw.hanford.gov/arpir/pdf.cfm?accession=DA02350695).

J1.1.2 Groundwater

The 100-KR-4 OU includes groundwater affected by contaminant releases from 100-K facilities and waste sites. Most of the facilities and waste sites are associated with historical operation of the KE and KW Reactors and their support facilities.

Principal groundwater issues for the 100-KR-4 OU include: a large chromium plume created by past disposal to the 116-K-2 trench near the Columbia River, localized chromium plumes near the KE and KW Reactors, radiological contamination associated with past discharges to the cribs near the KE and KW Reactors, and loss of shielding water from the reactors' fuel storage basins. Contaminants of interest (COIs) in the OU include carbon-14, strontium-90, tritium, Cr(VI), total chromium, nitrate, and trichloroethene, as discussed in Chapter 6; these COIs were recommended for further evaluation in the feasibility study (FS). Discussion of the potential for these groundwater contaminants to pose an ecological risk is discussed in Chapter 7.

Groundwater beneath 100-K flows generally toward the northwest to the Columbia River. Average rates of flow toward the Columbia River are 0.1 to 0.3 m/d (0.32 to 0.98 ft/d), as estimated from hydraulic gradients and from migration rates of plumes (PNNL-14031, *Evaluation of Potential Sources for Tritium Detected in Groundwater at Well 199-K-111A, 100-K Area*). This suggests a 10- to 12-year travel time for tritium and other dissolved waste constituents to travel from near the KE Reactor to the river. Waste constituents that interact with sediment, such as strontium-90, travel more slowly.

Locally, groundwater flow is affected by extraction and injection wells at the three pump and treat systems. Water levels in the Columbia River are controlled by upstream hydroelectric dams. Seasonal high water levels in the spring and summer slow plume migration to the Columbia River by decreasing the hydraulic gradient toward the river. As a result, chromium concentrations typically decrease in near-river wells during the spring and summer, then rise in the fall. The daily and seasonal water level increases contribute a flow component that parallels the river in nearshore groundwater.

J2 Data Evaluation

Analytical data collected from the riparian and nearshore zones were evaluated to focus on the contaminants of potential ecological concern (COPECs) that could be related to Hanford Site operations. This data evaluation encompassed groundwater (characterized by near-river wells and aquifer tubes), pore water, seeps/springs, surface water, sediments, and riparian soil data, obtained from a range of Hanford Site sources.

These sources included groundwater monitoring activities documented in the annual groundwater monitoring reports; sampling of sediments, seeps, and surface water conducted as part of the Surface Environmental Surveillance Program; and sampling of sediments, pore water, surface water, and riparian soils conducted as part of DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* (hereinafter called the RCBRA).

These analytical results were compared with ecological benchmarks and criteria to confirm whether these should be identified as COPECs. Analytical data quality, in particular filtered versus unfiltered analyses of water samples, was considered in making the comparisons with benchmarks and criteria. The spatial relationships of contaminant concentrations in surface water, pore water, and groundwater were evaluated to address whether detected contaminants were related to Hanford Site operations (i.e., originated from upland groundwater sources) or reflected ambient background conditions.

J2.1 Data Sources and Data Processing

The dataset used in this evaluation consisted of sampling and analysis data collected from 24 nearshore monitoring wells, 52 aquifer tubes, 4 pore water locations, 3 seep/spring locations, and 13 surface water locations within the boundaries of the 100-KR-4 OU. A list of the nearshore wells, aquifer tubes, and springs used in this evaluation is provided in Table J-1. Riparian soil, sediment, seep/spring, pore water, and surface water sampling locations are based on sampling locations identified in the RCBRA. Figure J-1 shows the sampling locations for each type of water media, riparian soil, and sediment.

The dataset was obtained from the Hanford Environmental Information System (HEIS) and included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

The analytical data were processed to eliminate unusable results and identify one set of results per sampling location and date of sample collection. The following sections describe the data processing steps.

J2.1.1 Laboratory and Data Validation Flags

Analytical data are received from the laboratory with data qualification flags. Validation qualifiers are assigned during the data validation process. The following rules determine how flagged or qualified sample results are used in identifying contaminants of interest:

- Sample results flagged with a “U” qualifier, or combination of qualifiers that include a “U,” such as a “UJ,” are considered nondetected results.
- Sample results without a “U” qualifier are considered detected concentrations, including results with no qualifier or with a “J” qualifier.
- Sample results that are rejected and flagged with an “R” qualifier are not used in identifying COPECs.

J2.1.2 Analytes Reported by Numerous Analytical Methods

Often analytes are reported by more than one analytical method, resulting in multiple results for the same analyte from the same location and sample data. When analytes are reported by more than one analytical

method for a sample, the set of data that best represents the actual concentrations is retained. For example, the gamma spectroscopy method provides concentration results for the uranium isotopes; however, uranium concentrations reported by a uranium-isotope-specific method are preferred.

J2.1.3 Field Duplicate and Field Split Results

Field quality control (QC) samples (field duplicates and field splits) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (i.e., monitoring well) on the same date, resulting in more than one sample per location/date. The following criteria are used to reduce multiple sample results for an individual location/date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

J2.2 Identification of Contaminants of Interest

After extracting and processing the analytical dataset from HEIS, a multi-step screening process was used to identify initial COIs:

- Apply exclusion criteria
- Identify nondetected analytes
- Identify analytes with maximum detected concentrations less than their respective effect levels (Tables J-2 through J-4)
- Identify analytes with maximum detected concentrations greater than their respective effect levels (Tables J-2 through J-4)

J3 Contaminants of Interest – Water

J3.1 Apply Exclusion Criteria

The first step in the COI identification process is to apply certain exclusion criteria. Analytes that meet the exclusion criteria were eliminated as a COI. The only exclusion criterion used was the absence of toxicity information for an analyte; if there were no effect levels available as described in Tables J-2 through J-4, that analyte was not carried into the next step of the data evaluation process. Analytes that did not meet any of the exclusion criteria were carried forward into the next step.

The analytes in nearshore groundwater wells, aquifer tubes, pore water, seeps/springs, and surface water samples that do not have effect levels are summarized in Tables J-5 through J-9. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum method detection limits (MDLs) are also provided in Tables J-5 through J-9.

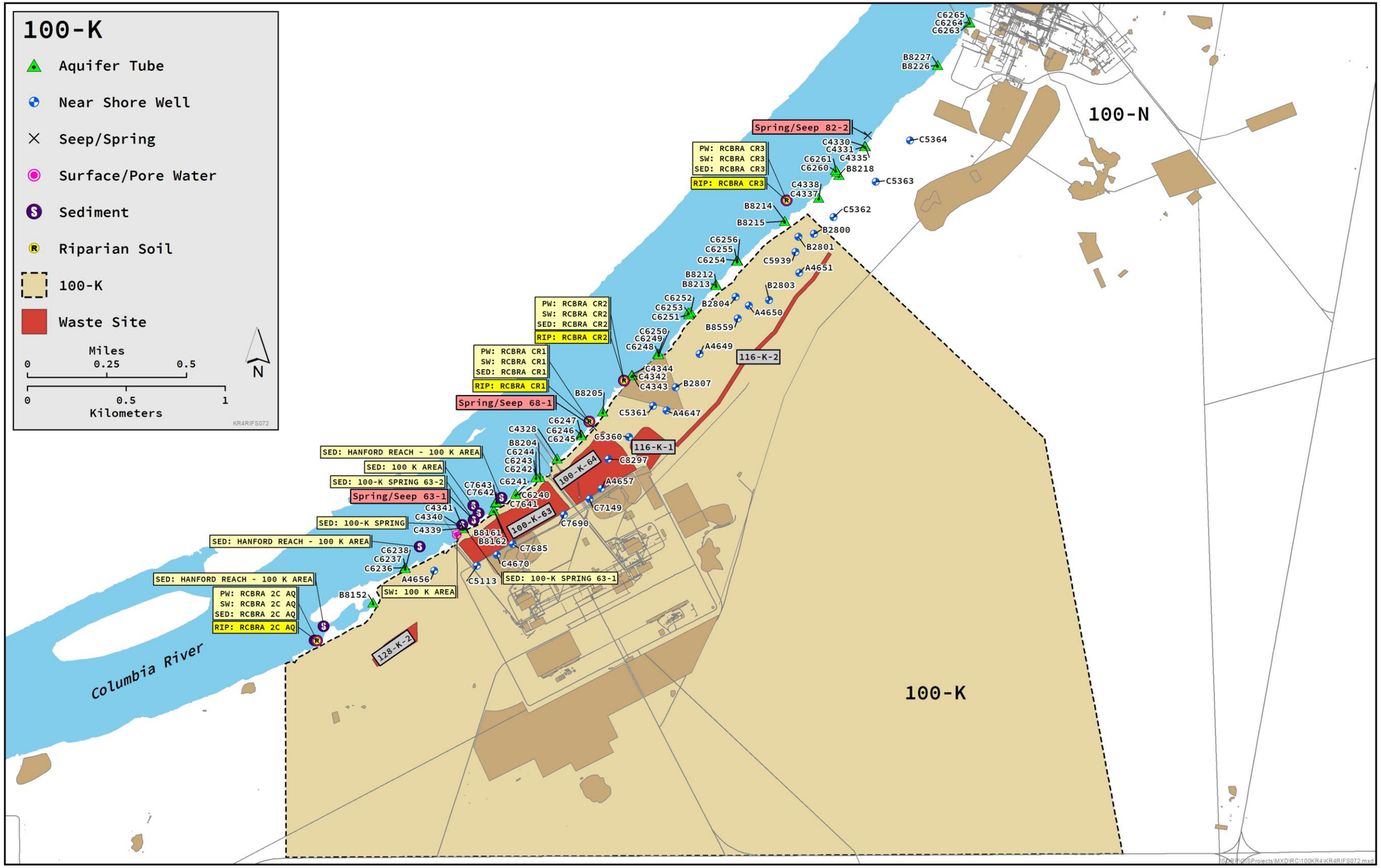

Figure J-1. Sampling Locations Evaluated in the Riparian/Nearshore Conceptual Site Model

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J3.2 Identify Nondetected Analytes

The next step in the COI identification process was to identify nondetected analytes. Chemicals and radionuclides that have been analyzed for, but not detected in any sample (collected from appropriate locations, with adequate detection limits), are eliminated as COIs. All analytes detected at least once were carried forward to the next step.

Analytes that were not detected in nearshore groundwater wells, aquifer tubes, pore water, seeps/springs, and surface water samples are summarized in Tables J-10 through J-14.

J3.3 Identify Analytes with Maximum Detected Concentrations Less Than Effect Levels

This step identifies analytes with maximum concentrations less than effect levels. In this screening step, the maximum concentration of each analyte detected in groundwater was compared to its effect level, to identify analytes not likely to contribute significantly to overall risk. If the maximum detected concentration of an analyte was less than its effect level, the analyte was eliminated as a contaminant of interest.

A list of analytes with maximum concentrations less than their effect level is presented in Tables J-15 through J-19.

J3.4 Identify Analytes with Maximum Detected Concentrations Greater Than Effect Levels

This step identifies analytes with maximum concentrations greater than their respective effect levels. Such analytes are likely to contribute to overall risk. If the maximum detected concentration of an analyte is greater than its effect level, the analyte is identified as a COI. The following paragraphs describe analytes with maximum detected concentrations greater than their respective effect levels. Tables J-20 through J-23 provide a summary of the analytes with maximum detected concentrations greater than their respective effect level for each water media except for surface water. Detected surface water concentrations are below their respective effect level. Table J-24 summarizes the results for all water media COIs (exceed the water effect level in at least one medium).

Those analytes that have maximum concentrations above the effect level and are also COPECs from the RCBRA [arsenic, cadmium, chromium, hexavalent chromium (Cr(VI)), lead, manganese, mercury, TPH-diesel, and uranium, and zinc], DOE/RL-2010-117, *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment*; hereinafter called the CRC; chromium, Cr(VI), and manganese), or groundwater COCs as identified in Chapter 6 of this remedial investigation report, (carbon-14, strontium-90, tritium, Cr(VI), total chromium, nitrate, and trichloroethene). The COPECs and COCs are discussed below.

J3.4.1.1 Cadmium

Groundwater. Cadmium was detected in 8 of 230 unfiltered groundwater samples (3.5% frequency). Chromium concentrations in unfiltered samples ranged from 0.1 to 0.6 μg/L. Although the maximum detected concentration is greater than the effect level of 0.22 μg/L, cadmium is reported at an unfiltered concentration less than the Hanford Site background level of 0.92 μg/L.

Cadmium was detected in 7 of 231 filtered groundwater samples (3% frequency). Chromium concentrations in filtered samples ranged from 0.1 to 0.8 μg/L. Although the maximum detected

concentration is greater than the effect level of 0.22 μg/L, cadmium is reported at a filtered concentration less than the Hanford Site background level of 0.92 μg/L.

Aquifer Tubes. Cadmium was detected in 1 of 115 unfiltered aquifer tube samples (0.9% frequency) at a concentration of 0.17 μg/L. The cadmium concentration is less than the effect level of 0.22 μg/L. Most MDLs are less than the effect level.

Cadmium was detected in 1 of 115 filtered aquifer tube samples (0.9% frequency) at a concentration of 0.122 μg/L. Cadmium concentrations in unfiltered samples are less than the effect level of 0.22 μg/L. Most MDLs are less than the effect level.

Pore Water. Cadmium was detected in one of seven unfiltered pore water samples (14% frequency). The single cadmium concentration in unfiltered samples was detected at location RCBRA CR1 (0.72 μg/L) (DOE/RL-2007-21). Although the maximum detected concentration is greater than the effect level of 0.22 μg/L, cadmium is reported at a concentration less than the Hanford Site background level of 0.92 μg/L. All MDLs are greater than the effect level of 0.22 μg/L.

Seeps/Springs. Cadmium was detected in 4 of 21 unfiltered seep/spring samples (19% frequency) with concentrations ranging from 0.13 to 0.351 μg/L. Although two detected results were reported with concentrations greater than the effect level, the detected concentrations for these samples were less than the Hanford Site background level.

Cadmium was not detected in filtered seeps/spring samples. Most MDLs are less than the effect level of 0.22 μg/L.

Surface Water. Cadmium was not detected in unfiltered surface water samples (four samples). All MDLs are greater than the effect level of 0.22 μg/L.

J3.4.1.2 Carbon-14

Groundwater. Carbon-14 was detected in 202 of 286 unfiltered groundwater samples (71% frequency). Carbon-14 concentrations in unfiltered samples ranged from 9.14 to 10,900 pCi/L. Of the 202 detected results, 40 samples were reported with concentrations greater than the effect level of 609 pCi/L. Carbon-14 was detected above the effect level at wells 199-K-132 and 199-K-185.

Aquifer Tubes. Carbon-14 was detected in 87 of 166 unfiltered aquifer tube samples (52% frequency). Carbon-14 concentrations in unfiltered samples ranged from 5.15 to 416 pCi/L. Carbon-14 concentrations in unfiltered samples are less than the effect level of 609 pCi/L.

Pore Water. Carbon-14 was not detected in unfiltered pore water samples (six samples). All MDLs are less than the effect level of 609 pCi/L.

Seeps/Springs. Carbon-14 was detected in 18 of 31 unfiltered seep/spring samples (58% frequency). Carbon-14 concentrations in unfiltered samples ranged from 16.2 and 2,150 pCi/L. Of the 18 detected results, two samples were reported with concentrations greater than the effect level of 609 pCi/L at sample location Spring/Seep 63-1.

Surface Water. Carbon-14 was not detected in unfiltered surface water samples (four samples). All MDLs are less than the effect level of 609 pCi/L.

J3.4.1.3 Hexavalent Chromium

Groundwater. Cr(VI) was detected in 356 of 437 unfiltered groundwater samples (81% frequency). Cr(VI) concentrations in unfiltered samples ranged from 1.5 μg/L to 201 μg/L. Of the 356 detected results, 190

samples were reported with results greater than the effect level of 10 μg/L. Unfiltered Cr(VI) was detected above the effect level at all groundwater sample locations except wells 199-K-113A, 199-K-114A, 199-K-117A, 199-K-120A, 199-K-125A, 199-K-185, 199-K-20, and 199-K-31.

Cr(VI) was detected in 172 of 206 filtered groundwater samples (84% frequency). Cr(VI) concentrations in filtered samples ranged from 1.7 μg/L to 203 μg/L. Of the 172 detected results, 97 samples were reported with concentrations greater than the effect level of 10 μg/L. Filtered Cr(VI) was detected above the effect level at the same groundwater sample locations as unfiltered Cr(VI).

All MDLs are less than the effect level.

Aquifer Tubes. Cr(VI) was detected in 153 of 316 unfiltered aquifer tube samples (48% frequency). Cr(VI) concentrations in unfiltered samples ranged from 1.5 to 49.8 μg/L. Of the 153 detected results, 25 samples were reported with concentrations greater than the effect level of 10 μg/L. Unfiltered Cr(VI) was detected above the effect level at aquifer tube sample locations B8214, C4339, C4342, C4343, C4344, C6246, C6247, C6252, C6253, and C6256.

Cr(VI) was detected in 88 of 184 filtered aquifer tube samples (48% frequency). Cr(VI) concentrations in filtered samples ranged from 1.5 to 44 μg/L. Of the 88 detected results, 19 samples were reported with concentrations greater than the effect level of 10 μg/L. Filtered Cr(VI) was detected above the effect level at aquifer tube sample locations B8214, B8215, C4342, C4343, C4344, C6245, C6246, C6247, C6256, and C6261.

All MDLs are less than the effect level.

Pore Water. Cr(VI) was detected in six of seven unfiltered pore water samples (86% frequency). Cr(VI) concentrations in unfiltered samples ranged from 3.0 μg/L to 42 μg/L. Of the six detected results, three samples were reported with concentrations greater than the effect level of 10 μg/L.

Seeps/Springs. Cr(VI) was detected in five of nine unfiltered seeps/springs samples (56% frequency). Cr(VI) concentrations in unfiltered samples ranged from 1.8 μg/L to 24.6 μg/L. Of the five detected results, a single sample was reported with concentration greater than the effect level of 10 μg/L at sample location Spring/Seep 63-1.

Cr(VI) was not detected in the single filtered seeps/springs water sample.

All MDLs are less than the effect level of 10 μg/L.

Surface Water. Cr(VI) was not detected in unfiltered surface water samples (four samples). All MDLs are less than the effect level of 10 μg/L.

J3.4.1.4 Chromium

Groundwater. Chromium was detected in 366 of 395 unfiltered groundwater samples (93% frequency). Chromium concentrations in unfiltered samples ranged from 0.686 to 203 μg/L. Of the 366 detected results, 13 samples were reported with concentrations greater than the effect level of 64 μg/L. Chromium was detected above the effect level at wells A4647, A4650, A4651, C5361, and C7149. Detected results from wells A4651 and A4647 were flagged with either a “D” or “B” qualifier, indicating the analyte was reported at a secondary dilution factor or chromium was detected in the blank sample, respectively.

Chromium was detected in 358 of 398 filtered groundwater samples (90% frequency). Chromium concentrations in filtered samples ranged from 0.582 to 188 μg/L. Of the 368 detected results, 12 samples were reported with concentrations greater than the effect level of 64 μg/L. Chromium was detected above the effect level at wells A4647, A4651, C5361, and C7149. Detected results from well A4651 were

flagged with either a "D" or "B" qualifier, indicating the analyte was reported at a secondary dilution factor or chromium was detected in the blank sample, respectively.

All MDLs are less than the effect level.

Aquifer Tubes. Chromium was detected in 82 of 124 unfiltered aquifer tube samples (66% frequency). Chromium concentrations in unfiltered samples ranged from 0.338 to 50.6 μg/L. Chromium concentrations in unfiltered samples are less than the effect level of 64 μg/L.

Chromium was detected in 74 of 124 filtered aquifer tube samples (80% frequency). Chromium concentrations in filtered samples ranged from 0.31 to 51.2 μg/L. Chromium concentrations in filtered samples are less than the effect level of 64 μg/L.

All MDLs are less than the effect level.

Pore Water. Chromium was detected in five of seven unfiltered pore water samples (71% frequency) with concentrations ranging 1.6 to 44 μg/L. All chromium concentrations and MDLs in unfiltered samples are less than the effect level of 64 μg/L.

Seeps/Springs. Chromium was detected in 11 of 21 unfiltered seep/spring samples (52% frequency) ranging from 0.539 to 36.4 μg/L. Chromium concentrations in unfiltered seep/spring samples are less than the effect level of 64 μg/L.

Chromium was detected in 9 of 21 filtered seep/spring samples (43% frequency) with concentrations ranging from 0.828 to 72.1 μg/L. Of the 9 detected results, one sample was reported with a concentration greater than the effect level of 64 μg/L at sample location Spring/Seep 63-1. The maximum detected result was flagged with a "D" qualifier, indicating the analyte was reported at a secondary dilution factor.

Surface Water. Chromium was not detected in unfiltered surface water samples (five samples). Most MDLs are less than the effect level of 64 μg/L.

J3.4.1.5 Lead

Groundwater. Lead was detected in 55 of 221 unfiltered groundwater samples (25% frequency). Lead concentrations in unfiltered samples ranged from 0.104 to 3.41 μg/L. Of the 55 detected results, two samples were reported with a concentration greater than the effect level of 2.1 μg/L. Unfiltered lead was detected above the effect level at wells B2807 and C8297 and the detected results were flagged with either a "D" or "B" qualifier, indicating the analyte was reported at a secondary dilution factor or chromium was detected in the blank sample, respectively.

Lead was detected in 41 of 222 filtered groundwater samples (18% frequency). Lead concentrations in filtered samples ranged from 0.082 to 2.8 μg/L. Of the 41 detected results, one sample reported a concentration greater than the effect level of 2.1 μg/L. Filtered lead was detected above the effect level at well A4657, with the reported result flagged with a "D" qualifier, indicating the analyte was reported at a secondary dilution factor.

All MDLs are less than the effect level of 2.1 μg/L.

Aquifer Tubes. Lead was detected in 16 of 72 unfiltered aquifer tube samples (22% frequency) with concentrations ranging from 0.13 to 0.809 μg/L. Lead was detected in 2 of 72 filtered aquifer tube samples (2.8% frequency) with concentrations of 0.17 and 0.48 μg/L. All lead concentrations and MDLs are less than the effect level of 2.1 μg/L.

Pore Water. Lead was not detected in unfiltered pore water samples (seven samples). Most MDLs are less than the effect level of 2.1 μg/L.

Seeps/Springs. Lead was detected in 9 of 15 seep/spring unfiltered samples (60% frequency). Lead concentrations in unfiltered samples ranged from 0.19 to 7.72 μg/L. Of the nine detected results, four samples were reported with a concentration greater than the effect level of 2.1 μg/L. Lead was detected above the effect level at Spring/Seep 63-1 and Spring/Seep 68-1.

Lead was detected in 2 of 15 filtered seep/spring samples (13% frequency). Lead concentrations in filtered samples are less than the effect level of 2.1 μg/L.

All lead MDLs are less than the effect level of 2.1 μg/L.

Surface Water. Lead was not detected in unfiltered surface water samples (four samples). Most MDLs are greater than the effect level of 2.1 μg/L.

J3.4.1.6 Manganese

Groundwater. Manganese was detected in 110 of 329 unfiltered groundwater samples (33% frequency). Manganese concentrations in unfiltered samples ranged from 0.32 to 235 μg/L. Of the 110 detected results, four samples were reported with concentrations greater than the effect level of 120 μg/L. Manganese was detected above the effect level at wells A4650 and C7685.

Manganese was detected in 91 of 332 filtered groundwater samples (27% frequency). Manganese concentrations in filtered samples ranged from 0.23 to 539 μg/L. Of the 91 detected results, 4 samples were reported with concentrations greater than the effect level of 120 μg/L. Manganese was detected above the effect level at well A4650.

All MDLs are less than the effect level.

Aquifer Tubes. Manganese was detected in 91 of 114 unfiltered aquifer tube samples (78% frequency). Manganese concentrations in unfiltered samples ranged from 0.49 to 89.8 μg/L. All manganese concentrations and MDLs in unfiltered samples are less than the effect level of 120 μg/L.

Manganese was detected in 27 of 114 filtered aquifer tube samples (44% frequency). Manganese concentrations in filtered samples ranged from 0.30 to 22 μg/L. All manganese concentrations and MDLs in filtered samples are less than the effect level of 120 μg/L.

Pore Water. Manganese was detected in all seven unfiltered pore water samples (100% frequency). Manganese concentrations in unfiltered samples ranged from 0.90 to 208 μg/L. Of the seven detected results, one sample was reported with a concentration greater than the effect level of 120 μg/L. Manganese was detected at location RCBRA CR2 (208 μg/L) (DOE/RL-2007-21).

Seep/Spring. Manganese was detected in 10 of 14 unfiltered seep/spring samples (71% frequency). Manganese concentrations in unfiltered samples ranged 1.09 to 445 μg/L. Of the 10 detected results, a single sample was reported with a concentration greater than the effect level of 120 μg/L at Spring/Seep 63-1.

Manganese was detected in 10 of 14 filtered seep/spring samples (71% frequency) with concentrations ranging from 0.248 to 304 μg/L. Of the 10 detected results, a single sample was reported with a concentration greater than the effect level of 120 μg/L at Spring/Seep 63-1.

All MDLs are less than the effect level of 120 μg/L.

Surface Water. Manganese was detected in all four unfiltered surface water samples (100% frequency) with concentrations ranging from 2.4 to 5.4 μg/L. Manganese concentrations in unfiltered samples are less than the effect level of 120 μg/L.

J3.4.1.7 Mercury

Groundwater. Mercury was not detected in unfiltered groundwater samples (19 samples). All MDLs are greater than the effect level of 0.012 μg/L.

Mercury was not detected in filtered groundwater samples (19 samples). All MDLs are greater than the effect level of 0.012 μg/L.

Pore Water. Mercury was not detected in unfiltered pore water samples (seven samples). All MDLs are greater than the effect level of 0.012 μg/L.

Surface Water. Mercury was not detected in unfiltered surface water samples (four samples). All MDLs are greater than the effect level of 0.012 μg/L.

J3.4.1.8 Uranium

Groundwater. Uranium was detected in 136 of 140 unfiltered groundwater samples (97% frequency) with concentrations ranging from 0.095 to 27 μg/L. Of the 136 detected results, a single sample was reported with concentration greater than both the effect level and Hanford Site background level of 5 and 9.85 μg/L, respectively at well B2800. Although two additional detected results were reported with concentrations greater than the effect level, the detected concentrations for these samples were less than the Hanford Site background level.

Uranium was detected in 127 of 129 filtered groundwater samples (98% frequency) with concentrations ranging from 0.069 to 5.54 μg/L. Of the 127 detected results, a single sample was reported with concentrations greater than the effect level of 5 μg/L, but the detected filtered concentration was less than the Hanford Site background level of 9.85 μg/L.

Aquifer Tubes. Uranium was detected in 53 of 55 unfiltered aquifer tube samples (96% frequency) with concentrations ranging from 0.087 to 11.5 μg/L. Of the 53 detected resulted, a single sample was reported with concentration greater than both the effect level and Hanford Site background level of 5.0 and 9.85 μg/L, respectively at sample location C4339. The maximum detected result at C4339 was flagged with a “D” qualifier, indicating the analyte was reported at a secondary dilution factor. Although four additional detected results were reported with concentrations greater than the effect level, the detected concentrations for these samples were less than the Hanford Site background level.

Uranium was detected in 54 of 55 filtered aquifer tube samples (98% frequency) with concentrations ranging from 0.082 to 10.2 μg/L. Of the 54 detected results, a single sample was reported with concentration greater than both the effect level and Hanford Site background level of 5.0 and 9.85 μg/L, respectively at sample location C4339. The maximum detected result at C4339 was flagged with a “D” qualifier, indicating the analyte was reported at a secondary dilution factor. Although four additional detected results were reported with concentrations greater than the effect level, the detected concentrations for these samples were less than the Hanford Site background level.

All MDLs are less than the effect level of 5.0 μg/L.

Pore Water. Uranium was not detected in unfiltered pore water samples (seven samples). All MDLs are greater than the effect level of 5.0 μg/L.

Seeps/Springs. Uranium was detected in all 12 unfiltered seeps/springs samples (100% frequency). All uranium concentrations in unfiltered samples are less than the effect level of 5 μg/L.

Uranium was detected in all 12 filtered seeps/springs samples (100% frequency). All uranium concentrations in filtered samples are less than the effect level of 5 μg/L.

Surface Water. Uranium was not detected in unfiltered pore water samples (four samples). All MDLs are greater than the effect level of 5.0 μg/L.

J3.4.1.9 Zinc

Groundwater. Zinc was detected in 195 of 329 unfiltered groundwater samples (59% frequency). Zinc concentrations in unfiltered samples ranged from 3.34 to 919 μg/L. Of the 195 detected results, 13 samples were reported with concentrations greater than the effect level of 90 μg/L. Unfiltered zinc was detected above the effect level at wells A4651, C5113, C5360, and C5362.

Zinc was detected in 186 of 332 filtered groundwater samples (56% frequency). Zinc concentrations in filtered samples ranged from 2.07 to 878 μg/L. Of the 186 detected results, 11 samples were reported with concentrations greater than the effect level of 90 μg/L. Filtered zinc was detected above the effect level at wells A4651 and C5362.

All MDLs are less than the effect level.

Aquifer Tubes. Zinc was detected in 22 of 114 unfiltered aquifer tube samples (19% frequency). All zinc concentrations and MDLs in unfiltered samples are less than the effect level of 90 μg/L.

Zinc was detected in 8 of 114 filtered aquifer tube samples (7% frequency). All zinc concentrations and MDLs in filtered samples are less than the effect level of 90 μg/L.

Pore Water. Zinc was detected in all seven unfiltered pore water samples (100% frequency) with concentrations ranging from 2.3 to 4.2 μg/L. All zinc concentrations are less than the effect level of 90 μg/L.

Seeps/Springs. Zinc was detected in 9 of 18 unfiltered seep/spring samples (50% frequency). Zinc concentrations in unfiltered samples ranged from 5.4 to 60.9 μg/L. All unfiltered zinc concentrations and MDLs in filtered samples are less than the effect level of 90 μg/L.

Zinc was detected in 7 of 18 filtered seep/spring samples (39% frequency). All zinc concentrations and MDLs in filtered samples are less than the effect level of 90 μg/L.

Surface Water. Zinc was detected in all four unfiltered surface water samples (100% frequency) with concentrations ranging from 1.6 to 4.2 μg/L. All zinc concentrations are less than the effect level of 90 μg/L.

A discussion of the ecological risk considerations associated with these results is presented in Chapter 7.

J4 Contaminants of Interest – Riparian Soil

J4.1 Apply Exclusion Criteria

Table J-25 summarizes the analytes in riparian soil without plant and invertebrate effect levels and Table J-26 summarizes analytes that do not have a wildlife screening level. Tables J-25 and J-26 also provide sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs.

J4.2 Identify Nondetected Analytes

Table J-27 summarizes analytes that were not detected in riparian soil samples and that have a plant or invertebrate soil effect level. Table J-28 summarizes analytes that were not detected in riparian soil samples but that have a wildlife effect level. Tables J-27 and J-28 also provide sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs.

J4.3 Identify Analytes with Maximum Detected Concentrations Less Than Effect Levels

Table J-29 provides a summary of the riparian soil analytes that do not exceed the lowest plant/invertebrate effect levels. Table J-30 provides a summary of the riparian soil analytes that do not exceed the lowest wildlife effect levels. Tables J-29 and J-30 also provide sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs.

J4.4 Identify Analytes with Maximum Detected Concentrations Greater Than Effect Levels

This step identifies analytes with maximum concentrations greater than their plant/invert or wildlife effect levels. Table J-31 summarizes the riparian soil analytes that exceed the lowest plant/invertebrate effect levels.

Aluminum was detected in 10 riparian soil samples with concentrations ranging from 9,100 to 11,000 mg/kg. Aluminum concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 11,800 mg/kg.

Bis(2-ethylhexyl)phthalate (BEHP) was detected in 10 riparian soil samples with concentrations ranging from 0.031 to 8 mg/kg. The maximum detected concentration of BEHP is greater than the effect level of 0.14 mg/kg. BEHP is considered a common laboratory contaminant and is not related to the Hanford Site.

Carbon-14 was detected in 3 of 10 riparian soil samples with concentrations ranging from 12 to 112 pCi/g. Carbon-14 was detected above the wildlife effect level of 32 pCi/g at the Riparian 5 sample location.

Vanadium was detected in 10 riparian soil samples with concentrations ranging from 37 to 46 mg/kg. Vanadium concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 85 mg/kg.

Chapter 7 discusses the ecological risk considerations associated with these results.

J5 Contaminants of Interest – Nearshore Sediment

J5.1 Apply Exclusion Criteria

Table J-32 summarizes the analytes in sediment that do not have an effect level. Table J-32 also provides sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs.

J5.2 Identify Nondetected Analytes

Table J-33 summarizes analytes that were not detected in sediment samples as well as providing sampling dates and minimum and maximum MDLs.

J5.3 Identify Analytes with Maximum Detected Concentrations Less Than Effect Levels

Table J-34 provides a summary of the sediment analytes that do not exceed the sediment screening levels in addition to sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs.

J5.4 Identify Analytes with Maximum Detected Concentrations Greater Than Effect Levels

This step identifies analytes with maximum concentrations greater than sediment screening levels. A summary of the sediment analytes that exceed the lower threshold sediment screening levels is provided in Table J-35. Table J-35 shows that concentrations of three analytes are greater than their sediment screening value—4,4' dichlorodiphenyltrichloroethane, antimony, and phosphorus.

The analytes listed above that exceed the lower threshold effect levels are subsequently compared to the upper threshold effect levels; the results of this comparison are shown in Table J-36. As listed in Table J-36, antimony exceeds the lower threshold effect levels.

Antimony was detected once and this concentration (2.3 mg/kg) is higher than the ecological screening value of 0.4 mg/kg. Antimony was detected above the Tier 2 ecological screening value of 0.6 mg/kg at 1 of 11 100-K Area sample locations. Antimony was not identified as site-related COI in Section 6 or the remedial investigation or as a COI in the RCBRA or CRC documents.

A discussion of the ecological risk considerations associated with this result is presented in Chapter 7.

J6 Conclusions

The purpose of this evaluation was to address, on a reactor decision area basis, the potential for Hanford Site contaminants in soil or groundwater to migrate to riparian or nearshore areas at concentrations that could be of concern for ecological receptors. This evaluation supplements the analysis of the RCBRA (DOE/RL-2007-21), which identified some contaminants of ecological concern on a site-wide/river corridor-wide basis, and the CRC (DOE/RL-2010-117), which identified some contaminants of ecological concern on an OU basis, that warranted further evaluation.

A range of inorganic and radionuclide contaminants were detected in near-river groundwater samples collected from the 100-KR-4 OU. Groundwater COCs, as identified in Chapter 6 of this report, carbon-14, strontium-90, tritium, Cr(VI), total chromium, nitrate, and trichloroethene. In several cases, these contaminants also could be detected in aquifer tube, pore water, spring/seep, and surface water samples (carbon-14, Cr(VI), and total chromium). In most cases, the analytical results that were most relevant to assessing aquatic water quality (that is, from filtered analyses) were at concentrations below aquatic criteria. Based on the results of the further evaluation contained in this appendix, except for Cr(VI), detected concentrations of contaminants in riparian or nearshore groundwater, seeps/springs, aquifer tubes, and pore water are not detectable at levels of ecological concern, or are not associated with contaminated groundwater resulting from Hanford Site operations. A more detailed discussion of potential ecological risks in the context of abiotic and biotic media evaluations and potential contributions to these risks from the Hanford Site is presented in Chapter 7. For alternatives evaluation in the subsequent 100-K FS (DOE/RL-2018-22), Cr(VI) in the 100-KR-4 Groundwater OU should be considered the only COPEC. Measurements of Cr(VI) in nearshore wells and measurements in pore water demonstrate continued exceedance of the Ambient Water Quality Criteria (AWQC) (11 µg/L) and Surface Water Quality Standards (SWQS) (10 µg/L), indicating a continued complete pathway from

100-K groundwater to the Columbia River. Since Cr(VI) results in pore water are above the 10 µg/L SWQS, which is an applicable or relevant and appropriate requirement (ARAR), Cr(VI) in the 100-KR-4 OU requires consideration in the FS, but discussion specific to risk reduction need only focus on exposure to potentially sensitive benthic organisms in the hyporheic zone rather than risk for tested genera listed in Table 7-16 for which there was no identified population or community level risk. For alternatives evaluation in the 100-K FS, Cr(VI) in the 100-KR-4 Groundwater OU should be considered the only constituent of environmental concern.

There are uncertainties in this evaluation related to analytical data quality. In many cases where analytical results were higher than aquatic effect levels, it was determined that the results were based on unfiltered samples. Unfiltered analytical results are inappropriate for comparison with aquatic criteria; in general, filtered analytical results were less than aquatic criteria.

J7 References

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DOE/RL-2010-97 Decisional Draft Comments

Tracking_ID	Chapter	Page_Num	Line_Num	Table_Figure	Comment_Basis	Agency Commenter	Disposition	Response_to_Comment	Concurrence	Date_Concurrence
RL-001	1	1-1	6		New paragraph	Hansen, James A	Accept	Paragraph has been added.	Yes	01/31/2019
RL-002	1	1-1	17		New paragraph	Hansen, James A	Accept	Paragraph has been added.	Yes	01/31/2019
RL-003	1	1-1	22		New paragraph	Hansen, James A	Accept	Paragraph has been added.	Yes	01/31/2019
RL-004	1	1-3		F 1-1	Laura had us make the subject OU bigger in B/C. That was a good change, Please follow that here too and make 100K label larger.	Hansen, James A	Accept	Revised Figure	Yes	01/31/2019
RL-005	1	1-4		F1-2	Why are we still struggling with making sense of OU boundaries? The struggle here seems to be that there is a portion of the "100-KR-1" OU that is outside of the "100-K Area."	Balone, Steven N	Accept	Revised Figure	Yes	01/30/2019
RL-006	1	1-5	18		Is this statement made in previous RI/FS documents? This is a commitment to continue to develop and incorporate new technologies, which is contrary to the objective of why we get RODs – which is to set the agreement of what we need to do to obtain closure. If we cannot achieve those ROD commitments, then EPA and DOE will discuss and agree to next steps which could be a lot of things from nothing to a new ROD. I don't see value in this statement, and it goes beyond what we need to do. If this is in previous RI documents, I want to consider removing here. Hansen provided follow up: No, just delete the highlighted text completely. If we don't meet ROD objectives, then according to the NCP, we will need to consider amending the ROD or re-starting the RI/FS	Hansen, James A	Accept	Revised the text.	Yes	02/14/2019
RL-007	1	1-7	16		We had agreement between the TPA agencies that we would not pursue dose estimates and dose-based cleanup any longer because EPA has no regulatory authority to do so, and we constantly get criticized for doing so by EPA NRRB and others. Please scrub dose out of the document. If you feel we need to have a discussion with Laura before we do that, then set up a meeting.	Hansen, James A	Accept	Revised text - removed dose (All chapters checked)	Yes	01/31/2019
RL-008	1	1-9	28		Do you mean "switchyard?"	Balone, Steven N	Accept	Edited to electrical substation	Yes	01/30/2019
RL-009	1	1-9	29		Add the KW Fuel Storage Basin and Annex as "active" facilities.	Balone, Steven N	Accept	Revised text	Yes	01/30/2019
RL-010	1	1-11	15		The amended decision does not really say this. All it says is the NEPA decision is for ISS for UP TO 75 years. The amended decision identifies that disposition is anticipated to be a CERCLA removal action. If you read this carefully, it does not say that the reactors are planned to be transported to the 200 area. Please review the 2010 amendment and update this statement. Please discuss if you feel I am incorrect.	Hansen, James A	Accept	Deleted this sentence here, this is discussed later to indicate it's a CERCLA decision.	Yes	01/31/2019
RL-011	1	1-17	25		were (note: (sewe also added r))	Balone, Steven N	Accept	Revised text	Yes	01/30/2019
RL-012	1	1-17	38		Any more intel on this? The CHPRC field engineer (Aryn Kerr) during KE FSB demolition stated that he saw no perforated collection pipes under the FSB.	Balone, Steven N	Accept	Sent e-mail requests for info on 12/19, 1/23. No information received, Steve Balone indicated acceptable to leave as is.	Yes	01/30/2019
RL-013	1	1-22	21		French is always capitalized. I know tech editing would catch, but it is driving me crazy. Global comment.	Hansen, James A	Accept	CHPRC current standard is lower case, all changed to French.	Yes	01/31/2019
RL-014	1	1-26		F 1-12	Upon zooming, it appears that 116-KW-1 is shaded as a "Area where primary releases were distributed" rather than a "Primary Release Location" as shown for 116-KE-1- these both should be "Primary Release Locations"	Balone, Steven N	No Change	Figure shading around KW-1 distorts the color, it is shaded as a primary release location.	Yes	01/30/2019
RL-015	1	1-27		F 1-13	All of the KW Rx bldg. and the KW FSB are shown as "Areas where primary releases were distributed", but on the KE side, only the southwest corner of the Rx bldg. is thus shown, and none of the KE FSB (which had more historical leakage than any other facility in 100-K).	Balone, Steven N	Accept	Revised figure, no longer demonstrating that the KW Reactor showing a release.	Yes	01/30/2019
RL-016	1	1-27		F 1-13	Why don't we show the K-2 trench break-throughs as "Areas where primary releases were distributed"?	Balone, Steven N	No Change	This figure uses the generic WIDS shape for 116-K-2 which does not include these areas. No change per discussion between Steve Balone and Jason Capron.	Yes	01/30/2019
RL-017	1	1-29	45		Also Grifflon found, e.g., 100-K-99	Balone, Steven N	Accept	The reference cited did not include Grifflon, added based on 100-K-99 discovery site evaluation checklist.	Yes	01/30/2019
RL-018	1	1-31	6		This might be a good place to mention that some of these sanitary systems have been removed.	Balone, Steven N	Accept	Added: The 1607-K2, 1607-K3, and 1607-K4 waste sites were interim closed prior to April 2017.	Yes	01/30/2019
RL-019	1	1-31	29		What is the "KW Building"? Do you mean "reactor"?	Balone, Steven N	Accept	Changed to Reactor	Yes	01/30/2019
RL-020	1	1-37	9		Isn't the KW RX stack still in place?	Balone, Steven N	Accept	Yes, corrected as KE only	Yes	01/30/2019
RL-021	1	1-37	15		"otherwise"	Balone, Steven N	Accept	Added	Yes	01/30/2019

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RL-022	1	1-38	1		We continue to explain this as if the removal decision has been made. It has not. DOE has not decided on a one piece removal. The NEPA decision identified that from a NEPA perspective, a one piece removal was the best choice based on the information available at the time. The CERCLA removal decision will decide based on CERCLA, which could be something very different. The CERCLA action could identify that the NEPA decision needs to be revised based on whatever future decisions are there. I have expressed concerns with these sections about the reactor which is not even part of the 100-K decision. Please remove the over-explanation and be consistent with what NEPA does for the CERCLA decision.	Hansen, James A	Accept	Edited text	Yes	01/31/2019
RL-023	1	1-39	18		And sludge	Balone, Steven N	Accept	Added	Yes	01/30/2019
RL-024	1	1-39	21		Inconsistent with table	Hansen, James A	Accept	Table corrected to 2016.	Yes	01/31/2019
RL-025	1	1-39	24		Maybe here, maybe elsewhere, we need to clarify that the 151-KE Substation will remain active for many years to come, as it Is linked to the primary power for the Columbia Generation station (get exact language from Randy Krekel). However, the 151-KW substation is inactive and needs to be D4'd.	Balone, Steven N	No Change	Sent e-mail request 12/20, received response indicating the substation will be active through 2025. Indicated that other active facilities would also need to be discussed, therefore no text change.	Yes	01/30/2019
RL-026	1	1-42	42		Paragraph is repeated from above	Balone, Steven N	Accept	Deleted	Yes	01/30/2019
RL-027	1	1-44	1		Do we also discuss interim condition documentation somewhere? For example, there is such a document that describes the partial removal of the tunnel between the KE Rx and the 165KE building.	Balone, Steven N	No Change	Waste site data are also discussed in Chapter 4 and presented in Appendix D.	Yes	01/30/2019
RL-028	1	1-45	2		I am seeing a lot of different dates for basing this RI/FS and ROD. Earlier I saw a Dec 2016 and a Dec 2017 date. I think this will lead to a lot of confusion.	Hansen, James A	Accept	The earlier discussion was in regard to facilities, 2017 date was corrected to 2016 so that the table is consistent with the text. April 2017 is used for waste sites and groundwater data	Yes	01/31/2019
RL-029	1	1-47	6		Terminology?	Balone, Steven N	Accept	Deleted this sentence (consistent with 100-BC)	Yes	01/30/2019
RL-030	1	1-54	33		Nothing on the rebound test at the KW Headhouse?	Balone, Steven N	Accept	Added text on following page; discussion is included in Section 4.4	Yes	01/30/2019
RL-031	1	1-55	16		This section could use additional info on P&T progress, removal of CR-VI, plume shrinkage and near-shore management of plumes	Balone, Steven N	Accept	Added to end of section: Section 4.4 provides additional discussion of groundwater remedial action progress.	Yes	01/30/2019
RL-032	3	3-21		F 3-10	Seems to me that if we are going to produce a map of this sort, then we should show vertical cross sections of the wells denoted, screen locations, and geological soil matrices (strata).	Glossbrenner, Ellwood T	No Change	The detailed cross-sections are presented in Appendix C. The introduction to the section on page 3-19 provides a pointer.	Yes	01/31/2019
RL-033	3	3-52		F 3-21	The water elevation in well 199-K-32B ranges 1-4 meters above the 100-K River guage. Can you give an explanation for this?	Glossbrenner, Ellwood T	No Change	The difference in elevation is due to the upward vertical hydraulic gradient, as 32B is screened in the confined aquifer.	Yes	01/31/2019
RL-034	3	3-76	1		Need to develop this section like the one in the 100-BC RI, chapter 3, section 3.10.	Glossbrenner, Ellwood T	Accept	Text updated to align with final resolution for BC Section 3.10.	Yes	01/31/2019
RL-035	4	4-7		T 4-3	This is an inland segment that will be dispositioned differently than the river portion (100-K-113). Likely a safety concern, rather than CERCLA.	Glossbrenner, Ellwood T	Accept with Modification	The RI/FS does not address potential measures for subsidence mitigation.	Yes	01/31/2019
RL-036	4	4-8		T 4-3	This is an inland segment that will be dispositioned differently than the river portion (100-K-114). Likely a safety concern, rather than CERCLA.	Glossbrenner, Ellwood T	Accept with Modification	The RI/FS does not address potential measures for subsidence mitigation.	Yes	01/31/2019
RL-037	4	4-15		F 4-1	This picture of the 116-K-2 Trench Excavation Footprint is inaccurate. There were additional remediations that extended shore-ward around the area of 199-K-201 well and a location between this well and the old KR-4 P&T building (1604K).	Glossbrenner, Ellwood T	No Change	Exploratory test pits were excavated in these areas, but were not considered as part of the "remediation footprint" for site closure. The footprint is based on the 116-K-2 cleanup verification package.	Yes	01/31/2019
RL-038	4	4-16	6		The TI white paper states the following: "The highest Sr 90 groundwater concentration in the K1/K2 plume in 2016 was 164 pCi/L. Left untreated, the remaining inventory of Sr 90 in 100-K groundwater is expected to decay to a concentration of <8 pCi/L in approximately 300 years." This is different from the data listed in this section and the corresponding table below. This may be premature at this time, it might be covered further into this document.	Glossbrenner, Ellwood T	No Change	The information presented in this section is soil data. Groundwater data are discussed in Section 4.4.7, and groundwater modeling projections are discussed in Chapter 5. This discussion is for soil, the groundwater data cited in the TI includes a different time period.	Yes	01/31/2019
RL-039	5	5-1	1		I am seeing enough concern with new language and structure to this chapter compared to previous documents that I want assurances that this is consistent with 100-B/C and 100-D/H. I want to make sure there are not new graphics or new concepts that Laura has not seen before. So, I want a discussion about that with document authors and document leads, please.	Hansen, James A	Accept	This section was copied from 100-B/C and then revised to be 100-K specific. All EPA 100-B/C comments were incorporated through this process.	Yes	01/31/2019
RL-040	5	5-1	4		Secondary sources of contamination into groundwater?	Hansen, James A	Accept	Text changed.	Yes	01/31/2019
RL-041	5	5-1	6		This seems like the wrong term in this sentence. The approach is for the assessment as in the previous sentence. The approach for the assessment could be based on the CSM.	Hansen, James A	Accept with Modification	See next sentence: "An ~~approach~~ analysis is also presented to describe the future behavior of contaminants (carbon 14, Cr(VI), nitrate, strontium 90, trichloroethene, and tritium) already present in groundwater at 100 K."	Yes	01/31/2019
RL-042	5	5-1	10		Also seems like thee wrong word.	Hansen, James A	Accept	Changed to "analysis".	Yes	01/31/2019

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RL-043	5	5-1	10		This introduction is more of an executive summary that is not consistent with other chapters or previous RI/FS documents. This needs to be moved to the end of the chapter with references to the sections where the evaluation is presented.	Hansen, James A	No Change	This is consistent with 100-B/C. This chapter is unlike most other chapters in that it has a lot of quantitative results that are difficult to just pick out of the text. This summary was introduced in 100-B/C to help the reader	Yes	01/31/2019
RL-044	5	5-1	14		This is a new concept in this chapter that I do not think we have used before in previous RI/FS documents. This seems very confusing. The waste sites move forward, not this group of waste sites in a concept we have not used before.	Hansen, James A	Accept with Modification	WCH used this concept in reporting results in RSVPs and CVPs. We retained their convention for consistency with the soil remediation. Jason Capron added clarifying text here and in Chapter 4. This comment also ties in to comments RL-062 and RL-076.	Yes	01/31/2019
RL-045	5	5-1	18		What does this mean?	Hansen, James A	Accept with Modification	Text changed to clarify that these four decision units are associated with the 116-KE-1 crib.	Yes	01/31/2019
RL-046	5	5-1	30		The evaluation has not been presented yet to support this statement. Hansen provided followup: I think this is poorly structured, and should at a minimum be identified as a chapter summary. We can see what Laura thinks	Hansen, James A	No Change	Consistent with the presentation in 100-B/C RI chapter 5, a summary of this chapter's findings is presented at the front for the benefit of the reader.	Yes	02/14/2019
RL-047	5	5-2	36		There needs to be an introduction of natural attenuation in the role of persistence	Hansen, James A	Accept	Added text explaining that persistence is determined by natural attenuation. Changed persistence on page 5-3 line 1 to natural attenuation.	Yes	01/31/2019
RL-048	5	5-3	22		I am not understanding why this is important here. This seems more like remedial technology information. The whole discussion on iron seems odd to only conclude there is no significance. Okay if you put this into natural attenuation context. Hansen provided follow up: You should state "the point" as the topic sentence. The topic sentence you have is not appropriate for the content of the paragraph.	Hansen, James A	Accept with Modification	A similar discussion was presented in the 100-B/C RI. The point of the discussion is that in the oxidizing groundwater environment present in 100-K groundwater Cr(VI) can't be reduced to Cr(III) and thus naturally attenuate. Text revised to incorporate concept of degradation per JAH follow on comment.	Yes	02/14/2019
RL-049	5	5-4	3		Put this in the context of natural attenuation	Hansen, James A	Accept	Sentence changed to emphasize that reductive dechlorination is a natural attenuation process.	Yes	01/31/2019
RL-050	5	5-5	1		Below in the blue box, both SSL and PRG are "residential", only one is with irrigation. So in the second paragraph, third line down, add "that includes irrigation" after residential use. Actually, remove the term residential from this blue box and from any text associated with SSL and PRG for protection of groundwater. The graphic at the bottom indicates that residential is only protected if we are below the irrigation based value, which is incorrect.	Hansen, James A	Accept	Text box and included figure have been edited to remove all mention of residential use. Also checked remainder of document.	Yes	01/31/2019
RL-051	5	5-6	7		Fix this whole section to be consistent with B/C and D/H. Please discuss with me if this is consistent because we may need to correct this problem.	Hansen, James A	No Change	This section is consistent with 100-BC. We discussed with Dr. Hansen on January 7 and he's okay with this passage (which does NOT mention residential).	Yes	01/31/2019
RL-052	5	5-36		T 5-7	Please put the concentrations in standard natural format rather than in scientific notation.	Hansen, James A	Accept	Changed to natural format per JAH comment through entire chapter.	Yes	01/31/2019
RL-053	5	5-40		T 5-8	Same here, put concentrations in standard format rather than scientific notation	Hansen, James A	Accept	Changed to natural format per JAH comment through entire chapter.	Yes	01/31/2019
RL-054	5	5-47	6		This would not impact the irrigation based SSL. Irrigation is higher than bare soil natural recharge. Make sure this point is clear and stated several times where appropriate in this chapter.	Hansen, James A	Accept	Clarified the first sentence in the paragraph on line 2, and added a note at the end of the paragraph about SSLs representing irrigation.	Yes	01/31/2019
RL-055	5	5-52		T 5-11	Whole chapter – put concentrations in natural units and not scientific notation	Hansen, James A	Accept	Text has been changed.	Yes	01/31/2019
RL-056	5	5-56	3		We can see how Laura reacts to this approach, but placing ICs to restrict irrigation is a ROD decision, so those sites that exceed the scaled SSL should also go to the FS and maybe even consider remedial action to compare to an IC to then make the IC decision in the ROD. Maybe we can save time and discuss this approach with Laura to make sure we will not have to rework this later. Maybe she will agree with a presumptive IC and only explain as a ROM cost estimate for actions. Hansen provided followup: I like the text additions, BUT Table 5-14 is unclear that these waste sites fail the irrigation PRG. As a rule, all tables should be "stand-alone" so that if they are extracted and used in another context, the meaning is understood. Add to the title so that it is clear that these sites exceed the irrigation-based PRG. For table 5-11, my preference would be to add that the SSL is the natural recharge SSL because the terms SSL and PRG are not correctly being used. We can see if Laura will continue to entertain this. Just be clear in a footnote that this is under natural recharge.	Hansen, James A	Accept	This text informs the FS, but does not presume a decision. It's the same text as in 100-B/C. Added a clause at the end to clarify. Made changes in Sections 5.4.1 and 5.4.2 to clarify the point. Following commenter's clarification also revised table footnotes to make table stand-alone.	Yes	02/14/2019

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RL-057	6	6-2	30		Why are we making this statement? DOE's future land use is conservation. Just delete.	Hansen, James A	Accept	Deleted	Yes	01/31/2019
RL-058	6	6-3	17		Why are we identifying monument worker as a future land use?	Hansen, James A	Accept with Modification	This is the same discussion as BC, relating to the RCBRA, deleted monument worker to avoid mis-interpretation	Yes	01/31/2019
RL-059	6	6-34	24		Looks like we have abandon dose per discussions with EPA and Ecology before Laura became the RPM. We should confirm that decision with her and Dave Hansen added followup: Just to confirm, you have deleted dose and are just using risk. If so, I agree.	Hansen, James A	Accept	Document scrubbed to remove use of dose.	Yes	01/31/2019
RL-060	6	6-65	18		Why isn't this table here instead of the bullets below? This would be much easier to review if it were in a table Hansen added followup: This is important information that is much easier to review and use if it were here. Okay to have in both places. I would like the table here.	Hansen, James A	Accept	Revised section to add table here.	Yes	01/31/2019
RL-061	7	7-153	15		This should duplicate what Laura agreed with in B/C	Hansen, James A	No Change	This chapter follows BC format.	Yes	01/31/2019
RL-062	4	4-10		T 4-3	This grouping was very common during 100-K soil remediation. Rather than this long list of table footnotes, should we create a table showing this grouping, as described in the relevant RSVPs? Its important that in several cases, the remediation grouping did not encompass the entirety of each waste site in the group, so there are portions of some partially remediated waste sites that still need to be addressed (unless this has changed in the past 3 years). This is also true of some "structures," like the tunnel between the KE RX and the KE Power Control Building.	Balone, Steven N	Accept	Revised Table 4-3, site groupings added as an associated column.	Yes	01/30/2019
RL-063	4	4-11	35		So, this is is our "data date" for the RI/FS? We are using 2016 data for areal extent of Cr-VI plumes (Table 4-37)	Balone, Steven N	No Change	The data cut-off date is April 2017; the Cr(VI) plumes are based on CY 2016 annual groundwater, though we incorporate monitoring results through April 2017	Yes	01/30/2019
RL-064	4	4-26	12		Maybe more informative to say "at the completion of excavation." Also, the veracity of the 1M dpm measurement came into question during and after drilling of the KE-3 borehole; should this be mentioned here?	Balone, Steven N	Accept	Text revised	Yes	01/30/2019
RL-065	4	4-27		F 4-5	The shading shown for the KE Rx is mis-leading; where well K-222 is shown, the shading is in the location of the former FSB, not the reactor. Also, (please confirm) the cross-hatched "Waste Site" should not extend below the reactor.	Balone, Steven N	Accept	Figure revised	Yes	01/30/2019
RL-066	4	4-27		F 4-5	In the legend, 116-KE-3 is mistakenly referred to as a "trench" Please change to "crib"	Balone, Steven N	Accept	Changed	Yes	01/30/2019
RL-067	4	4-33	10		This sentence kinda leaves us "hanging." Maybe add a sentence stating how this contamination was driven deeper, and that it is no longer happening (if this is the right place for such a statement).	Balone, Steven N	Accept	Text revised	Yes	01/30/2019
RL-068	4	4-39	12		No- 199-K-186 is located just downgradient from the KE power control building, 165-KE	Balone, Steven N	Accept	Text revised	Yes	01/30/2019
RL-069	4	4-97		T 4-37	Available with 2017 data? Or, if we're intent on sticking with a particular data cutoff date, do we have a statement somewhere that points the reader to more recent data? We are using decayed- to-2017 values for soil waste sites.	Balone, Steven N	Accept with Modification	We did not do 2017 plume maps, as the annual report plumes provide more representative depictions and there would only be limited data for 2017. We do indicate annual reports provide contaminant data, e.g., Section 4.4.1.	Yes	01/30/2019
RL-070	4	4-107	5		Suggested addition after "River": (i.e., significantly downgradient from the secondary source area beneath the former KW Headhouse)	Balone, Steven N	Accept	Text revised as requested	Yes	01/30/2019
RL-071	4	4-107	15		Suggested addition: (the well located closest to the secondary source area beneath the former KW Headhouse, Figure 4-36)	Balone, Steven N	Accept	Text revised as requested	Yes	01/30/2019
RL-072	4	4-107	19		"…confirmed the suspected secondary source…	Balone, Steven N	Accept	Text revised as requested	Yes	01/30/2019
RL-073	4	4-167	30		Is there a better way to say this? "provides a means" makes it soukd like a benefit.	Balone, Steven N	Accept	Text revised	Yes	01/30/2019
RL-074	4	4-168	30		and five	Balone, Steven N	Accept	Text revised as requested	Yes	01/30/2019
RL-075	4	4-169	3		"…island soil samples were collected…"	Balone, Steven N	Accept	Text revised as requested	Yes	01/30/2019
RL-076	5	5-1	18		100K remediation to date has been managed in part by splitting some waste sites (most notably, pipelines) into several pieces and sometimes combining these pieces with other, nearby waste sites or waste site pieces. This has been done to support more efficient remedial action. Suggest a table (and supporting figures in an appendix?) to describe/define which waste site portions have been combined other waste sites/portions. These combinations have been documented in the relevant RSVPs. Have discussed this with J. Virgin- perhaps this table belongs in Chapter 4.	Balone, Steven N	Accept	Table 4-3 revised to provide a grouped wastes site listing. Text also added to Section 4.2.1 to introduce decision unit concept; page 5-7, line 27. Also see comment RL-062	Yes	01/30/2019

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RL-077	5	5-12		T 5-1	need to repeat column headings	Balone, Steven N	Accept	Revised table to repeat column headings on new page. Text editor to note that this header is likely to shift with pagination changes and will need to be checked for accurate placement in final document.	Yes	01/30/2019
RL-078	5	5-12		T 5-1	it appears evident that the values for hyd conductivity were chosen based upon an assumed relationship between vertical and horizontal conductivities- does this deserve a footnote? From page 5-23: "Following convention for Hanford sediments (SGW 44022; SGW 46279), an anisotropy ratio of vertical to horizontal saturated hydraulic conductivity of 0.1 was applied to obtain vertical hydraulic conductivity values from the horizontal values discussed above." Maybe a second note to describe the exception for backfill.	Balone, Steven N	Accept	Added footnotes a and b; "a. Saturated vertical hydraulic conductivity values were computed based on assumed anisotropic ratio of 0.1 to saturated horizontal hydraulic conductivity consistent with the convention used in SGW-44022 and SGW-46279. b. Saturated hydraulic conductivity for backfill was assumed to be isotropic."	Yes	01/30/2019
RL-079	5	5-13	11		Can we say "managed" rather than "minimized?"	Balone, Steven N	Accept	Text revised.	Yes	01/30/2019
RL-080	5	5-20		T 5-3	Write-out long-form scientific notation	Balone, Steven N	Accept	Changed to natural format per JAH comment through entire chapter.	Yes	01/30/2019
RL-081	5	5-23	37		"…step-function fashion…"	Balone, Steven N	Accept	Changed to natural format per JAH comment through entire chapter.	Yes	01/30/2019
RL-082	5	5-34	20		? let's talk	Balone, Steven N	No Change	John Virgin discussed with Steve Balone: question was on bulk densities for different material. Confirmed that the densities presented are from the cited references.	Yes	01/30/2019
RL-083	5	5-34	31		Good- makes sense	Balone, Steven N	No Change	No action required.	Yes	01/30/2019
RL-084	5	5-46	12		"This (conservative) assumption…"	Balone, Steven N	Accept	Text changed.	Yes	01/30/2019
RL-085	5	5-84	8		causes	Balone, Steven N	Accept	Text changed.	Yes	01/30/2019
RL-086	5	5-97		F 5-40	100-K-66 is a "waste site" coincident with the KW Power Control Building; why show this, and not the 100-K-67 "waste site" (the KE Power Control Bldg)? Also, since we are discussing the TCE plume, why don't we show, and label, the 1724K Maintenance Shop, which was as likely a source for the TCE as any other identified in 100K? (or maybe discussion belongs in Chap 4 with N&E)	Balone, Steven N	No Change	A generic base map was used for all the plume maps irrespective of the COPCs. Only the known/suspected key waste sites were labeled.	Yes	01/30/2019
RL-087	ES	ES-iii	4		I guess this is an ok way to say this, but strictly speaking, aren't the areas listed in the NPL, the 100, 200, 300 and 1100 Areas?	Balone, Steven N	Accept	Revised to indicate 100-K is a portion of the 100 Area.	Yes	01/30/2019
RL-088	ES	ES-iv	11		It might be worthwhile to discuss in this section how the 100-K area differs from other river corridor OUs in terms of the proportion of remediation completed versus "to-go"	Balone, Steven N	No Change	John Virgin discussed with Steve Balone that adding information here would need to introduce 100 Area, River Corridor, and possibly other concepts.	Yes	01/30/2019
RL-089	ES	ES-viii	1		Ks,h from chapter 5 for use in STOMP is over 18 feet/day, compared to that reported here of about 1 inch/day; please confirm proper values here and in Chapters 4 and 5 if appropriate	Balone, Steven N	No Change	Saturated hydraulic conductivity (Ch. 5) is not the same as groundwater velocity (V = [Ks,h*Gradient]/Porosity.	Yes	01/30/2019
RL-090	ES	ES-viii	21		Two things wrong with this- one, the contamination at the UPR-100-K-1 waste site is not associated with "cooling water effluent leakage;" the water in (and, leaking out of) the basin was there for shielding of spent fuel (thus, "Fuel Storage Basin"), and two, this is at the KE FSB, NOT the KW FSB. Also, check Chapter 4	Balone, Steven N	Accept	Revised text to indicate it was shielding water from the FSB. Checked Chapters 1 and 4 discussions, verified not referred to as cooling water in those. Corrected KW to KE	Yes	01/30/2019