DOE/RL-2009-127
Draft A

Remedial Investigation Report for the 200-BP-5 Groundwater Operable Unit

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Executive Summary

The U.S. Department of Energy (DOE) has completed a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] remedial investigation (RI) of the 200-BP-5 Groundwater Operable Unit (OU) within the 200 Areas National Priorities List[2] site, located at the Hanford Site in Washington State. The RI was conducted to (1) collect data to define the nature and extent of contamination; (2) assess contaminant fate and transport; and (3) evaluate potential risks to human health and the environment from 200-BP-5 OU contaminants and whether, based on these risks, a feasibility study (FS) to evaluate remedial alternatives is warranted.

The information collected during the RI and associated analysis will support the development of a combined FS for the 200 East Area groundwater OUs (200-BP-5 and 200-PO-1). The RI/FS was prepared based on previous information available for the OU, as well as additional groundwater data collection and characterization completed for the RI, and includes a refined conceptual site model for the OU.

Background

The 200-BP-5 OU (Figure ES-1) extends north-northwest from the 200 East Area, across the Hanford Site, to the Columbia River. The observed groundwater contamination in the 200-BP-5 OU resulted largely from liquid waste generated during the operational period of B Plant and associated facilities within the northern portion of the 200 East Area. The liquid waste was discharged to surface ponds (e.g., B Pond), cribs, and trenches and then allowed to infiltrate into the soil column. Unplanned releases of liquid waste also occurred within the OU and were generally associated with leaks, spills, or overfill of tanks; aboveground and belowground pipelines; and other conveyance and storage facilities. The estimated liquid waste inventories generated from these sources are provided in this RI report. Current continuing sources to groundwater have been identified at the B Complex and Waste Management Area (WMA) C (Figure ES-2).

[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq. Available at: http://epw.senate.gov/cercla.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.ecfr.gov/cgi-bin/text-idx?SID=0cff01005f9529de9127ab4a8e355abd&node=40:28.0.1.1.1&rgn=div5#ap40.28.300_11105.b.

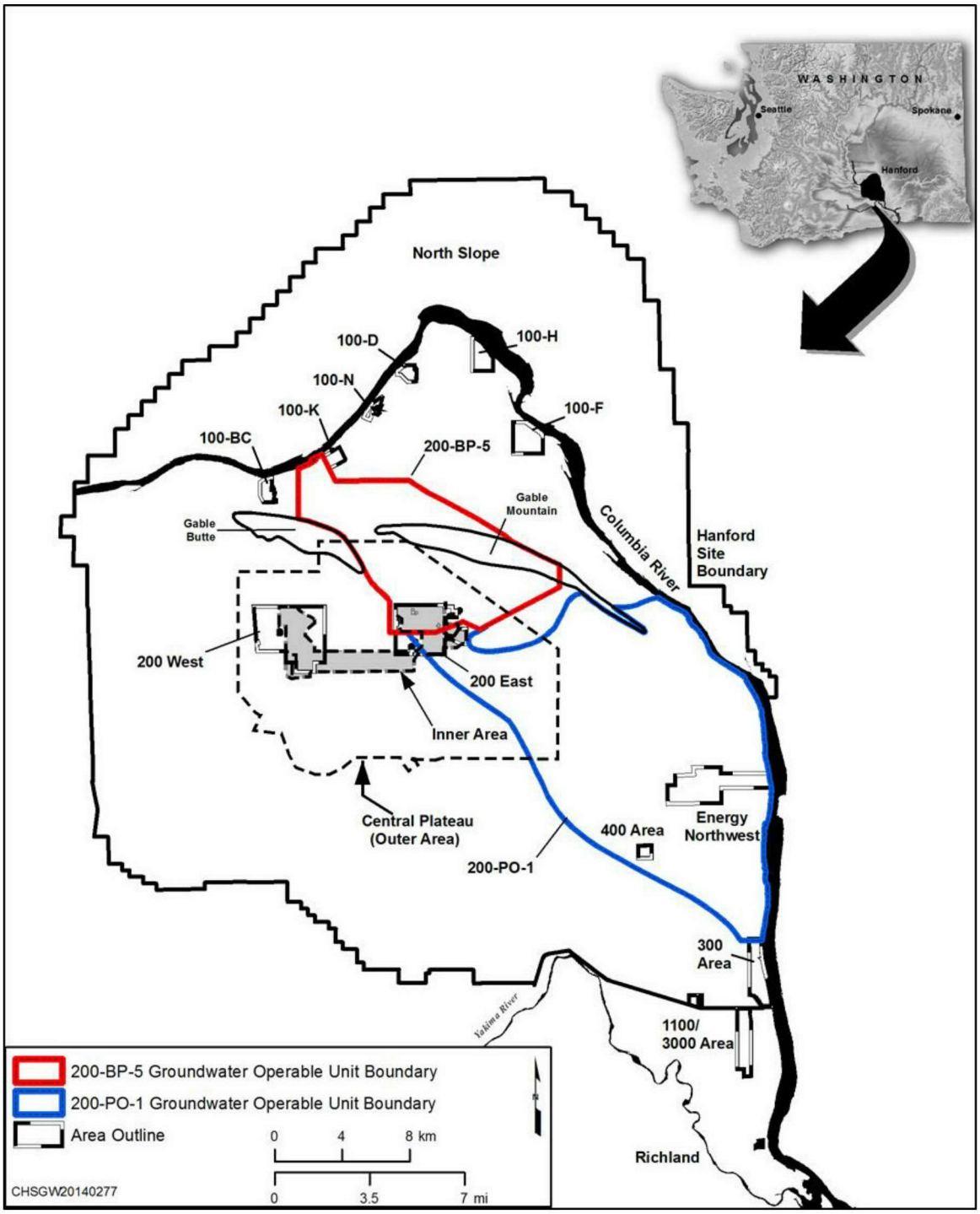

Figure ES-1. Location of the 200-BP-5 OU

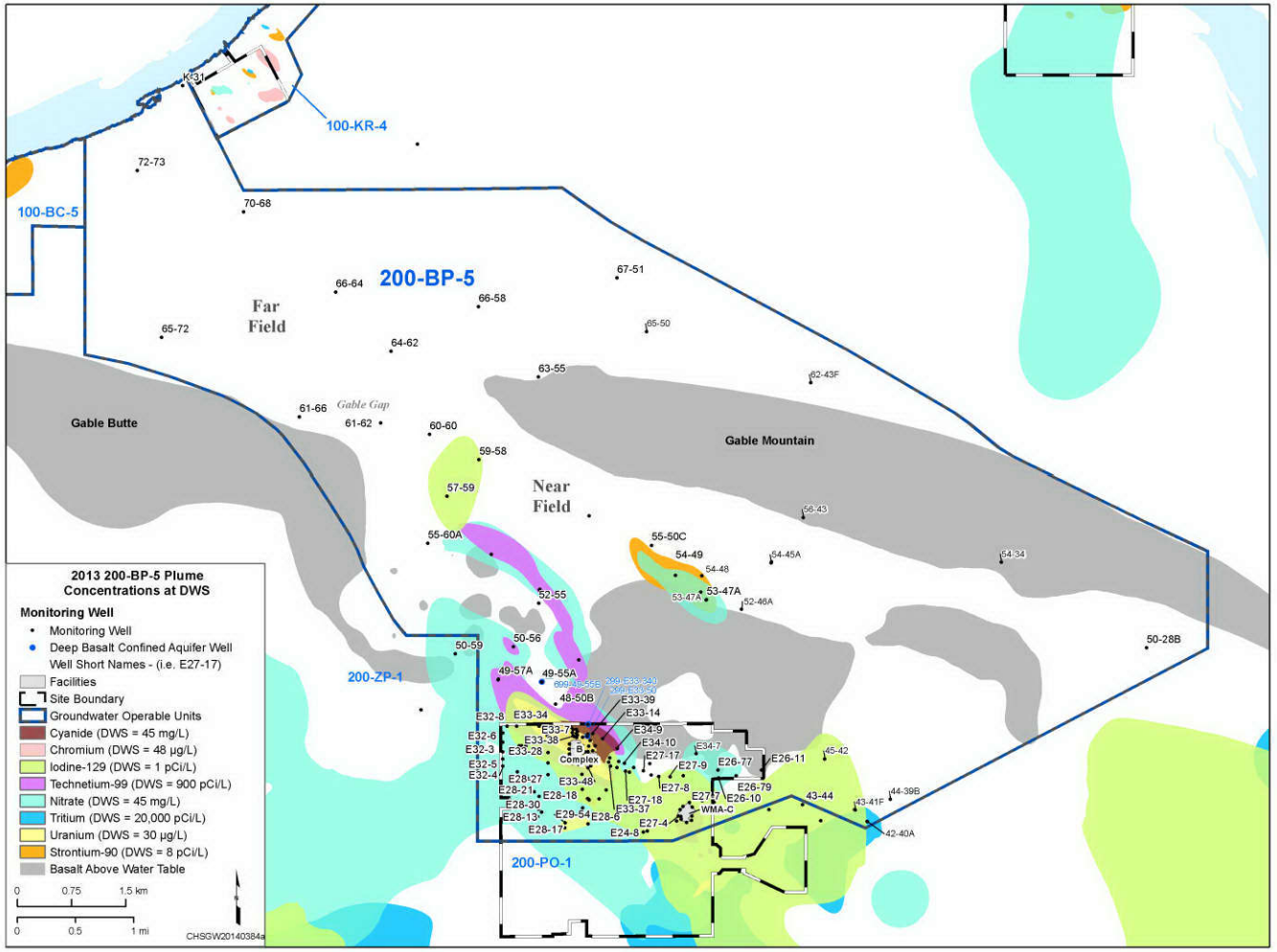

Figure ES-2. 200-BP-5 OU Constituent Contaminant Distribution Based on the 2014 Annual Groundwater Monitoring Report[3]

[3] 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.

Remedial Investigation Activities

To organize the characterization and evaluation for 200-BP-5 OU groundwater, the OU and corresponding network of groundwater monitoring wells were divided into near-field and far-field areas. The near-field area includes the northern portion of the 200 East Area (southern portion of the 200-BP-5 OU), where the contamination originated (B Plant separations processing area) and the highest groundwater contaminant concentrations have been detected. The far-field area, consisting of the broad geographic area extending north between the 200 East Area and the Columbia River, is located north and historically downgradient of source areas and existing groundwater plumes. Groundwater contaminant concentrations in the far-field area have naturally dispersed over time.

The RI characterization activities were designed to obtain data and information to support the resolution of data gaps identified through the data quality objective process. The characterization activities were categorized into the following major tasks:

- Drilling and construction of 16 new wells
- Sediment sampling (vadose zone and saturated zone) during drilling of new wells
- Depth-discrete groundwater sampling
- Hydrologic testing of new wells
- Geophysical investigations (surface and borehole methods)
- Groundwater monitoring of existing and new wells

Sediment samples from the vadose zone were collected from several wells to support the 200-DV-1, 200-IS-1, and 200-EA-1 Source OUs. An additional well, which was not anticipated during the data quality objective planning process, was constructed to monitor a perched water zone (containing high concentrations of nitrate and uranium) at the B Complex that was encountered during RI drilling. Contamination within this perched zone is currently being remediated by the 200-DV-1 OU. Existing and new monitoring wells in the OU monitor both the unconfined and confined aquifers.

Physical/Environmental Setting

Surface elevations overlying the 200-BP-5 OU range from 320 m (1,050 ft) at the top of Gable Mountain (i.e., a bedrock high) to a low of approximately 120 m (394 ft) at the Columbia River.

The geology of the OU consists of unconsolidated and partly consolidated sediments of the Miocene through Holocene ages (approximately 8.5 million years to the present, and referred to as suprabasalt sediments) overlying basalt bedrock. These suprabasalt sediments contain the unconfined aquifer system within the OU and are the primary location of groundwater contaminants associated with the OU.

During operations at the 200-BP-5 OU, large volumes of liquids were discharged to the subsurface, raising the groundwater elevation in the 200 East Area and vicinity. When groundwater flow during this time was northerly (from the northern 200 East Area), contamination migrated through Gable Gap and toward the Columbia River. Since the termination of processing operations, the groundwater mounds in the 200 East Area have been dissipating and groundwater flow velocities have slowed. By 2009, a broad, relatively flat water table and groundwater divide within the unconfined aquifer was identified near the northern half of the 200 East Area in the OU. The exact location of this divide is variable and is not well understood. In 2011, groundwater flow within the unconfined aquifer in the southern portion of the 200-BP-5 OU (south of Gable Mountain) changed flow direction by 180 degrees due to ongoing water table declines in the 200 East Area and temporal Columbia River stage changes. Since July 2011, the flow direction has maintained a south-southeast flow from the southern portion of Gable Gap into the northwestern portion of the 200 East Area.

Nature and Extent of Contamination

The RI groundwater monitoring program focused on contaminants that were found to exceed identified federal and Washington State statutory and risk-based groundwater cleanup standards.

Historically, during nuclear fuel processing operations, groundwater plumes migrated north through Gable Gap into the far-field area and toward the Columbia River. Since the cessation of fuel processing operations and the corresponding decrease in the water table mounds in the 200 East Area, current groundwater plumes associated with the OU exist within the Gable Gap area south to the 200 East Area. Figure ES-2 illustrates the

distribution of groundwater contaminants in the OU. Chapter 4 provides additional information on the nature and extent of the existing contaminant plumes.

The most widely distributed contaminants within the OU are nitrate, iodine-129, technetium-99, cyanide, and uranium. Nitrate, technetium-99, cyanide, and uranium are associated with sources from the B Complex in the northeastern portion of the 200 East Area. During the RI, concentrations of nitrate deep in the unconfined aquifer were detected in the B Plant area. Technetium-99 is associated with the B Complex and WMA C (Figure ES-2). Iodine-129 within the 200-BP-5 OU is primarily attributed to releases associated with Plutonium-Uranium Extraction Plant operations within the 200-PO-1 OU that have migrated to the 200-BP-5 OU. Iodine-129 is detected in a confined to semiconfined portion of the aquifer near B Pond, which is likely attributed to the relatively high hydraulic heads in the unconfined aquifer during Hanford Site operations and the interconnection of the unconfined and confined aquifers in this area.

The less widely distributed contaminants that are detected in small, localized areas are arsenic, cesium-137, cobalt-60, fluoride, hexavalent chromium (Cr(VI)), gross alpha, plutonium-239/240, strontium-90, sulfate, and tritium.

Groundwater Fate and Transport

Computer simulations to understand and estimate the fate and transport of 200-BP-5 OU groundwater contamination were used to evaluate concentrations and plume movements over time for cyanide, Cr(VI), iodine-129, nitrate, strontium-90, technetium-99, tritium, and uranium. These contaminants were selected because they occur in well-defined distributions or at high concentrations (or both), and they have the potential for future migration. Simulations were conducted using existing groundwater contaminants at their measured concentrations. The simulations also considered additional impacts from the source areas (continuing source) for nitrate, technetium-99, and uranium from the B Complex; technetium-99 from WMA C; and with and without future discharges from the Treated Effluent Disposal Facility (TEDF), which is currently an operational liquid effluent discharge source in the area.

Without a continuing source impact being simulated (source term), the times for the existing contaminants to naturally reach the drinking water standard (DWS) ranged from several months (0.2 years) for Cr(VI) to 800 years for technetium-99. Cr(VI), iodine-129, tritium, and uranium naturally attenuate below DWSs within the area defined as the

Central Plateau. Cyanide, nitrate, strontium-90, and technetium-99 take longer to attenuate in the Gable Gap area (where the groundwater flow rates are slower) than to the south in the 200 East Area (where groundwater velocities are greater).

The addition of TEDF discharges does not significantly increase or decrease the simulation time to reach the DWS, with the sole exception of cyanide, in which the addition of future TEDF discharges actually decreased the time to reach the DWS by 150 years.

The addition of the continuing sources, with or without future TEDF discharges, greatly increases the time to reach the DWS for nitrate, technetium-99, and uranium near the B Complex and WMA C.

Baseline Risk Assessment

The purpose of the groundwater baseline risk assessment (BRA) is to determine whether a groundwater remedial action may be required under CERCLA. The primary objective of the groundwater risk assessment is to identify the contaminants of potential concern (COPCs) that require evaluation of remedial alternatives in the FS.

Chapter 6 describes the BRA that was conducted to evaluate current and potential future risks to hypothetical human and ecological receptors. For the BRA evaluations, the near-field area was divided into nine exposure areas (low-level waste management are [LLWMA]-1, LLWMA-2 and the 216-B-63 Trench, WMA B-BX-BY, WMA C, B Plant, Semiworks, LERF, Gable Mountain Pond, and 200-BP-5 west), and the far-field area was divided into two exposure areas (far-field and near-river). The near-field area includes a separate confined aquifer exposure area that is composed of wells to monitor basalt interbeds.

Data analyses, which included the previous 6 years of groundwater sampling, were used to identify a final data set that was evaluated in the BRA. The BRA used the U.S. Environmental Protection Agency tap water (residential) scenario to calculate cumulative cancer risks for radionuclides and chemicals, and cumulative noncancer hazards for chemicals. COPCs that require evaluation in the FS were identified when the following risk and hazard thresholds were met:

- When the cumulative cancer risk for chemicals was greater than 1 in 100,000 (1×10^{-5}), or when the hazard index for chemicals was greater than 1, as described in

the 2007 Model Toxics Control Act (MTCA) Human Health Risk Assessment (HHRA) Procedures (WAC 173-340-708(5)(a)).[4]

- When the cumulative cancer risk for radiological analytes was greater than 1 in 10,000 (1×10^{-4}), which is described as the upper end of the risk range specified in 40 CFR 300.[5]

In addition to the groundwater BRA, all individual groundwater measurements were compared to DWS groundwater cleanup levels (WAC 173-340-720[6]) based on a target risk level of 1 in 1,000,000 (1×10^{-6}) or a hazard quotient of 1.

The BRA and individual groundwater measurement evaluation identified 15 COPCs: arsenic, cesium-137, cobalt-60, cyanide, Cr(VI), fluoride, gross alpha, iodine-129, nitrate, plutonium-239/240, strontium-90, sulfate, technetium-99, tritium, and uranium.

The ecological risk assessment for the 200-BP-5 OU considered groundwater beneath the Central Plateau and the far-field area leading to the Columbia River. Several ecological risk assessments have been conducted at groundwater OUs where the groundwater discharges to the river. Additionally, a separate risk assessment, the Columbia River Component (CRC),[7] was conducted. The CRC concluded that seven contaminants of ecological concern were present in sediment, pore water, island soil, and shoreline sediment. These include aluminum, chromium, Cr(VI), lead, manganese, nickel, and nitrate. Based on this analysis, none of the seven contaminants of ecological concern merit being retained for the OU.

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[4] WAC 173-340-708, "Model Toxics Control Act–Cleanup," "Human Health Risk Assessment Procedures," *Washington Administrative Code*, Olympia, Washington. Available at: http://app.leg.wa.gov/WAC/default.aspx?cite=173-340-708.

[5] 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=0cff01005f9529de9127ab4a8e355abd&node=40:28.0.1.1.1&rgn=div5.

[6] WAC 173-340-720, "Model Toxics Control Act–Cleanup," "Groundwater Cleanup Standards," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720.

[7] DOE/RL-2010-117, 2012, *Columbia River Component Risk Assessment Volume I, Parts 1 & 2: Screening-Level Ecological Risk Assessment*, Rev. 0 (available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0092299), and DOE/RL-2010-117, 2012, *Columbia River Component Risk Assessment Volume II, Parts 1 & 2: Baseline Human Health Risk Assessment*, Rev. 0 (available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0090731 and http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0090730), U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Based on the information provided in the RI and related BRA, DOE believes that it is appropriate to proceed with an FS for the 200-BP-5 OU to address the risks that were concluded to be above the relevant state and federal standards, and that are not predicted to attenuate in a reasonable time frame.

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Terms

AEA	*Atomic Energy Act of 1954*
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
BEHP	bis(2-ethylhexyl) phthalate
bgs	below ground surface
BRA	baseline risk assessment
BWIP	Basalt Waste Isolation Project
CAS	Chemical Abstracts Service
CCC	criteria continuous concentration
CCU	Cold Creek unit
CCU_z	Cold Creek unit fine-grained
CDI	chronic daily intake
CEM	conceptual exposure model
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHB	constant head boundary
CLARC	Cleanup Levels and Risk Calculations
CMC	criteria maximum concentration
COEC	contaminant of ecological concern
COPC	contaminant of potential concern
Cr(VI)	hexavalent chromium
CRC	Columbia River Component
CSM	conceptual site model
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CWA	*Clean Water Act of 1977*
DOE	U.S. Department of Energy
DQA	data quality assessment
DQO	data quality objective
DWS	drinking water standard

Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
F&T	fate and transport
FS	feasibility study
FY	fiscal year
gpm	gallons per minute
HCP EIS	*Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*
HEAST	Health Effects Assessment Summary Tables
HEIS	Hanford Environmental Information System
HFB	horizontal flow boundary
HHE	human health and the environment
HHRA	human health risk assessment
HI	hazard index
HMS	Hanford Meteorological Station
HQ	hazard quotient
HRR	high-resolution resistivity
HSGM	Hanford South Geoframework Model
HSU	hydrostratigraphic unit
ID	identification
IRIS	Integrated Risk Information System
K_d	distribution coefficient
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDL	method detection limit
MRDL	maximum residential disinfectant level

MTCA	"Model Toxics Control Act—Cleanup" (WAC 173-340)
N/A	not applicable
NCP	National Contingency Plan (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan")
NPL	National Priorities List (40 CFR 300, Appendix B)
ORP	DOE Office of River Protection
OU	operable unit
P2R	Plateau-to-River Groundwater Transport Model
PCB	polychlorinated biphenyl
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium-Uranium Extraction (Plant)
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation (Plant)
RfD	reference dose
RI	remedial investigation
RLM	Ringold lower mud
RME	reasonable maximum exposure
ROD	record of decision
Rtf	Ringold upper unit
RUM	Ringold upper mud
Rwia	Ringold fluvial gravel unit A
Rwie	Ringold fluvial gravel unit E
SALDS	State-Approved Land Disposal Site
SAP	sampling and analysis plan
SST	single-shell tank
SVOC	semivolatile organic compound
TCE	trichloroethene
TEDF	Treated Effluent Disposal Facility
TPH	total petroleum hydrocarbon

Tri-Parties	DOE, EPA, and Ecology
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and disposal
UCL	upper confidence limit
UPR	unplanned release
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound
WIDS	Waste Information Data System
WMA	waste management area

1

1 Introduction

This report presents the results of the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation (RI) conducted for the 200-BP-5 Groundwater Operable Unit (OU), located at the U.S. Department of Energy (DOE) Hanford Site in Washington State (Figure 1-1). The evaluation of risk posed to human health and the environment (HHE) by current groundwater conditions is presented in this RI report. The feasibility study (FS) for the 200-BP-5 OU will evaluate remedial technologies and compare remedial alternatives to address the risks described in this RI report. The FS will be developed jointly with the adjacent 200-PO-1 Groundwater OU (Figure 1-1).

This RI report was prepared in accordance with U.S. Environmental Protection Agency (EPA) guidance for conducting an RI (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*). Figure 1-2 summarizes the work elements involved in this process.

Chapter 1 is largely devoted to summarizing site background information, groundwater characterization efforts, and remediation work completed to date, as well as other relevant studies that have been completed. This information is provided to describe current 200-BP-5 OU groundwater conditions and to establish a foundation for the remainder of this RI report.

An RI involves developing a conceptual site model (CSM), which is a written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources, through environmental media, and to environmental receptors within the ecosystem (ASTM E1689-95, *Standard Guide for Developing Conceptual Site Models for Contaminated Sites*). The CSM is the backbone of the RI/FS process and is initially described in the RI/FS work plan, including associated uncertainties. The CSM is refined based on known information, RIs, modeling, and risk assessment evaluations. The CSM continues to be refined throughout the CERCLA RI/FS decision process.

As described in ASTM E1689-95, the six basic steps associated with developing a CSM (not necessarily listed in order) are as follows:

1. Identify potential contaminants (Section 6.4).
2. Identify and characterize contaminants (Sections 2.1 and 4.2).
3. Delineate the potential migration pathways through groundwater (Sections 4.4 and 5.3).
4. Establish background areas of contaminants for each contaminated medium (Section 4.1).
5. Identify and characterize the potential environmental receptors (human and ecological) (Sections 6.2).
6. Determine the limits of the study area or system boundaries (Section 1.2).

The CSM is composed of what is known about the site (Chapter 1), additional data collected as part of remedial investigations (Chapter 2), the physical characteristics (Chapter 3), nature and extent of contamination (Chapter 4), and exposure model (Chapter 6). The conceptual exposure model (CEM) is used to determine if groundwater contamination could pose a substantial threat to HHE because the exposure pathways are complete.

1.1 Purpose and Scope of Report

The purpose and scope of the 200-BP-5 OU RI report were defined in DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*, hereafter referred to as the 200-BP-5 RI/FS work plan, and a summary is provided in the following subsections. The RI was conducted and has been completed in accordance with the 200-BP-5 RI/FS work plan, with minor deviations required due to conditions encountered in the field. These deviations are discussed in Chapter 2.

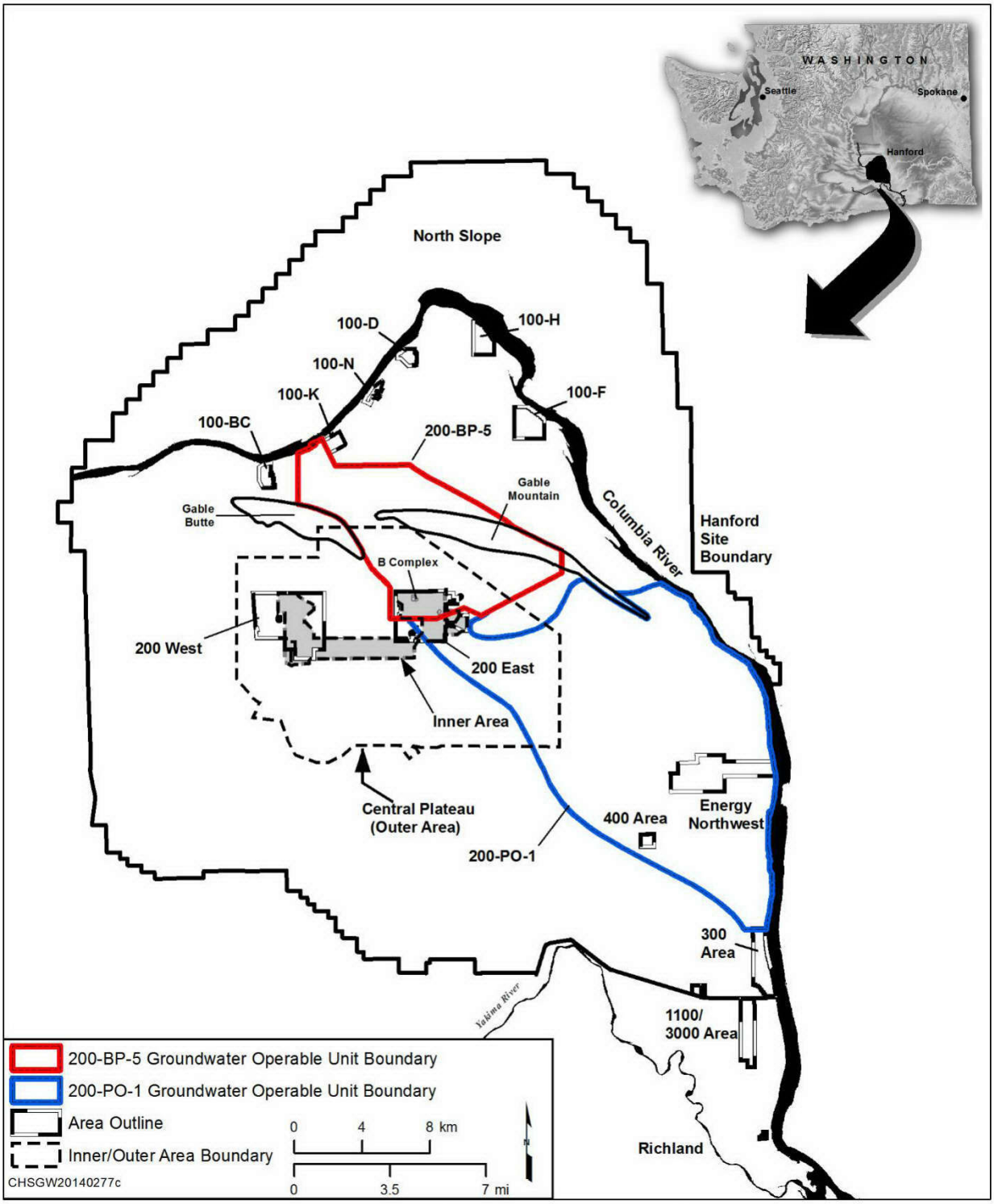

Figure 1-1. Location of the 200-BP-5 and 200-PO-1 OUs

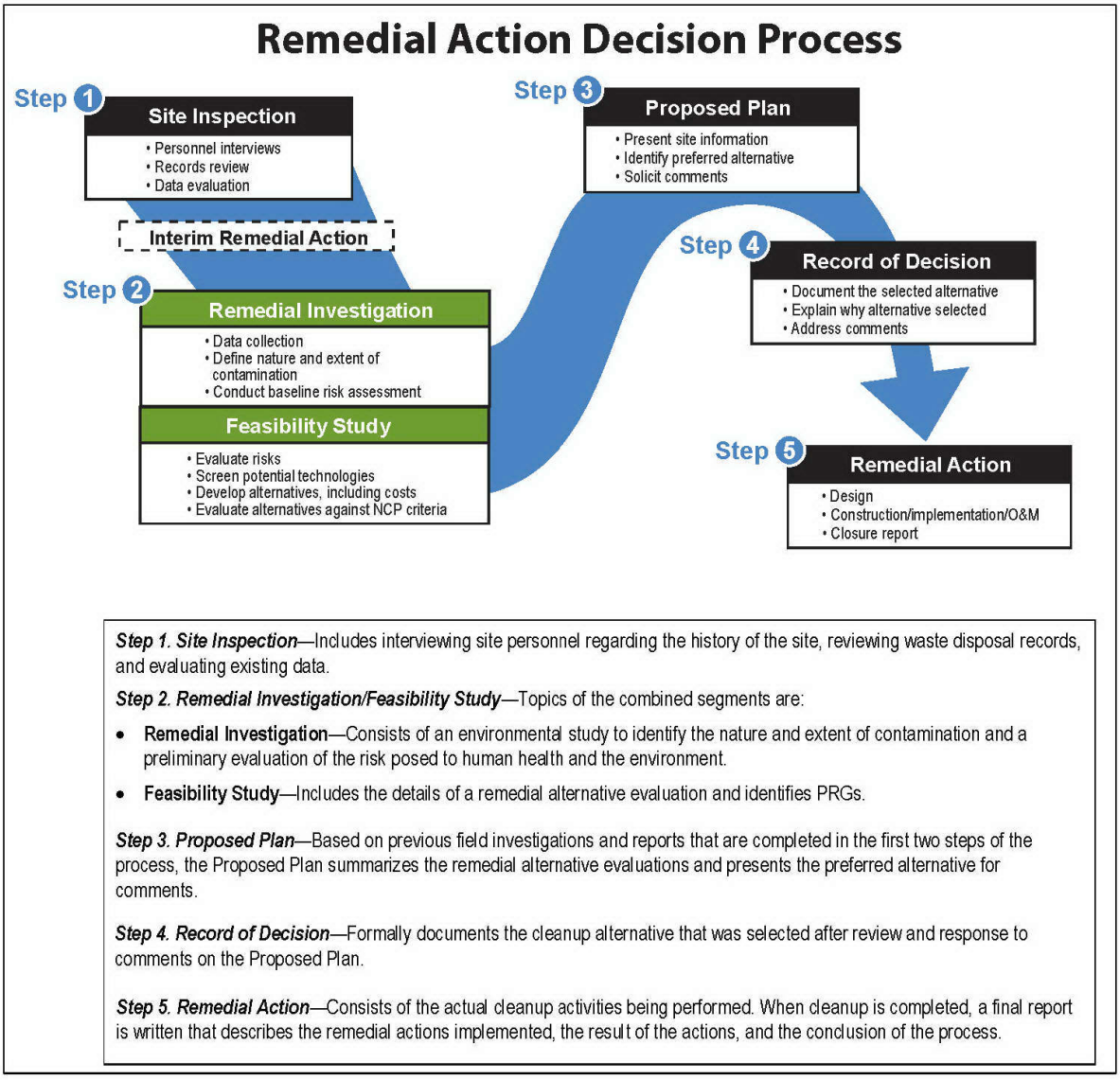

Figure 1-2. The CERCLA Process

This report builds upon the existing information collected as part of the Hanford Site routine groundwater monitoring program, previous assessments, and recent RI activities. Most importantly, this report presents the calculated potential risks to HHE for current and future conditions and also presents the basis for remedial actions to reduce risk.

1.1.1 Purpose

The purpose of this RI report is to provide a summary of the activities conducted during the 200-BP-5 OU RI, including analyses of the data collected during the investigation, as described in the 200-BP-5 RI/FS work plan (DOE/RL-2007-18). This RI report supports the preparation of a combined FS and Proposed Plan for the 200-BP-5 and 200-PO-1 OUs.

This RI report describes the groundwater contamination conditions in the 200-BP-5 OU and will be used to determine the need for remedial action evaluation in an FS. The specific objectives of this report are as follows:

- Determine the nature and extent of groundwater contamination that pose the majority of the potential risk to HHE. These are referred to as contaminants of potential concern (COPCs).
- Present the results of the groundwater analyses (using the last 6 years of data).
- Describe the nature and extent of contamination present in groundwater, the hydrogeology of the OU, the potential for migration of contamination, and the potential for adverse HHE effects if no risk reduction/remedial action is taken and potential exposure occurs (i.e., baseline risk). This objective was achieved by evaluating the following:
  - Historical facility operations
  - COPCs in dissolved-phase groundwater
  - Potential migration pathways
  - Potential receptors
  - Human and ecological exposure (dose)
  - Contaminant toxicity
- Present the results of the human health risk assessment (HHRA) for contaminants in the OU, including identifying contaminants that present unacceptable levels of risk and require further consideration in the FS.
- Define uncertainties associated with the nature and extent of contamination and how these uncertainties may affect the determination of risk.

1.1.2 Scope

The scope of this RI report involves the groundwater contamination associated with the 200-BP-5 OU (Figure 1-1). Information related to historical and ongoing waste disposal operations, and conditions related to residual contamination in the vadose zone overlying the 200-BP-5 OU, is presented to provide context and historical perspective.

The locations of current and historical releases to the environment have resulted in impacts to groundwater are discussed, including ongoing and predicted future contaminant releases from the vadose zone. This information will be considered in the FS as part of remedial alternative evaluations. Source area investigations and evaluations (surface soil and vadose zone) from areas not currently impacting groundwater will be presented in separate source area RI/FS reports.

The scope of this report includes the following components:

- A description of the work conducted during the RI in accordance with the 200-BP-5 RI/FS work plan (DOE/RL-2007-18), the results of the data quality assessment (DQA) of the analytical results generated under the work plan, and an understanding of site conditions based on integration of the new RI information with existing historical information.
- Description of the aquifer systems within the OU, and the nature and extent of groundwater contamination within the OU.

- A baseline risk assessment (BRA) for human health and ecological risk, which presents an evaluation of potential impacts from groundwater conditions in the 200-BP-5 OU. Human health impacts are assessed through consideration of a hypothetical exposure of human receptors to OU contaminants in groundwater through a drinking water pathway, and also by comparison of site conditions to established drinking water standards (DWSs) or other identified regulatory action levels (e.g., Washington State Department of Ecology [Ecology] WAC 173-340, "Model Toxics Control Act–Cleanup" [MTCA], cleanup levels). Ecological receptors are evaluated through consideration of a hypothetical exposure to contaminated groundwater entering the Columbia River at the aquifer discharge boundary. The baseline conditions were developed using groundwater sampling and analysis results collected during the last 6 years.

Consistent with the Tri-Party Agreement (Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order*); DOE/RL-2007-20, *Hanford Integrated Groundwater and Vadose Zone Management Plan*; and DOE/RL-2009-81, *Central Plateau Cleanup Completion Strategy*, the remediation of waste sites and impacted vadose zone soils overlying the four Central Plateau groundwater OUs will be addressed (1) as a discrete CERCLA OU with its own accompanying Record of Decision (ROD), (2) as a combined *Resource Conservation and Recovery Act of 1976* (RCRA)/CERCLA OU with its own corrective action decision/ROD, or (3) through the RCRA closure/corrective action process for tank farm waste management areas (WMAs). In April 2010, a tentative agreement was reached between the Tri-Parties (i.e., DOE, EPA, and Ecology) to define the CERCLA decision structure accompanying the Central Plateau strategy to be consistent with the division of decision making between the groundwater OUs and waste site OUs.

The environmental cleanup mission for the Hanford Site began in 1989, including the transition following the plutonium-production era (from 1943 through 1989), to the mission of waste management and environmental cleanup. During plutonium production, the Hanford Site was divided into production areas, including the 200 East and 200 West Areas, which contain the major nuclear fuel processing, waste management, and disposal facilities. This RI report presents information related to the primary sources of contamination from plutonium production in the 200 East Area. The historical designations for the 200 East and 200 West Areas (Figure 1-1) are used in context throughout this RI report, where appropriate.

The Central Plateau encompasses the 200 Area National Priorities List (NPL) (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List") and includes two principal areas (Figure 1-1):

- The Inner Area covers approximately 26 km^2 (10 mi^2) in the middle of the Central Plateau, where the majority of the chemical processing and waste management activities occurred. The Inner Area is envisioned to be the smallest practical final cleanup footprint where waste management and containment of residual contamination will occur.

- The Outer Area covers an area greater than 168 km^2 (65 mi^2) and includes much of the open area on the Central Plateau. Limited processing activity occurred in the Outer Area.

The relation of the 200-BP-5 Groundwater OU to the Central Plateau is described in following sections.

1.2 Site Background

The physical location of the 200-BP-5 OU, including a description of the area, the processes that contributed to site contamination, and previous investigations that have provided information about the nature and extent of site contamination are discussed in this section. The site background information in

this section was summarized primarily from the 200-BP-5 RI/FS work plan (DOE/RL-2007-18); WMP-28945, *Data Quality Objectives Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process*; and PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*. This section also considers the regulatory basis for activities, as well as current and future land-use activities that provide a context for potential future remedial actions.

1.2.1 Site Description

The 200-BP-5 OU encompasses contaminated groundwater associated with historical operation of DOE nuclear fuel reprocessing and the waste storage and disposal facilities located primarily within the 200 East Area of the Hanford Site. The 200-BP-5 OU extends from the 200 East Area, northwest to the Columbia River, and east to the eastern flank of Gable Mountain (Figure 1-3). The boundaries of the 200-BP-5 OU encompass an area of approximately 84.5 km^2 (32.6 mi^2). At its northernmost extent, the 200-BP-5 OU borders the Columbia River, adjacent to two other groundwater OUs (100-BC-5 and 100-KR-4). The BRA for the 200-BP-5 OU will consider the results from CERCLA activities conducted for the adjacent 200-PO-1, 100-BC-5, and 100-KR-4 OUs. The aquifers included in the 200-BP-5 OU include the uppermost unconfined aquifer and the affected portions of underlying semiconfined and confined aquifer units.

The land surface area overlying the 200-BP-5 OU includes both active and inactive nuclear processing and waste management facilities, many of which were the sources for the current groundwater contamination. In addition to the industrial facilities, the majority of the affected aquifer area of this OU is overlain by tracts of undeveloped land on the Hanford Site. The undeveloped land area generally consists of shrub-steppe habitat that contains numerous plant and animal species adapted to the semiarid environment in the region. The developed areas consist of industrial buildings interconnected by roads, railroads, pipelines, and electrical transmission lines. The Columbia River flows through the Hanford Site along the northern boundary of the 200-BP-5 OU. Although the river is free flowing near the Hanford Site, daily and seasonal water-level fluctuations are controlled by upriver dams.

The 200-BP-5 OU was established primarily to address groundwater contamination associated with historical operations of B Plant (241-B Building) and other associated Central Plateau facilities within the northern portion of the 200 East Area. The 200-PO-1 OU, established primarily to address groundwater contamination associated with historical operations at the Plutonium-Uranium Extraction (PUREX) Plant (241-A), extends southeast from the southern boundary of the 200-BP-5 OU (Figure 1-1). A detailed description of the 200-PO-1 OU is provided in DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*. Although the 200-BP-5 OU underlies a large area of present and historical nuclear industrial operations, 200-BP-5 is strictly a groundwater OU and does not address any of the overlying contaminant source sites or the underlying residual vadose zone contamination.

In order to distinguish between groundwater contamination that is clearly associated with specific waste disposal activities originating in the 200 East Area and the more regionally dispersed contamination that has a broader origin, the network of Hanford Site groundwater monitoring wells associated with 200-BP-5 OU was segregated into "near-field" and "far-field" areas (Figure 1-3). The near-field area underlies contaminant source areas within the 200 East Area, where contamination originated from the source areas overlying 200-BP-5 OU; this is currently the location of the highest contaminant concentrations. The far-field area consists of the broad geographic area extending from Gable Gap to the Columbia River and includes the aquifer historically affected by contaminants migrating from the Central Plateau area northward toward the river.

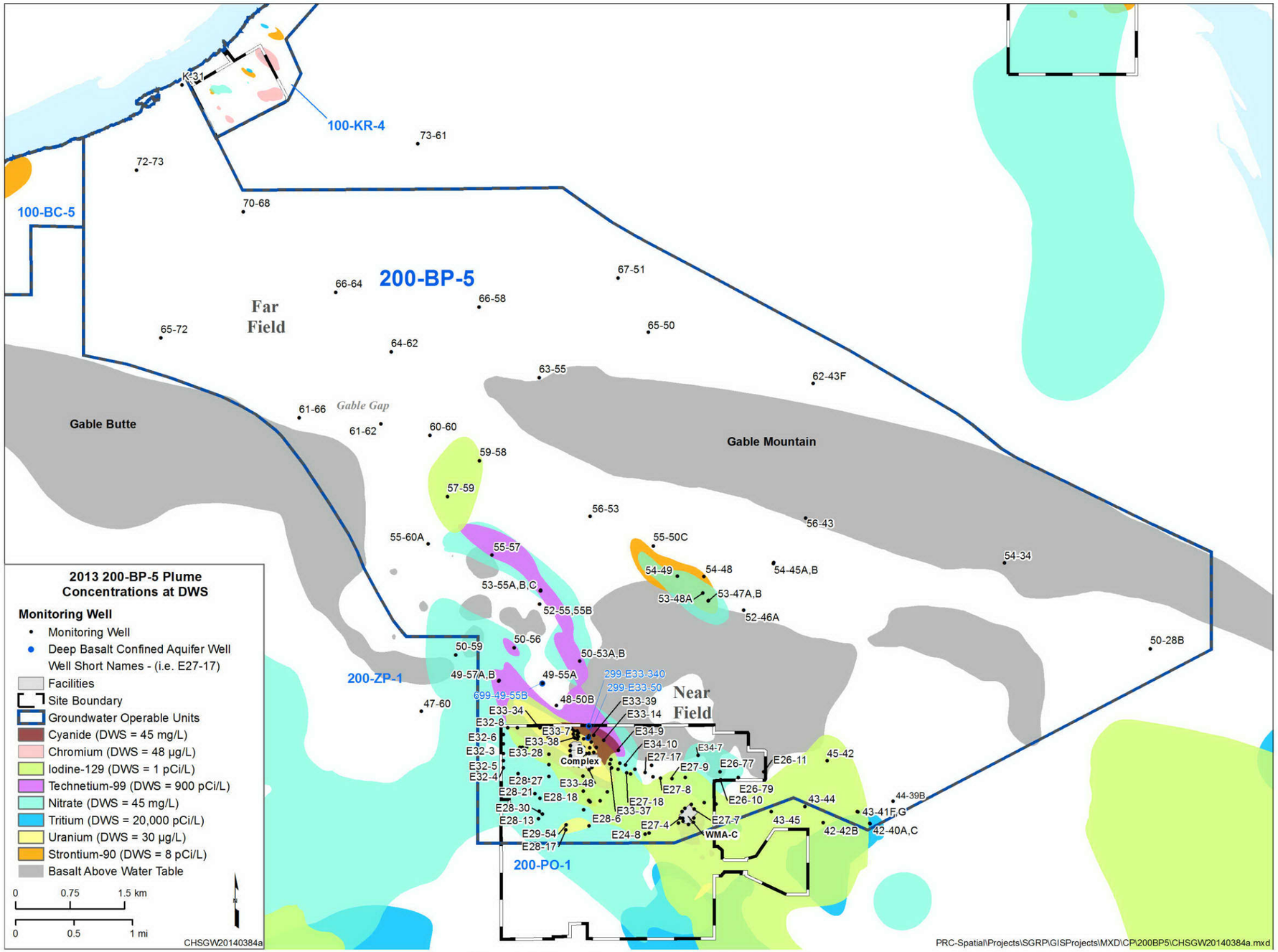

Figure 1-3. Contaminant Plumes in the 200-BP-5 OU

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An extensive annotated bibliography of historical documents is provided in Appendix A and includes technical documents that describe the process chemistry for the various liquid effluent wastes discharges, waste inventory-related documents, information on the vadose zone conditions overlying the 200-BP-5 OU, and information on the groundwater within the 200-BP-5 OU. The annotated bibliography has been updated from that previously published in WMP-28945.

1.2.2 Site History

Groundwater contamination observed in the 200-BP-5 OU largely originated from planned releases of wastewater and liquid process wastes directly to the ground, with additional contributions from leaks, spills, and other unplanned releases (UPRs) of liquids during operations. Discharge of liquid wastes to the ground through engineered facilities (e.g., cribs, ditches, ponds, and trenches) has been a practice in the 200 East Area since the inception of Hanford Site plutonium-processing activities. Groundwater contamination is primarily related to waste disposal associated with past B Plant operations. Figure 1-4 presents a general facility layout for these waste disposal sites.

B Plant was operated from 1945 to 1956 to recover plutonium from irradiated fuel using the bismuth phosphate process (PNNL-13080, *Hanford Site Groundwater Monitoring: Setting, Sources and Methods*; DOE/RL-92-05, *B Plant Source Aggregate Area Management Study Report*). B Plant was subsequently reconfigured and used from 1968 to 1985 to recover cesium and strontium isotopes from high-level waste stored at tank farms (DOE/RL-95-100, *RCRA Facility Investigation Report for the 200-PO-1 Operable Unit*).

In 1954 and 1955, scavenged uranium recovery waste liquids (supernatants) were discharged to the 216-BY Cribs (hereafter referred to as the BY Cribs) and the 216-B-42 Trench in the 200 East Area (PNNL-13080) (Figure 1-4). This waste contained large amounts of ferrocyanide and other chemical and radiological components. Disposal of this waste was discontinued because high levels of cobalt-60 were detected in the groundwater shortly after disposal. Following completion of the uranium recovery program, an in-tank solidification process was initiated to remove excess liquid from the tanks by evaporating the liquid and sending the condensate to the 216-B-50 and 216-B-57 Cribs (DOE/RL-2007-18; PNNL-19277).

The 201-C Process Building (i.e., Hot Semiworks Plant) was constructed as a pilot plant for reprocessing reactor fuel using first the reduction-oxidation (REDOX) chemical process and then the PUREX chemical process (DOE/RL-2007-18; DOE/RL-92-18, *Semiworks Source Aggregate Area Management Study Report*). The plant was later converted to recover strontium from fission product waste. Wastes were discharged primarily to the 216-C-1 Crib.

Wastewater considered to be uncontaminated (e.g., cooling water and steam condensate) was disposed to open trenches and ponds, and was later flushed with fresh water. Radiologically contaminated liquid process waste was disposed to cribs, trenches, and French drains. High-level radioactive waste derived from reactor fuel reprocessing was directed to underground tanks. With the exception of the tanks at WMA C (C Tank Farm), the single-shell, high-level waste tanks were designed and operated as flow-through settling tanks, with the overflowing waste liquids discharging to cribs associated with the tank farms. Some of the unplanned discharges from tanks have been associated with UPRs to the soil column. Other UPRs of process waste and wastewater from waste conveyance components (e.g., pipelines, diversion boxes, or other associated release points) may also have contributed contamination at the 200-BP-5 OU.

By June 1995, in accordance with Tri-Party Agreement (Ecology et al., 1989) Milestone M-017-10, liquid waste disposal to ground was terminated, with the exception of permitted discharges to the Treated

Effluent Disposal Facility (TEDF) in the 200 East Area and the State-Approved Land Disposal Site (SALDS) in the 200 West Area. The TEDF and SALDS are still in use.

The 200-BP-5 OU underlies 71 CERCLA liquid effluent waste sites, which have groundwater monitoring requirements under CERCLA and the *Atomic Energy Act of 1954* (AEA). CERCLA facilities that are known to have contributed the largest quantities or highest concentrations of contaminants to groundwater in the 200-BP-5 OU include the following:

- BY Cribs
- 216-B-7A and B Cribs
- 216-B-8 Crib
- 216-B-12 Crib
- 216-B-62 Crib
- 216-C-1 Crib
- 216-B-5 injection/reverse well
- 216-B-6 injection/reverse well
- 216-A-25 Gable Mountain Pond

The 200-BP-5 OU also underlies six RCRA treatment, storage, and disposal (TSD) units. These RCRA TSD units are primarily monitored for nonradioactive contaminants under RCRA and for radioactive contaminants under CERCLA and AEA requirements. The following are RCRA TSD units that overlie the 200-BP-5 OU:

- Low-Level Waste Management Area 1 (LLWMA-1) (218-E-10 Landfill)
- LLWMA-2 (218-E-12B Landfill)
- 216-B-63 Trench
- Liquid Effluent Retention Facility (LERF)
- WMA B-BX-BY Tank Farms (hereafter referred to as the B-BX-BY Tank Farms)
- WMA C Tank Farm (hereafter referred to as the C Tank Farm)

The UPRs at the B-BX-BY and C Tank Farms have affected groundwater quality and are discussed in detail in Chapter 4. Residual groundwater contamination from these processes is the subject of this RI report.

1.2.3 Previous Investigations and Remediation

Groundwater monitoring at the 200-BP-5 OU is conducted under three major programs: CERCLA; RCW 70.105, "Hazardous Waste Management," for TSD units and RCRA past-practice facilities; and the federal AEA. These programs accomplish the following general objectives:

- Determine groundwater quality baseline conditions
- Characterize hydrogeologic and geochemical trends in the natural groundwater system resulting from historical Hanford Site operations
- Assess existing and emerging groundwater quality problems and impacts to the aquifer system
- Support analyses, including groundwater flow and contaminant fate and transport (F&T) evaluations

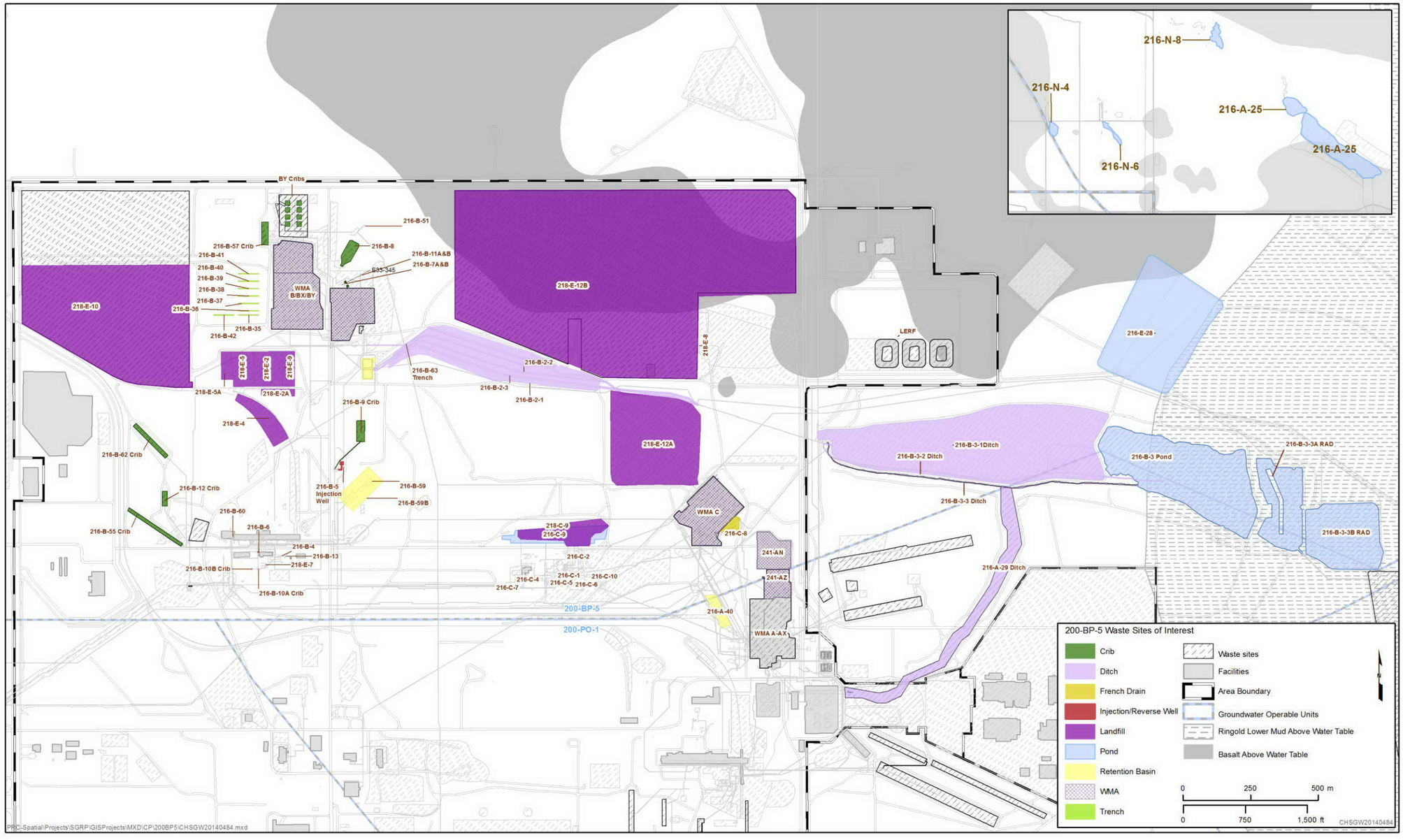

Figure 1-4. Location of Waste Disposal Facilities Overlying the 200-BP-5 OU

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Various site characterization and monitoring programs have been developed for individual waste sites, as well as for the various groupings of sites, to assess contamination and remediation in the 200-BP-5 OU. Analytical results and site information are maintained in the Hanford Environmental Information System (HEIS) and the Waste Information Data System (WIDS) databases.[1] Table 1-1 summarizes previous investigations and remediation of the 200-BP-5 OU.

In 2012, DOE initiated the 200-BP-5 OU treatability test in the area of the B-BX-BY Tank Farms in accordance with DOE/RL-2010-74, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*. The treatability test for identified perched groundwater contamination (primarily technetium-99 and uranium) will be used to evaluate groundwater flow and recovery to support the FS for the 200 East Area.

1.2.4 Regulatory Basis and History

In 1989, the Hanford Site was listed on the NPL (40 CFR 300, Appendix B) pursuant to CERCLA. To address groundwater contamination in the 200 East Area, the 200-BP-5 and 200-PO-1 OUs were established as separate groundwater OUs in 1993.

Details regarding the regulatory history of the 200-BP-5 OU are presented in Table 1-1.

1.2.5 Current Land and Groundwater Use, Demography, and Future Land Use

This section describes the current and future land use, current groundwater use, and the demography for the 200-BP-5 OU.

1.2.5.1 Current Land and Groundwater Use

The northern portion of the 200-BP-5 OU extends to the Columbia River. Land use in the River Corridor is currently controlled by DOE and the U.S. Fish and Wildlife Service (USFWS), which jointly manage this federally owned land to protect natural and cultural resources while conducting cleanup activities. As part of the Central Plateau, the southern portion of the 200-BP-5 OU resides within the Central Plateau Inner Area in a land-use area designated by DOE as industrial.

The National Contingency Plan (NCP) (40 CFR 300) states that EPA expects a remedy to return groundwater to highest beneficial use whenever practicable, within a reasonable time period. Federal decisions for groundwater cleanup generally defer to state determinations of current and future groundwater uses, as described in EPA/540/G-88/003, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*, and the memorandum regarding OSWER Directive 9283.1-09 (Fields, 1997b, "The Role of CSGWPPs in EPA Remediation Programs"). Washington State has determined that groundwater in the 200-BP-5 OU meets the Washington State's potable groundwater definition, and the highest beneficial use for the groundwater is as a potential source of domestic drinking water.

1.2.5.2 Demography

No residences exist on the Hanford Site. The nearest inhabited residences are farm homes on land located approximately 16 km (10 mi) east of the center of the 200-BP-5 OU and 27 km (17 mi) north of the center of the 200-BP-5 OU. Approximately 411,000 people live within an 80 km (50 mi) radius of the 200 Area Central Plateau. The primary population centers are the cities of Richland, Kennewick, and Pasco (south of the Hanford Site); Prosser (to the southwest); Sunnyside (to the southwest); and Benton City (to the southwest).

[1] The HEIS and WIDS databases are available online at https://ehs.hanford.gov/eda/.

Table 1-1. 200-BP-5 OU History of Major Technical Investigations and Regulatory Strategies

Year	Activity	Documentation
1979	A characterization study was conducted to determine the radionuclide concentrations in the groundwater at the 216-B-5 Reverse Well. The 216-B-5 Reverse Well was used from 1945 to 1947 to discharge contaminated liquid wastes from the 221-B B Plant and the 224-B Concentration Facility directly to the unconfined aquifer.	RHO-ST-37, *216-B-5 Reverse Well Characterization Study*
1989	The 200-BP-5 OU was defined as a combined source and groundwater OU and was added to the NPL pursuant to CERCLA. Inclusion on the NPL initiated the RI/FS process for characterizing the nature and extent of contamination, assessing risks to HHE, and selecting remedial actions. Other OUs in the vicinity of B Plant in the 200 East Area were designated as combined source and groundwater OUs (200-BP-1, 200-BP-2, 200-BP-3, 200-BP-4, and 200-BP-11).	40 CFR 300, Appendix B, "National Oil and Hazardous Substances Pollution Contingency Plan," "National Priorities List"
1989	The Tri-Party Agreement defined RCRA treatment, storage, and disposal groups within the 200 East Area that were to be closed or permitted in accordance with Washington State's "Dangerous Waste Regulations" (WAC 173-303).	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
1991	The 1991 revision to the Tri-Party Agreement described and justified a streamlined approach for managing and implementing all past-practice investigations under one characterization and remediation strategy, regardless of the regulatory agency lead (as defined in the Tri-Party Agreement).	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
1992	The Hanford past-practice strategy was developed to implement a streamlined approach for integrating the past-practice remedial action processes for CERCLA and RCRA into a single process for the Hanford Site. The strategy required the conduct of AAMSs, which are similar in nature to an RI/FS scoping study.	DOE/RL-91-40, *Hanford Past-Practice Strategy*
1992	The investigation to characterize the release and determine the risk of migrating scavenged waste from the BY Cribs, 216-B-50 Crib, and 216-B-57 Crib included tasks that characterized the groundwater in the 200-BP-1 OU (now part of the 200-BP-5 OU). One task used seismic refraction to define the surface elevation of the uppermost basalt layer and to identify possible paleochannels in the basalt that might influence the migration of contaminant plumes in groundwater. Another task involved installing 10 groundwater wells (7 wells to monitor the unconfined aquifer and 3 wells to monitor the confined aquifer) in the 200-BP-1 OU (now the 200-BP-5 OU).	DOE/RL-92-70, *Phase I Remedial Investigation Report for 200-BP-1 Operable Unit*, Vols. 1 and 2
1993	The AAMS report prepared for 200 East Area groundwater summarized information about groundwater contaminants and included a preliminary CSM summarizing the understanding of the aggregate area with respect to the types and the extent of contamination and the relevant exposure pathways and receptors.	DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*

Table 1-1. 200-BP-5 OU History of Major Technical Investigations and Regulatory Strategies

Year	Activity	Documentation
1993	The AAMS report prepared for the B Plant source area summarized information about facility operations and waste site contaminants and included a preliminary CSM summarizing the understanding of the aggregate area with respect to the types and the extent of contamination and the relevant exposure pathways.	DOE/RL-92-05, *B Plant Source Aggregate Area Management Study Report*
1993	The AAMS report prepared for the Semiworks source area summarized information about facility operations and waste site contaminants and included a preliminary CSM summarizing the understanding of the aggregate area with respect to the types and the extent of contamination and the relevant exposure pathways.	DOE/RL-92-18, *Semiworks Source Aggregate Area Management Study Report*
1993	The groundwater north of an apparent groundwater divide under the 200 East Area was defined as a groundwater-only OU in the 200 East Area groundwater AAMS in accordance with the recommendation in the B Plant source AAMS report (DOE/RL-92-05). The OU was defined as including those plumes in the B Plant aggregate area (including Gable Mountain Pond). In the 200 East Area groundwater AAMS report, this OU was tentatively named GW-OU-4.	DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*
1993	The GW-OU-04 groundwater-only OU was designated as the 200-BP-5 OU in Tri-Party Agreement Change Control Form C-93-06. According to Change Control Form C-93-06, the 200-BP-5 OU is north of the center of a groundwater mound found beneath the B Pond system. Groundwater flow from the northern half of the divide flows generally northwest toward Gable Gap or northeast toward the Columbia River.	*Federal Facility Agreement and Consent Order Change Control Form C-93-06, Redesignation of the 200-BP-5 and 200-PO-1 Groundwater Operable Units and Reassignment of Associated Groundwater Investigations, Waste Management Units, and Unplanned Releases* (DOE et al., 1993)
1993	EPA was designated the lead regulatory agency for the 200-BP-5 OU in 1993, and it was agreed that groundwater OUs would be addressed as CERCLA past-practice units.	*Federal Facility Agreement and Consent Order Change Control Form C-93-06, Redesignation of the 200-BP-5 and 200-PO-1 Groundwater Operable Units and Reassignment of Associated Groundwater Investigations, Waste Management Units, and Unplanned Releases* (DOE et al., 1993)

Table 1-1. 200-BP-5 OU History of Major Technical Investigations and Regulatory Strategies

Year	Activity	Documentation
1993	The 200 East Area AAMS recommended that the strontium-90 concentrations at the 216-B-5 Reverse Well be considered for an expedited response action, following the rationale outlined in the Hanford Site past-practice strategy (DOE/RL-91-40). The cesium-137 and plutonium-239/240 concentrations at the 216-B-5 reverse well were identified as candidates for an interim response measure. All three contaminants were grouped for ease of treatment.	DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*
1993	The 200 East Area AAMS identified the cobalt-60, technetium-99, cyanide, and nitrate concentrations at the BY Cribs as candidates for an interim response measure, following the rationale outlined in the Hanford Site past-practice strategy (DOE/RL-91-40).	DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*
1993	The Tri-Parties agreed to enact the two recommendations in the 200 East Area groundwater AAMS for early action. The agreement required preparation of a treatability test plan by January 1994 and startup of pilot-scale pump-and-treat treatability test systems at each plume site by August 1994. The treatability tests, if successful, were to be the first step toward developing a full-scale interim remedial measure treatment system for each plume. The change agreement also specified that cobalt-60, cesium-137, plutonium-239/240, strontium-90, and technetium-99 would be the primary target contaminants; cyanide and nitrate were considered secondary contaminants of concern.	*Federal Facility Agreement and Consent Order Change Control Form M-13-93-03, 200 Area Groundwater Operable Units Scope Revision* (DOE et al., 1994)
1994 to 1995	Treatability testing began on August 29, 1994. Regular operations started on January 18, 1995, and were halted on May 29, 1995. One pilot-scale treatability test system was set up in proximity to the 216-B-5 Reverse Well because the associated plumes were believed to be confined around the well (i.e., the original waste disposal facility). Well 299-E28-23 was the extraction well, and Wells 299-E28-7 and 299-E28-25 served as injection wells. The other pilot-scale treatability test system was set up at the center of the plume that had migrated north from the BY Cribs toward Gable Gap. Well 699-50-53A was the extraction well, and Well 699-49-55A was the injection well. Ion-exchange technology was selected as the treatment technology for both 200-BP-5 OU pilot-scale treatability tests. Aquifer pumping at the 216-B-5 Reverse Well site easily provided substantial quantities of groundwater containing significant concentrations of cesium-137, strontium-90, and lesser quantities of plutonium-239/240 that had adsorbed to the sediments. The treatment system performed satisfactorily for removal of all three contaminants. However, it was recommended that the treatability test be discontinued because the future risks from these plumes were assessed to be low. Poor groundwater extraction rates at the BY Cribs plume site emphasized the large degree of uncertainty about plume geometry and aquifer characteristics. The treatment system performed	DOE/RL-95-59, *200-BP-5 Operable Unit Treatability Test Report*

Table 1-1. 200-BP-5 OU History of Major Technical Investigations and Regulatory Strategies

Year	Activity	Documentation
	satisfactorily for removal of cobalt-60 and technetium-99 contaminants. It was recommended that the treatability test be discontinued because of the poor extraction rates.	
2002	The field investigation for WMA B-BX-BY overlying the 200-BP-5 OU included a detailed evaluation of the soil and groundwater contamination near the tank farms. The investigation concluded that some of the groundwater contamination directly east of the BX Tank Farm was most likely due to releases from the BX Tank Farm.	RPP-10098, *Field Investigation Report for Waste Management Area B-BX-BY*
2004	The groundwater sampling and analysis requirements for the 200-BP-5 OU under CERCLA and the AEA were described in a SAP. The 200-BP-5 OU monitoring network consists of 91 monitoring wells. The plan identified specific contaminants to be analyzed, sampling frequency, sampling and analysis protocol, quality assurance and quality control requirements, groundwater-level monitoring, and data management requirements associated with groundwater monitoring of the 200-BP-5 OU. The text identified the revisions made in the monitoring network for the 200-BP-5 OU from the previous version of the document.	DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*
2001 to 2010	The groundwater sampling and analysis requirements for RCRA facilities overlying the 200-BP-5 OU were described in separate SAPs for each RCRA facility.	PNNL-13022, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area B-BX-BY at the Hanford Site* PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site* PNNL-14112, *Groundwater Monitoring Plan for the 216-B-63 Trench on the Hanford Site* RPP-21895, *241-C-103 and 241-C-109 Tanks Waste Retrieval Work Plan* WA78900089067, *Hanford Facility Resource Conservation and Recovery Act Permit*, Chapter 4, "Operating Unit 3, Liquid Effluent Retention Facility and 200 Area Effluent Treatment Facility"

Table 1-1. 200-BP-5 OU History of Major Technical Investigations and Regulatory Strategies

Year	Activity	Documentation
		DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*
2006	The RI for the 200-BP-5 OU was initiated in accordance with DOE/RL-2006-55, which is the SAP for drilling and sampling of the first three characterization wells.	DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/ Feasibility Study*
2007 to 2008	The RI/FS work plan for the 200-BP-5 OU was submitted in 2007 in support of Tri-Party Agreement Milestone (Ecology et al., 1989) M-013-06B, established in 2006 by Tri-Party Agreement Change Control Form M-013-06-01. The RI/FS work plan included the SAP for additional RI activities, including drilling 12 additional characterization wells.	DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*
2008 to 2009	The RI for the adjacent 200-PO-1 OU extended geophysical surveys into the area overlying 200-BP-5 OU.	DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*
2009	The RCRA facility investigation for WMA B-BX-BY overlying the 200-BP-5 OU included a detailed evaluation of the soil and groundwater contamination near the tank farms. The investigation concluded that waste from WMA B-BX-BY had impacted groundwater.	DOE/ORP-2008-01, *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas*
2010	The conceptual models for the B Complex were developed to evaluate which waste sites have been the significant sources of the contaminants in the groundwater. Based on existing data, conceptual models attribute the source of the cyanide and most of the technetium-99 currently in the groundwater to the BY Cribs, the source of the uranium to the 1951 241-BX-102 Tank overfill event, and the source of most of the chromium to the 216-B-7-A&B Cribs and the 216-B-8 Crib and Tile Field.	PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*
2010	The hydrogeologic conceptual model for the Gable Gap was updated (based on analysis of old and new geologic, hydrologic, and groundwater chemistry data) to evaluate groundwater and contaminant movement through this area.	PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*
2011	Planning for a perched water pumping/pore water extraction treatability test in WMA B-BX-BY were completed and extraction of contaminated perch water was initiated.	DOE/RL-2011-40, *Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test*

Table 1-1. 200-BP-5 OU History of Major Technical Investigations and Regulatory Strategies

Year	Activity	Documentation
		DOE/RL-2011-37, *Sampling and Analysis Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test*
2013	An evaluation of the perched water area under WMA B-BX-BY was completed and recommendations for a path forward for the perched water zone remediation were issued.	PNNL-22499, *Perched-Water Evaluation for the Deep Vadose Zone Beneath the B, BX, and BY Tank Farms Area of the Hanford Site* SGW-53604, *Path Forward Recommendations Report for the Uranium Contamination in the B Area*

AAMS = aggregate area management study
AEA = *Atomic Energy Act of 1954*
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CSM = conceptual site model
EPA = U.S. Environmental Protection Agency
FS = feasibility study
HHE = human health and the environment
NPL = National Priorities List
OU = operable unit
RCRA = *Resource Conservation and Recovery Act of 1976*
RI = remedial investigation
SAP = sampling and analysis plan
Tri-Party Agreement = *Hanford Federal Facility Agreement and Consent Order and Consent Order*
WMA = waste management area

More complete discussions regarding the area demography can be found in PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*; DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (HCP EIS); and USFWS, 2008, *Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement – Adams, Benton, Grant and Franklin Counties, Washington.*

1.2.5.3 Future Land Use

DOE worked for several years with cooperating agencies to define land-use goals for the Hanford Site. The cooperating agencies and stakeholders included the National Park Service, Tribal Nations, the states of Washington and Oregon, local county and city governments, economic and business development interests, environmental groups, and agricultural interests. Early efforts to develop land-use assumptions are described in Drummond, 1992, *The Future for Hanford: Uses and Cleanup: The Final Report of the Hanford Future Site Uses Working Group*, which recognized that the Central Plateau would be used for waste management activities for the foreseeable future. DOE then issued the HCP EIS (DOE/EIS-0222-F) in 1999, the associated ROD (64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)") in 1999, and a supplemental analysis (DOE/EIS-0222-SA-01, *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement*) in 2008.

The land use above the portion of the 200-BP-5 groundwater OU within the Inner Area is designated as industrial. The remainder of the land use above the 200-BP-5 groundwater OU is designated as preservation and conservation (mining) (DOE/EIS-0222-F). The goal for groundwater restoration is highest beneficial use.

1.3 Document Approach

This RI report consists of the following:

- **Chapter 1, Introduction:** Consists of purpose and scope for the RI report, and site background that describes the existing site knowledge.
- **Chapter 2, Study Area Investigation:** Describes the RI activities that were performed and summarizes the DQA.
- **Chapter 3, Physical Characteristics of the Study Area:** Describes the surface and subsurface features of the 200-BP-5 OU (surface features, meteorology, surface water hydrology, geology, hydrogeology, water use, and ecology).
- **Chapter 4, Nature and Extent of Contamination:** Discusses existing groundwater contamination and describes the waste sources overlying the 200-BP-5 OU.
- **Chapter 5, Contaminant Fate and Transport:** Describes the future movement and distribution of contaminants described in Chapter 4.
- **Chapter 6, Baseline Risk Assessment:** Evaluates the present or anticipated future impact to HHE from contaminants identified in the 200-BP-5 OU in the absence of a remedial action. The BRA contributes to the conceptual exposure portion of the CSM.
- **Chapter 7, Summary and Conclusions:** Provides a summary and conclusion from the RI.
- **Chapter 8, References:** Includes the references cited.

2 Study Area Investigation

The RI combined the results of previous studies and groundwater data collected in accordance with the 200-BP-5 RI/FS work plan (DOE/RL-2007-18). Previous data included groundwater analytical data and geological data from wells and boreholes. The 200-BP-5 RI/FS work plan identified additional information needed to provide an understanding of the nature and extent of contamination in the OU and to support a remedial alternative evaluation and remedy decision. The data needs and the investigation approach for the 200-BP-5 OU RI were developed through the data quality objective (DQO) process, which is summarized in WMP-28945. The RI tasks specified in the 200-BP-5 RI/FS work plan were completed as described in this chapter. This report also documents other routine and nonroutine activities that were conducted in the 200-BP-5 OU from November 30, 2004, through December 31, 2013. In addition, groundwater monitoring data collected during the 6-year period from January 1, 2008, through January 31, 2014, are also reported and were used in the BRA summarized in Chapter 6.

The results of RI activities are combined with previous studies to describe the physical characteristics of the study area (Chapter 3), to describe the nature and extent of contamination (Chapter 4), and to develop the exposure model presented in Chapter 6.

In this chapter, Section 2.1 describes the data needs, the data collected to fill the data needs, and the corresponding scope of work (including field activities, analyses, and data sources) that were completed for the RI. Section 2.2 describes the DQA that was conducted to evaluate whether the groundwater data collected for the 200-BP-5 OU are suitable for use in the BRA (Chapter 6).

2.1 Investigation Activities

The RI characterization activities were designed to obtain data and information to support the resolution of data gaps identified through the DQO process (WMP-28945; DOE/RL-2007-18, Chapter 3). The characterization activities were categorized into the following major tasks, which are also summarized in Table 2-1:

- Drilling and construction of new wells
- Sediment sampling (vadose zone and saturated zone)
- Depth-discrete groundwater sampling
- Hydrologic testing
- Geophysical investigations (surface and borehole methods)
- Groundwater monitoring of existing and new wells
- Supplemental investigations

The installation of 15 new wells was planned during the 200-BP-5 RI (DOE/RL-2007-18). Of these 15 wells, samples were to be collected from 7 wells to characterize the vadose zone in support of the 200-DV-1, 200-IS-1, and 200-EA-1 OUs; from 5 wells to characterize the unconfined aquifer; and from 3 wells to characterize the confined aquifer. The well locations were determined during the DQO process (WMP-28945). The primary rationale for each well location is summarized in Table 5-2 of the 200-BP-5 RI/FS work plan (DOE/RL-2007-18).

During the RI, 12 wells were constructed to monitor the unconfined aquifer, and 3 wells were constructed to monitor the confined aquifer, as planned (Table A3-1 in DOE/RL-2007-18). An additional well that was not anticipated during the DQO planning process was constructed to monitor a perched water zone.

Table 2-1. Status of RI Tasks for the 200-BP-5 OU

Task	Requirement in 200-BP-5 RI/FS Work Plan (DOE/RL-2007-18)	Status
Drilling and construction of new wells	Install 15 new wells (DOE/RL-2007-18, Table 5-1 and Figure A1-1 for location; DOE/RL-2007-18, Table 5-2 for rationale).	16* wells installed (discussed in Section 2.1 and Table 2-2 of this document).
Sediment sampling during drilling (vadose zone)	Collect sediment samples in the vadose zone during drilling of 15 new wells (DOE/RL-2007-18, Table 5-3 and Tables A3-2 through A3-10; DOE/RL-2006-55, Tables 3-1, 3-2, and 3-3).	Sediment samples were collected in the vadose zone during drilling of all 16* of the new wells (discussed in Section 2.1.9 and Table 2-6 of this document). Chemical data are provided in Appendix B.
Sediment sampling during drilling (saturated zone)	Collect sediment samples in the saturated zone during drilling of 15 new wells (DOE/RL-2007-18, Table 5-4 and Tables A3-2 through A3-10; DOE/RL-2006-55, Tables 3-1, 3-2, and 3-3).	Sediment samples were collected in the saturated zone during drilling of all 16* of the new wells (discussed in Section 2.1.9 and Table 2-6 of this document). Chemical data are provided in Appendix B.
Groundwater sampling during drilling	Collect groundwater samples during drilling of 15 new wells (DOE/RL-2007-18, Table 5-5 and Tables A3-2 through A3-10; DOE/RL-2006-55, Table 3-4).	Groundwater samples were collected, when possible, during drilling of 16* new wells. Not all planned groundwater samples were collected because of field conditions (discussed in Section 2.1.10 and Table 2-7 of this document). The data are provided in Appendix B.
Hydrologic testing	Conduct hydrologic testing after drilling of 15 new wells and selected existing wells (DOE/RL-2007-18, Tables 5-6 and A3-14).	Hydrologic testing was performed after installation of each of the 15 new wells completed in the unconfined or confined aquifer; several tests could not be completed because of field conditions (discussed in Section 2.1.10 and Table 2-8 of this document).
Geophysical investigations (surface methods)	Conduct surface-based geophysical investigations (HRR) in the vicinity of the B-BX-BY Tank Farms and C Tank Farm (DOE/RL-2007-18, Table 5-7).	Investigations using HRR were planned for the vicinities of the B-BX-BY Tank Farms and C Tank Farm by ORP to support vadose zone characterization of the tank farms. The HRR survey of B-BX-BY Tank Farms was completed in 2007 (RPP-34690). Additional evaluation of those data was completed in 2013 (PNNL-22520). An HRR survey of UPR-200-E-81 near C Tank Farm was completed in 2009 (RPP-RPT-41236).
Geophysical investigations (borehole methods)	Conduct borehole-based geophysical investigations during the drilling of 15 new wells (DOE/RL-2007-18, Table 5-7).	All 16* of the new boreholes were logged using the spectral gamma logging tool and the neutron moisture logging tool during drilling, as planned (discussed in Section 2.1.8 of this document).

Table 2-1. Status of RI Tasks for the 200-BP-5 OU

Task	Requirement in 200-BP-5 RI/FS Work Plan (DOE/RL-2007-18)	Status
Groundwater monitoring of existing and new wells	Monitor existing wells in accordance with DOE/RL-2001-49; add the 15 new wells to the groundwater monitoring network as each is completed (DOE/RL-2007-18, Section 5.5).	Groundwater monitoring was conducted as planned (discussed in Section 2.1.10 of this document).
Supplemental investigations.	Consider using supplemental data derived from other groundwater and vadose zone investigations performed onsite pursuant to projects under requirements for CERCLA, RCRA, and DOE O 435.1 (DOE/RL-2007-18, Section 5.6).	Groundwater data collected under the RCRA groundwater monitoring program were used to develop the contaminants of potential concern, to develop the risk assessment, and to refine the CSM (discussed in Chapters 4, 5, and 6 of this document). The 200-PO-1 geophysical survey results (DOE/RL-2009-85) were used for refinement of the CSM and development of the fate and transport model (discussed in Section 2.1.8 of this document). The CTUIR geophysical survey results (SGW-43746) were used for refinement of the CSM and development of the fate and transport model (discussed in Section 2.1.8 of this document). Water-level measurements were used to determine groundwater movement and hydraulic gradient (discussed in Section 2.1.10 of this document). Aquifer tube sampling results were used as supplemental information (discussed in Section 2.1.7 of this document).
Data evaluation	Evaluate data before using the data to update CSM and before incorporating the data into the BRA (DOE/RL-2007-18, Section 5.6).	The DQA (SGW-44071) was completed (discussed in Section 2.2 in this document).
Groundwater modeling	Conduct numerical modeling to simulate groundwater flow and contaminant transport to support the development and evaluation of remedial alternatives (DOE/RL-2007-18, Section 5.7).	Numerical modeling in support of the BRA was completed (discussed in Chapter 5 of this document).

Table 2-1. Status of RI Tasks for the 200-BP-5 OU

Task	Requirement in 200-BP-5 RI/FS Work Plan (DOE/RL-2007-18)	Status

Sources:

DOE O 435.1 Chg 1, *Radioactive Waste Management*.

DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*.

DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*.

DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*.

PNNL-22520, *Re-inversion of Surface Electrical Resistivity Tomography Data from the Hanford Site B-Complex*.

RPP-34690, *Surface Geophysical Exploration of the B, BX, and BY Tank Farms at the Hanford Site*.

RPP-RPT-41236, *Surface Geophysical Exploration of UPR-200-E-81 Near the C Tank Farm*.

SGW-43746, *Landstreamer/Gimbaled GeoPhone Acquisition of High Resolution Seismic Reflection Data North of the 200 Areas – Hanford Site*.

SGW-44071, *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit*.

* Fifteen wells were installed as planned; one well was added based on unanticipated conditions (perched water) encountered during drilling and completed as a perched water monitoring well.

BRA = baseline risk assessment
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CSM = conceptual site model
CTUIR = Confederated Tribes of the Umatilla Indian Reservation
DOE = U.S. Department of Energy
DQA = data quality assessment
HRR = high-resolution resistivity
ORP = DOE, Office of River Protection
RCRA = *Resource Conservation and Recovery Act of 1976*
UPR = unplanned release
WMA = waste management area

Based on the conditions encountered during drilling, DOE, EPA, and Ecology agreed that the initial well drilled at this location would be completed to monitor this perched water zone, and a replacement well would be drilled in the same approximate location to monitor the unconfined aquifer (FH-0800228, "Distribution Unit Managers' Meeting, 200 Area Groundwater Source Operable Units," Attachment 3, "Issue Resolution Meeting Agreements and Issues List") in accordance with the 200-BP-5 RI/FS work plan (DOE/RL-2007-18).

During planning, each well was temporarily designated by a letter identifier (i.e., "A" through "O"). During drilling and construction, each well was assigned a permanent well identification number (e.g., C5858) and well name (e.g., 299-E33-343). Table 2-2 provides a crosswalk of the temporary letters and the permanent well identification numbers and well names.

Table 2-2. Installation Data for the 200-BP-5 OU RI Wells

Well Designation Letter[a]	Well Name	Well ID Number	Dates Drilled		Monitoring Zone	Total Depth Drilled (m [ft]) bgs	Screened Interval (m [ft]) bgs		Ground Surface Elevation[b] (m [ft])	Coordinates[c] (m)	
			Start Drilling	Finish Drilling			Top	Bottom		Northing	Easting
A	299-E33-343	C5858	01/15/2008	03/10/2008	Unconfined aquifer	80.4 (263.8)	76.2 (249.9)	79.2 (259.9)	198.823 (652.306)	137382.25	573743.98
B[d]	299-E33-344	C5859	12/17/2007	01/23/2008	Perched water	73.8 (242.1)	66.4 (217.9)	72.3 (237.09)	199.139 (653.343)	137387.31	573782.91
B[d]	299-E33-345	C6226	01/24/2008	04/04/2008	Unconfined aquifer	80.4 (263.8)	76.1 (249.68)	79.2 (259.68)	199.095 (653.199)	137388.24	573780.87
C	299-E33-205	C5989	04/30/2008	08/21/2008	Unconfined aquifer	82.5 (270.6)	78.5 (257.5)	81.5 (267.5)	200.322 (657.224)	137406.22	573633.38
D	299-E33-341	C5856	04/28/2008	06/09/2008	Unconfined aquifer	72.2 (237.0)	68.0 (222.98)	70.7 (232.07)	191.254 (627.474)	137652.50	573565.21
E	299-E33-342	C5857	03/12/2008	04/23/2008	Unconfined aquifer	74.8 (245.5)	70.9 (232.6)	70.9 (232.6)	194.135 (636.926)	137579.96	573625.68
F	299-E33-50	C5195	12/28/2006	03/29/2007	Confined aquifer	116.1 (381.0)	96.3 (316.1)	100.9 (331.1)	190.742 (625.794)	137599.30	573773.61
G	299-E33-340	C5853	04/09/2008	10/13/2008	Confined aquifer	109.4 (358.85)	93.9 (308.18)	98.5 (323.17)	188.340 (617.913)	137763.84	573779.64
H	699-52-55B	C5862	06/12/2008	08/21/2008	Confined aquifer	89 (292)	69.6 (228.46)	74.2 (243.46)	174.854 (573.668)	139440.66	573102.17
I	699-48-50B	C5196	10/25/2006	12/05/2006	Unconfined aquifer	65.6 (215.2)	62.2 (204.2)	65.4 (214.5)	185.562 (608.799)	138044.28	573334.48
J	699-50-56	C5197	10/15/2006	12/15/2006	Unconfined aquifer	50.0 (164.1)	46.1 (151.2)	49.1 (161.2)	168.178 (551.765)	138841.55	572748.21

Table 2-2. Installation Data for the 200-BP-5 OU RI Wells

Well Designation Letter[a]	Well Name	Well ID Number	Dates Drilled		Monitoring Zone	Total Depth Drilled (m [ft]) bgs	Screened Interval (m [ft]) bgs		Ground Surface Elevation[b] (m [ft])	Coordinates[c] (m)	
			Start Drilling	Finish Drilling			Top	Bottom		Northing	Easting
K	299-E29-54	C5860	11/18/2009	02/08/2010	Unconfined aquifer	114.4 (375.2)	91.4 (299.9)	97.5 (319.8)	214.77 (704.626)	136403.12	573467.15
L	299-E24-25	C7514	11/09/2009	01/08/2010	Unconfined aquifer	110.3 (361.9)	87.2 (286.04)	93.3 (306.04)	209.632 (687.769)	136287.23	574598.56
M	299-E28-30	C7515	01/12/2010	02/24/2010	Unconfined aquifer	114.5 (375.6)	91.7 (301)	97.8 (321)	215.062 (705.584)	136550.79	573140.34
N	699-52-55	C5861	11/20/2007	01/22/2008	Unconfined aquifer	55.9 (183.32)	51.8 (169.8)	54.8 (179.8)	174.958 (574.009)	139443.20	573102.44
O	299-E27-155	C5852	09/26/2007	11/13/2007	Unconfined aquifer	103.6 (340)	91.6 (300.46)	102.2 (335.46)	207.680 (681.365)	136429.08	575003.11

a. Well designation letters are as shown in Appendix A of DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

b. Elevation of brass survey marker (NAVD88, *North American Vertical Datum of 1988*); values are rounded to the nearest 0.001 m.

c. Northing and easting coordinates are based on Washington State Plane Coordinates NAD83, *North American Datum of 1983*, rounded to the nearest 0.01 m.

d. Well 299-E33-344 (C5859) was completed to monitor a perched water zone, and replacement Well 299-E33-345 (C6226) was drilled in the same approximate location to monitor the unconfined aquifer.

bgs = below ground surface

ID = identification

Two sampling and analysis plans (SAPs) were prepared to provide details regarding sample collection methods, sample types, sample depths, and sample analytical methods for each well. One SAP (DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*) was prepared and approved prior to completion of the 200-BP-5 RI/FS work plan (DOE/RL-2007-18) to allow initiation of drilling of the first three wells. The second SAP (DOE/RL-2007-18, Appendix A) was prepared and approved as part of the 200-BP-5 RI/FS work plan to provide details for the other RI activities. Table 2-3 shows the SAP associated with each new well. Table 2-3 also shows the borehole summary report prepared for each new well after drilling and construction to document field activities. Figure 2-1 provides a map of the installed well locations.

The activities conducted within the 200-BP-5 OU as part of the RI primarily consisted of geological and geophysical investigations, soil and vadose zone investigations, and groundwater investigations (Sections 2.1.8, 2.1.9, and 2.1.10, respectively).

2.1.1 Historical Information Review

No reviews of historical information were planned or conducted during the RI for the 200-BP-5 OU. An extensive review of historical information was conducted as part of the DQO process and is documented in WMP-28945. A historical information review was also conducted during preparation of the conceptual model for the B Complex and is documented in PNNL-19277. An updated version of the annotated bibliography is presented in Appendix A.

2.1.2 Surface Features

No investigations of surface features were planned or conducted during the RI for the 200-BP-5 OU. Surface features are discussed in Section 3.1.

2.1.3 Contaminant Source Investigations

No specific investigations of contaminant sources were planned or conducted during the RI for the 200-BP-5 OU. Opportunistic samples from seven 200-BP-5 OU boreholes were collected for the 200-DV-1, 200-IS-1, and 200-EA-1 Vadose Zone OUs (SGW-46352, *Data Quality Assessment Report for Vadose Zone Samples Collected During Drilling of Wells 299-E24-25, 299-E28-30, 299-E29-54, 299-E33-205, 299-E33-342, 299-E33-343, and 299-E33-344 in the 200 East Area*). An extensive review of contaminant sources was conducted as part of the DQO process and is documented in the DQO summary report (WMP-28945) and the 200-BP-5 RI/FS work plan (DOE/RL-2007-18). Additional evaluation of contaminant sources was conducted during conceptual model development for the B Complex (PNNL-19277). A summary of contaminant source information is discussed in Section 4.2 of this RI report.

2.1.4 Land and Water Use Surveys

No surveys of land and water use were planned or conducted during the RI for the 200-BP-5 OU. The land uses for the areas overlying the OU are discussed in Section 1.2.5. The water uses for the OU are discussed in Section 3.7.

2.1.5 Meteorological Investigations

No meteorological investigations were planned or conducted during the RI for the 200-BP-5 OU. Meteorology is discussed in Section 3.2.

2.1.6 Air Investigations

No air investigations were planned or conducted during the RI for the 200-BP-5 OU.

Table 2-3. Documentation Associated with Each Well Installed during the RI for the 200-BP-5 OU

Well Designation Letter*	Well Name	Well ID Number	Sampling and Analysis Plan	Borehole Summary Report	DQO Report for Investigation-Derived Waste	Description of Work	Geophysical Log Data Report
A	299-E33-343	C5858	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-195, Rev. 0
B	299-E33-344	C5859	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-197, Rev. 0
B	299-E33-345	C6226	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-196, Rev. 0
C	299-E33-205	C5989	DOE/RL-2007-18, Appendix A	SGW-39496	RPP-ENV-3720	SGW-38871	HGLP-LDR-237, Rev. 0
D	299-E33-341	C5856	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-244, Rev. 0
E	299-E33-342	C5857	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-225, Rev. 0
F	299-E33-50	C5195	DOE/RL-2006-55	SGW-34034	WMP-31431	WMP-30726	HGLP-LDR-066, Rev. 0
G	299-E33-340	C5853	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-271, Rev. 0
H	699-52-55B	C5862	DOE/RL-2007-18, Appendix A	SGW-39626	SGW-35168	SGW-35017	HGLP-LDR-329, Rev. 0
I	699-48-50B	C5196	DOE/RL-2006-55	SGW-34034	WMP-31431	WMP-30726	HGLP-LDR-027, Rev. 0
J	699-50-56	C5197	DOE/RL-2006-55	SGW-34034	WMP-31431	WMP-30726	HGLP-LDR-049, Rev. 0
K	299-E29-54	C5860	DOE/RL-2007-18, Appendix A	SGW-46869	SGW-36277	SGW-35161, SGW-42227	HGLP-LDR-450, Rev. 0

Table 2-3. Documentation Associated with Each Well Installed during the RI for the 200-BP-5 OU

Well Designation Letter*	Well Name	Well ID Number	Sampling and Analysis Plan	Borehole Summary Report	DQO Report for Investigation-Derived Waste	Description of Work	Geophysical Log Data Report
L	299-E24-25	C7514	DOE/RL-2007-18, Appendix A	SGW-46869	SGW-42680	SGW-42669	HGLP-LDR-421, Rev. 0
M	299-E28-30	C7515	DOE/RL-2007-18, Appendix A	SGW-46869	SGW-42680	SGW-42669	HGLP-LDR-436, Rev. 0
N	699-52-55	C5861	DOE/RL-2007-18, Appendix A	SGW-37834	SGW-34748	SGW-34422	HGLP-LDR-201, Rev. 0
O	299-E27-155	C5852	DOE/RL-2007-18, Appendix A	SGW-37834	SGW-34748	SGW-34422	HGLP-LDR-101, Rev. 0

Sources:

DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*.

DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

HGLP-LDR-027, *699-48-50B (C5196) Log Data Report*.

HGLP-LDR-049, *699-50-56 (C5197) Log Data Report*.

HGLP-LDR-066, *299-E33-50 (C5195) Log Data Report*.

HGLP-LDR-101, *299-E27-155 (C5852) Log Data Report*.

HGLP-LDR-195, *299-E33-343 (C5858) Log Data Report*.

HGLP-LDR-196, *299-E33-345 (C6226) Log Data Report*.

HGLP-LDR-197, *299-E33-344 (C5859) Log Data Report*.

HGLP-LDR-201, *699-52-55A (C5861) Log Data Report*.

HGLP-LDR-225, *299-E33-342 (C5857) Log Data Report*.

HGLP-LDR-237, *299-E33-205 (C5989) Log Data Report*.

HGLP-LDR-244, *299-E33-341 (C5856) Log Data Report*.

HGLP-LDR-271, *299-E33-340 (C5853) Log Data Report*.

HGLP-LDR-329, *699-52-55B (C5862) Log Data Report*.

HGLP-LDR-421, *299-E24-25 (C7514) Log Data Report*.

HGLP-LDR-436, *299-E28-30 (C7515) Log Data Report*.

Table 2-3. Documentation Associated with Each Well Installed during the RI for the 200-BP-5 OU

Well Designation Letter*	Well Name	Well ID Number	Sampling and Analysis Plan	Borehole Summary Report	DQO Report for Investigation-Derived Waste	Description of Work	Geophysical Log Data Report

HGLP-LDR-450, *299-E29-54 (C5860) Log Data Report*.

RPP-ENV-3720, *Data Quality Objective Summary Report for the Waste Characterization of Well C5989 in the 200-BP-5 Operable Unit*.

SGW-34034, *Borehole Summary Report for the Installation of Three Groundwater Wells in the 200-BP-5 Operable Unit, FY 2007*.

SGW-34422, *Description of Work for Calendar Year 2007 Installation of Two Groundwater Wells (299-E27-155, and 699-52-55A) at the 200-BP-5 Operable Unit*.

SGW-34748, *Data Quality Objectives Summary Report for the Installation of Wells C5852 and C5861 in the 200-BP-5 Operable Unit*.

SGW-35017, *Description of Work for FY2008 Installation of Seven Groundwater Wells at the BP-5 Operable Unit*.

SGW-35161, *Description of Work for the Installation of Groundwater Well (299-E29-54) at the 200-BP-5 Operable Unit*.

SGW-35168, *Data Quality Objective Summary Report for FY 2008 Installation of Six Groundwater Monitoring Wells in the 200-BP-5 Operable Unit*.

SGW-36277, *Waste Management Data Quality Objectives Summary Report for the Drilling of Well C5860 in the 200-BP-5 Operable Unit*.

SGW-37834, *Borehole Summary Report for the Installation of Two Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2007*.

SGW-38871, *Description of Work for FY2008 Installation of Well C5989 at the BP-5 Operable Unit*.

SGW-39496, *Borehole Summary Report for the Installation of One Groundwater Monitoring Well at the 200-BP-5 Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

SGW-42227, *ARRA Description of Work for the Installation of One Well at 200-BP-5 Operable Unit*.

SGW-42669, *Description of Work for FY2009 Installation of Two Groundwater Monitoring Wells at the 200-BP-5 Operable Unit*.

SGW-42680, *Data Quality Objective Summary Report for the Drilling of Wells C7514 and C7515 in the 200-BP-5 Operable Unit*.

SGW-46869, *Borehole Summary Report for the Three (3) 200-BP-5 Wells, "K", "L", and "M," Fiscal Year 2010*.

WMP-30726, *Description of Work for Fiscal Year 2006 Installation of Three Wells (299-E33-50, 699-48-50B, and 699-50-56) at the 200-BP-5 Groundwater Operable Unit*.

WMP-31431, *Data Quality Objective Summary Report for the Installation of Wells C5195, C5196 and C5197 in the 200-BP-5 Operable Unit*.

* Well designation letters are as shown in Appendix A of DOE/RL-2007-18.

DQO = data quality objective

ID = identification

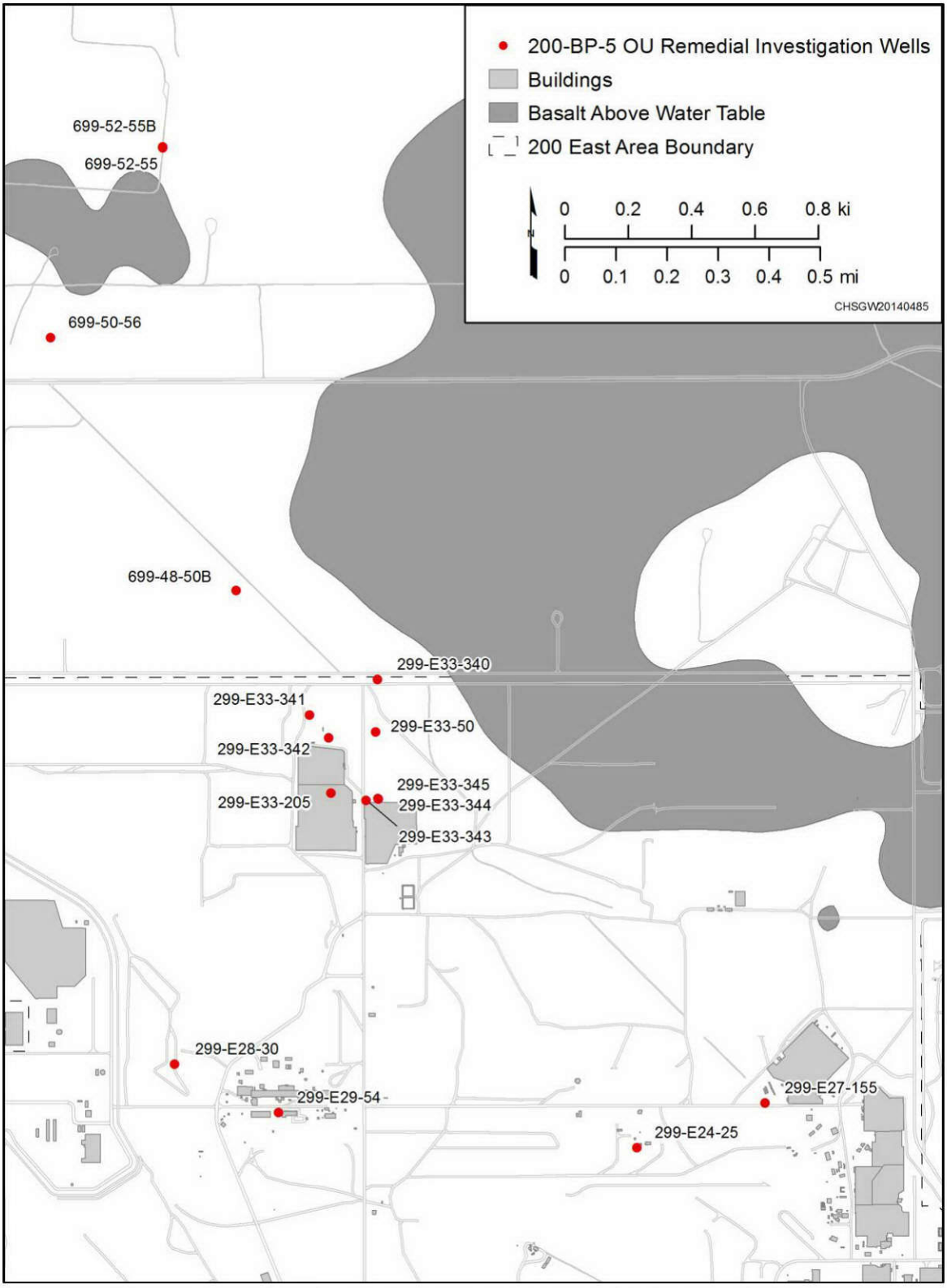

Figure 2-1. Location of New Wells Installed during the RI for the 200-BP-5 OU

2.1.7 Surface Water and Sediment Investigations

No investigations of surface water bodies, or sediment associated with surface water bodies, were planned or conducted during the RI for the 200-BP-5 OU.

Aquifer tube sampling is conducted annually along the river shore segment of the 200-BP-5 OU in accordance with DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*. These aquifer tubes are associated with either the 100-BC-5 OU or 100-KR-4 OU (Table 2-4). The samples collected from these aquifer tubes for the past 6 years were used to provide supplemental information for the 200-BP-5 OU.

Table 2-4. Aquifer Tubes Sampled along the Columbia River Shore Segment of the 200-BP-5 OU

Well Name	Well ID Number	Well Type	Shore Segment in DOE/RL-2000-59	Groundwater Area of Interest
12-D	B8146	Aquifer tube	BC5	200-BP-5
14-D	B8152	Aquifer tube	KR4	200-BP-5
C6236	C6236	Aquifer tube	KR4	200-BP-5
C6237	C6237	Aquifer tube	KR4	200-BP-5
C6238	C6238	Aquifer tube	KR4	200-BP-5

Source: DOE/RL-2000-59, *Sampling and Analysis Plan for Aquifer Sampling Tubes*.
ID = identification

2.1.8 Geological and Geophysical Investigations

Geological investigations were conducted as planned during the RI for the 200-BP-5 OU. Table 2-5 presents a summary of the data collected.

The geological data were used to refine the understanding of the configuration of the unconfined and confined aquifer systems, which influence groundwater flow directions and rates, as well as associated contaminant migration (presented in Chapter 3 and Appendix C). The geological data were also used to support numerical flow and transport calculations (presented in Chapter 5 and Appendix D).

Geological data were collected during the RI for the adjacent 200-PO-1 OU using geophysical survey techniques (DOE/RL-2009-85). The seismic reflection surveys and check shot surveys conducted for the 200-PO-1 OU also collected geological data within the 200-BP-5 OU (SGW-39675, *Reflection Seismic Survey Report, 200 East Area, Hanford Site*; SGW-39676, *Check Shot Survey Summary Report, 200 East Area, Hanford Site – Fiscal Year 2008*, respectively). Seismic reflection data were also collected within the 200-BP-5 OU by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) as a technology demonstration test for DOE (SGW-43746, *Landstreamer and Gimbaled GeoPhone Acquisition of High Resolution Seismic Reflection Data North of the 200 Areas – Hanford Site)*. Additional seismic information was collected by the CTUIR in 2011 (SGW-52160, *Landstreamer and Gimbaled Geophones Phase II – 200 Areas: A High Resolution Seismic Reflection Survey at the Hanford Site*).

Table 2-5. Geological Investigations Conducted during the RI for the 200-BP-5 OU

Geological Investigation	Types of Data Collected	Objectives for Collecting Data	Data Documentation
Geology at each new borehole location (DOE/RL-2007-18, Section 5.2.1)	Description of stratigraphy of sediments. Identification of contact depths for significant changes in lithology and key stratigraphic units. Identification of depths and thicknesses of low-permeability units and other features that might influence vertical and lateral spreading of contaminants. Identification of depth to top of basalt. Photographs of lithology every 1.5 m (5 ft) in each new borehole.	Refine the CSM of potential stratigraphic influences on contaminant migration. Support development of physical model configuration for numerical transport calculations.	The borehole log for each new borehole records the geologic information observed at each location. The borehole logs are provided in the borehole summary reports (Table 2-3). The photographs of lithology are provided in the borehole summary reports (Table 2-3). The geologic contacts information was added to the Hanford data set of geologic contacts.[a] The locations of the new boreholes are shown in Figure 2-1.
Geology at each new borehole location (DOE/RL-2007-18, Table 5-3)	Grab samples collected every 1.5 m (5 ft) and at major changes in lithology at each new borehole.	Maintain archive samples of lithology from each new borehole.	The grab samples are stored at the sample archive storage building.
Borehole geophysical logging at each new borehole location (DOE/RL-2007-18, Table 5-7)	Identification of naturally occurring and gamma-emitting radionuclides using spectral gamma logging and neutron moisture logging.	Support identification of contacts depths for significant changes in lithology.	The borehole geophysical log data reports are available for the RI wells as shown in Table 2-3. The locations of the new boreholes are shown in Figure 2-1.
Seismic reflection data in the 200 East Area (collected as part of the 200-PO-1 RI)	Seismic reflection data along north-south and east-west profiles.	Evaluate configuration of basalt surface underlying the 200 East Area to identify potential channels, faults, or other hydrogeologic features that may impact groundwater pathways controlling migration.	SGW-39675, DOE/RL-2009-85 The locations of the seismic reflection lines are shown in DOE/RL-2009-85, Figure 2-15.
Geophysical check shot data underneath the 200 East Area (collected as part of the 200-PO-1 RI)	Check shot seismic velocity surveys in five wells in the 200 East Area. Four of the wells surveyed are in the 200-BP-5 OU: 299-E32-10, 299-E34-7, 299-E28-6, and 299-E26-8.	Provide time-depth correlation information to aid the interpretation of the acquired seismic reflection data.	SGW-39676, DOE/RL-2009-85 The locations of the wells used for check shot surveys are shown in SGW-39676, Figure 1.

Table 2-5. Geological Investigations Conducted during the RI for the 200-BP-5 OU

Geological Investigation	Types of Data Collected	Objectives for Collecting Data	Data Documentation
High-resolution, seismic reflection data north of the 200 East Area (collected by the Confederated Tribes of the Umatilla Indian Reservation)	Seismic reflection data along eight seismic profiles.	Evaluate the potential for preferred vertical and horizontal pathways for mobile contaminants in the deep vadose zone and groundwater intervals. Demonstrate the feasibility of using a landstreamer[b] and gimbaled geophone acquisition approach to collect high-resolution seismic reflection data. Use the resulting information to compare the landstreamer and gimbaled geophone approach to recently acquired data in the 200 East Area using conventional spiked geophones.	SGW-43746 The locations of the seismic reflection profiles are shown in SGW-43746, Figure 3.1-1.

Sources:

DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*.

SGW-39675, *Reflection Seismic Survey Report, 200 East Area, Hanford Site*.

SGW-43746, *Landstreamer/Gimbaled GeoPhone Acquisition of High Resolution Seismic Reflection Data North of the 200 Areas – Hanford Site*.

a. The Hanford data set of geologic contacts is managed by Pacific Northwest National Laboratory. The data set indicates, for a given well, the depth to the top and bottom of each lithologic unit; the data is not formally published.

b. A landstreamer is a multichannel seismic cable designed to be pulled behind a vehicle.

CSM = conceptual site model

OU = operable unit

RI = remedial investigation

The objective of the seismic reflection surveys was to evaluate the feasibility of integrating seismic data and existing geologic data to improve the hydrogeologic conceptual model and to improve model confidence for the area. The design criteria for these surveys included imaging subsurface acoustic interfaces, between 23 and 305 m (75 and 1,000 ft) below ground surface (bgs), primarily to image the top of the basalt.

During fiscal year (FY) 2009, high-resolution seismic reflection surveys were acquired within the Gable Gap area north of the 200 East Area to help address data gaps regarding the presence or absence of potential channels, faults, or other hydrogeologic features that may control groundwater contaminant migration. Previously collected seismic data from the 200-BP-5 OU were used to augment the new surveys and to ensure a consistent, sitewide interpretation. The combined geophysical data set was used

to address data gaps for both the near-field and far-field areas of the 200-BP-5 OU and to refine construction of a top of basalt surface structural relief map.

Approximately 23 km (14.3 mi) of seismic reflection profiling was conducted during FY 2009 and FY 2011 in the Gable Gap area and north 200 East Areas using a seismic landstreamer. The design criteria included imaging top of basalt, as well as suprabasalt sedimentary interfaces within the upper 150 m (500 ft) bgs. Acquisition details and preliminary results are presented in SGW-43746.

Auxiliary information used to tie the seismic data to the underlying geology consisted of check shot seismic velocity surveying, sonic logs, and geologic information from wells adjacent to the profiles. Check shot surveys were conducted during FY 2007 for the Waste Treatment Plant design (PNNL-16559, *Downhole Measurements of Shear- and Compressional-Wave Velocities in Boreholes C4933, C4996, C4997 and C4998 at the Waste Treatment Plant DOE Hanford Site*; PNNL-16652, *Site-Specific Velocity and Density Model for the Waste Treatment Plant, Hanford, Washington*), in FY 2008 to support 200-PO-1 OU investigations (SGW-39676; SGW-42313, *Geophysical Investigations: 200-PO-1 Groundwater Operable Unit*), and in FY 2009 to support both the landstreamer surveys and 200-PO-1 OU investigation (SGW-42313). Sonic logs were acquired to support the Basalt Waste Isolation Project (BWIP) investigations. Seven check shot surveys and one sonic log were used to interpret the seismic data in the Gable Gap area and north 200 East Area. The locations of the check shot surveys are shown in Figure 1 in SGW-39676.

Seismic reflection data were used to revise and update the top of basalt surface map beneath Gable Gap and the northern 200 East Area but did not positively delineate the suprabasalt sediments. Basalt elevations derived from the seismic data are incorporated into the basalt topography map (Section 3.6). Seismic information was also used to help construct the geologic and hydrogeologic cross sections presented in Chapter 3. Results of the geophysical surveys for the 200-BP-5 OU are provided in SGW-48478, *Interpretation and Integration of Seismic Data in the Gable Gap.*

The complete catalog of available geological formation contact information through December 4, 2009, was used to populate a database in the Schlumberger[1] HydroGeo Analyst data management system, which includes subsurface characterization, mapping, and three-dimensional visualization (ECF-200BP5-10-0344, *Geologic Data Package: 200-BP-5 Hydrostratigraphic Database Development*). Well data in the 200 Areas geologic tops database were used to develop the geologic maps and cross sections that are discussed in Chapters 3, 4, and 5.

2.1.9 Soil and Vadose Zone Investigations

Soil and vadose zone investigations were conducted during the RI for the 200-BP-5 OU and were integrated with Central Plateau vadose zone OUs (DOE/RL-2007-02, *Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Unit, Volume I: Work Plan and Appendices*). Sediment grab samples were collected every 1.5 m (5 ft) for geologic archiving (Table 2-5). Sediment grab and split-spoon samples were collected from key strata in selected wells to evaluate the physical and geochemical properties in order to improve the reliability of modeling in support of the BRA and remedial design (DOE/RL-2007-18, Table 5-3). Samples also were analyzed to assess the nature and extent of COPCs in the sediment. Table A1-1 in the SAP (DOE/RL-2007-18, Appendix A) lists the initial COPCs for sample planning for the vadose zone. Table A1-3 in the SAP (DOE/RL-2007-18, Appendix A) lists the initial COPCs for sample planning for the saturated zone.

[1] Schlumberger© is a copyright name of Schlumberger Water Services, Waterloo, Ontario, Canada.

Vadose zone grab and split-spoon samples from seven of the 200-BP-5 OU RI wells were collected and analyzed in support of ongoing characterization activities for the RI/FS process for the 200-DV-1, 200-EA-1, and 200-IS-1 OUs. A DQA was conducted for the vadose zone samples from these wells and is documented in SGW-46352.

Sediment grab and split-spoon samples were collected from key strata in selected wells within the saturated zone (DOE/RL-2007-18, Table 5-4). Saturated zone sampling requirements typically began at the historical high water table elevation.

The sample collection strategy was designed to collect a comprehensive suite of samples. As planned, only a subset of the samples collected was analyzed (DOE/RL-2007-18, Section A3.3). The selection of samples for analysis was based on sample recovery, sediment type, field screening results, borehole geophysical profiles, and preliminary contaminant concentrations. Unused samples were retained for possible future analysis or disposal. The analyses will be considered during evaluation of the vadose zone in the RI reports for the source OUs.

Table 2-6 presents a summary of the sediment samples from the vadose zone and saturated zone that were analyzed for the initial list of COPCs developed for planning. One less sample was collected from Boreholes C5853 and C5859/C6226 because basalt was encountered at a shallower depth than expected. Analytical data are provided in Appendix B.

The DOE Office of River Protection (ORP) conducted investigations using high-resolution resistivity (HRR) in the vicinities of the B-BX-BY Tank Farms and C Tank Farm, which supported vadose zone characterization of the tank farms (DOE/RL-2007-18, Table 5-7). The HRR geophysical technology measures the electrical resistance of the vadose zone soils. A resistivity contrast indicates a change in soil geochemistry that is potentially caused by a change in the concentration of a contaminant such as nitrate. These investigations were included in the 200-BP-5 RI/FS work plan (DOE/RL-2007-18) because the results could be used to refine the CSM for the nature and extent of contamination in the vadose zone overlying the 200-BP-5 OU. The HRR survey of the B-BX-BY Tank Farms was completed in 2007 (RPP-34690, *Surface Geophysical Exploration of the B, BX, and BY Tank Farms at the Hanford Site*). A re-evaluation of the data was completed in 2013 (PNNL-22520, *Re-inversion of Surface Electrical Resistivity Tomography Data from the Hanford Site B-Complex*). An HRR survey of UPR-200-E-81 near the C Tank Farm was completed in 2009 (RPP-RPT-41236, *Surface Geophysical Exploration of UPR-200-E-81 Near the C Tank Farm*).

2.1.10 Groundwater Investigations

Groundwater sampling was conducted as planned during the drilling of nine of the wells for the 200-BP-5 OU RI (DOE/RL-2007-18, Table 5-5). Unanticipated field conditions encountered during drilling of the remaining wells resulted in fewer sample intervals being collected (Table 2-7). Groundwater samples were collected from November 2006 through February 2010 during drilling of the new RI wells to assess the lateral and vertical distribution (where sufficient aquifer thickness occurred) of COPCs. Additional groundwater sampling results collected from 200-BP-5 OU wells available as of January 2014 are provided in Appendix B. Table A1-3 in the SAP (DOE/RL-2007-18, Appendix A) lists the initial COPCs for sample planning for the saturated zone. Table 2-7 summarizes the depth-discrete groundwater samples collected from the unconfined aquifer and from the confined aquifer during drilling of the new RI wells.

Table 2-6. Sediment Split-Spoon Samples from New Wells during the RI for the 200-BP-5 OU

Objectives for Collecting Data[a]	Borehole	Number of Sample Intervals Analyzed		Date Collected
		Planned[b]	Analyzed	
COPC analysis	299-E24-25 (C7514) ("L")	14	14	11/09/2009 to 01/05/2010
	299-E27-155 (C5852) ("O")	4	4	10/15/2007 to 10/25/2007
	299-E28-30 (C7515) ("M")	4	3	02/09/2010 to 02/22/2010
	299-E29-54 (C5860) ("K")	14	14	11/30/2009 to 01/22/2010
	299-E33-50 (C5195) ("F")	3	3	03/01/2007 to 03/06/2007
	299-E33-205 (C5989) ("C")	5	6	06/02/2008 to 07/17/2007
	299-E33-340 (C5853) ("G")	3	2	06/24/2008 to 07/11/2008
	299-E33-341 (C5856) ("D")	1	2	05/22/2008
	299-E33-342 (C5857) ("E")	4	4	03/19/2008 to 04/04/2008
	299-E33-343 (C5858) ("A")	4	4	02/08/2008 to 02/22/2008
	299-E33-344 (C5859) ("B") 299-E33-345 (C6226) ("B" replacement)	5	4	12/20/2007 to 02/20/2008
	699-48-50B (C5196) ("I")	0	1	11/02/2006
	699-50-56 (C5197) ("J")	0	3	11/21/2006
	699-52-55 (C5861) ("N")	2	12	12/07/2007 to 12/10/2007
	699-52-55B (C5862) ("H")	3	4	07/09/2008 to 07/29/2008

a. From Table 1-8 in DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*, for Wells 299-E33-50, 699-48-50B, and 699-50-56; from Tables 5-3 and 5-4 in DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*, for all other wells.

b. From Tables A3-1 through A3-3 in DOE/RL-2006-55 for Wells 299-E33-50, 699-48-50B, and 699-50-56; from Tables A3-2 through A3-13 in DOE/RL-2007-18 for all other wells.

COPC = contaminant of potential concern

1

Table 2-7. Depth-Discrete Groundwater Samples Collected from New Wells during the RI for the 200-BP-5 OU

Objectives for Collecting Data[a]	Borehole	Number of Sample Intervals		Date Collected
		Planned[b]	Collected[c]	
Uranium isotope evaluation Chromium and nitrate evaluation Contaminant plume delineation	299-E24-25 (C7514) ("L")	Four in unconfined aquifer	Three in unconfined aquifer Because the top of basalt was shallower than expected, one of the planned samples was not collected (SGW-46869).	12/08/2009 to 01/06/2010
Contaminant plume delineation	299-E27-155 (C5852) ("O")	Four in unconfined aquifer	Four in unconfined aquifer	10/16/2007 to 10/26/2007
Uranium isotope evaluation Contaminant plume delineation	299-E28-30 (C7515) ("M")	Four in unconfined aquifer	Four in unconfined aquifer	02/09/2010 to 02/25/2010
Uranium isotope evaluation Chromium and nitrate evaluation Contaminant plume delineation	299-E29-54 (C5860) ("K")	Four in unconfined aquifer	Four in unconfined aquifer	01/07/2010 to 02/11/2010
Contaminant plume delineation Technetium-99 evaluation	299-E33-50 (C5195) ("F")	Three in confined aquifer	Three in confined aquifer	03/02/2007 to 03/07/2007
Uranium isotope evaluation Contaminant plume delineation	299-E33-205 (C5989) ("C")	Two in unconfined aquifer	Two in unconfined aquifer	07/16/2008 to 07/23/2008
Uranium isotope evaluation Uranium (total), technetium-99, and chromium evaluation	299-E33-340 (C5853) ("G")	Three in confined aquifer	Three in confined aquifer	06/26/2008 to 07/18/2008
Uranium isotope evaluation Contaminant plume delineation	299-E33-341 (C5856) ("D")	One in unconfined aquifer	One in unconfined aquifer	05/28/2008

Table 2-7. Depth-Discrete Groundwater Samples Collected from New Wells during the RI for the 200-BP-5 OU

Objectives for Collecting Data[a]	Borehole	Number of Sample Intervals		Date Collected
		Planned[b]	Collected[c]	
Uranium isotope evaluation Contaminant plume delineation	299-E33-342 (C5857) ("E")	Two in unconfined aquifer	One in unconfined aquifer The second groundwater sample was not collected because of the low amount of water in the aquifer (SGW-39626).	04/10/2008
Uranium isotope evaluation Contaminant plume delineation	299-E33-343 (C5858) ("A")	Two in unconfined aquifer	One in unconfined aquifer The second sample was collected as a post-development sample (SGW-39626).	02/22/2008 to 03/10/2008
Uranium isotope evaluation Contaminant plume delineation	299-E33-344 (C5859) ("B")	Three in unconfined aquifer	One in perched zone A perched water zone was encountered during drilling (SGW-39626). Because drilling was terminated at this zone, the other planned groundwater samples were to be collected during drilling of a replacement borehole (299-E33-345).	01/08/2008
Uranium isotope evaluation Contaminant plume delineation	299-E33-345 (C6226) ("B" replacement)	Three in unconfined aquifer	One in unconfined aquifer Because the top of basalt was shallower than expected, two of the planned samples were not collected (SGW-39626).	02/20/2008
Uranium and technetium-99 evaluation	699-48-50B (C5196) ("I")	One in unconfined aquifer	A groundwater sample could not be collected during drilling because of the thin aquifer (SGW-34034). Groundwater samples were collected after the well was completed.	N/A
Uranium and technetium-99 evaluation	699-50-56 (C5197) ("J")	One in unconfined aquifer	One in unconfined aquifer	11/28/2006

Table 2-7. Depth-Discrete Groundwater Samples Collected from New Wells during the RI for the 200-BP-5 OU

Objectives for Collecting Data[a]	Borehole	Number of Sample Intervals		Date Collected
		Planned[b]	Collected[c]	
Contaminant plume delineation	699-52-55 (C5861) ("N")	Three in unconfined aquifer	No groundwater samples were collected during well drilling or immediately after permanent pump placement because groundwater volume was insufficient (SGW-37834).	N/A
Uranium (total), technetium-99, and chromium evaluation	699-52-55B (C5862) ("H")	Three in confined aquifer	Three in confined aquifer	07/16/2008 to 08/01/2008

Sources:

SGW-34034, *Borehole Summary Report for the Installation of Three Groundwater Wells in the 200-BP-5 Operable Unit, FY 2007*.

SGW-37834, *Borehole Summary Report for the Installation of Two Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, FY 2007*.

SGW-39496, *Borehole Summary Report for the Installation of One Groundwater Monitoring Well at the 200-BP-5 Operable Unit.*

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells at the 200-BP-5 Operable Unit, CY 2008*.

SGW-46869, *Borehole Summary Report for the Three (3) 200-BP-5 Wells, "K," "L," and "M," Fiscal Year 2010*.

a. From Table 1-8 in DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*, for Wells 299-E33-50, 699-48-50B, and 699-50-56; from Table 5-5 in DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*, for all other wells.

b. From Table 3-4 in DOE/RL-2006-55 for Wells 299-E33-50, 699-48-50B, and 699-50-56; from Tables A3-2 through A3-13 in DOE/RL-2007-18 for all other wells.

c. Samples were collected from the unconfined aquifer using a submersible pump or a Kabis sampler (product of Sibak Industries, San Marco, California). Samples were collected from the confined aquifer using a submersible pump.

N/A = not applicable

Depth-discrete groundwater sampling was conducted in 14 existing wells within the 200-BP-5 OU from December 2009 through April 2010 in accordance with PNNL-19129, *Discrete Sampling Test Plan for the 200-BP-5 Operable Unit*. The list of wells sampled and a summary of the groundwater sampling are provided in Table 2-8. The locations of the wells are shown in Figure 2-2.

Table 2-8. Depth-Discrete Groundwater Samples Collected from Existing Wells in the 200-BP-5 OU during FY 2010

Objectives for Collecting Data	Borehole	Number of Sample Intervals		Date Collected
		Planned	Collected	
To evaluate the vertical distribution of the following potential COPCs in the groundwater in the unconfined aquifer: • Uranium • Cyanide • Nitrate • Sulfate • Tritium • Technetium-99 • Chloride	299-E27-4	3	3	04/20/2010
	299-E27-7	5	7	01/07/2010 to 02/16/2010
	299-E27-10	2	1	02/17/2010
	299-E27-21	4	3	02/25/2010
	299-E27-23	4	3	01/13/2010 to 04/21/2010
	299-E33-31	2	2	01/19/2010 to 02/23/2010
	299-E33-39	2	2	02/18/2010
	299-E33-49	4	3	01/04/2010
	299-E33-339	4	3	01/05/2010 to 02/22/2010
	299-E33-342	3	2	12/22/2009
	299-E33-343	4	3	12/17/2009
	299-E33-345	3	2	01/12/2010
	699-50-56	3	2	01/11/2010
	699-53-55C	5	5	01/14/2010 to 01/18/2010
Total	**14**	**48**	**41**	

COPC = contaminant of potential concern

Depth-discrete groundwater samples were also collected during drilling of four new RCRA wells in the 200-BP-5 OU. Two new wells (299-E26-77 and 299-E26-79 drilled at the LERF) were sampled from August 2008 through September 2008 in accordance with DOE/RL-2008-41, *Sampling and Analysis Plan for the Liquid Effluent Retention Facility (LERF) Replacement RCRA Wells*. Two new wells (299-E27-24 and 299-E27-25 drilled at WMA C) were sampled from April 2010 through May 2010 in accordance with SGW-44067, *Sampling and Analysis Plan for Waste Management Area C Assessment Groundwater Monitoring Well Installation*. Chapter 4 of this RI report discusses the results and locations of these four wells.

The analytical results from the depth-discrete samples collected during drilling of the new wells and from the existing wells were used to develop the vertical distributions of groundwater contaminants presented in Chapter 4. The process of developing the vertical distributions of contaminants is documented in SGW-47391, *200-BP-5 Depth Discrete Contaminant Cross Section Development*. All of the analytical data are provided in Appendix B. The DQA of the depth-discrete groundwater data is documented in SGW-44071, *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit*.

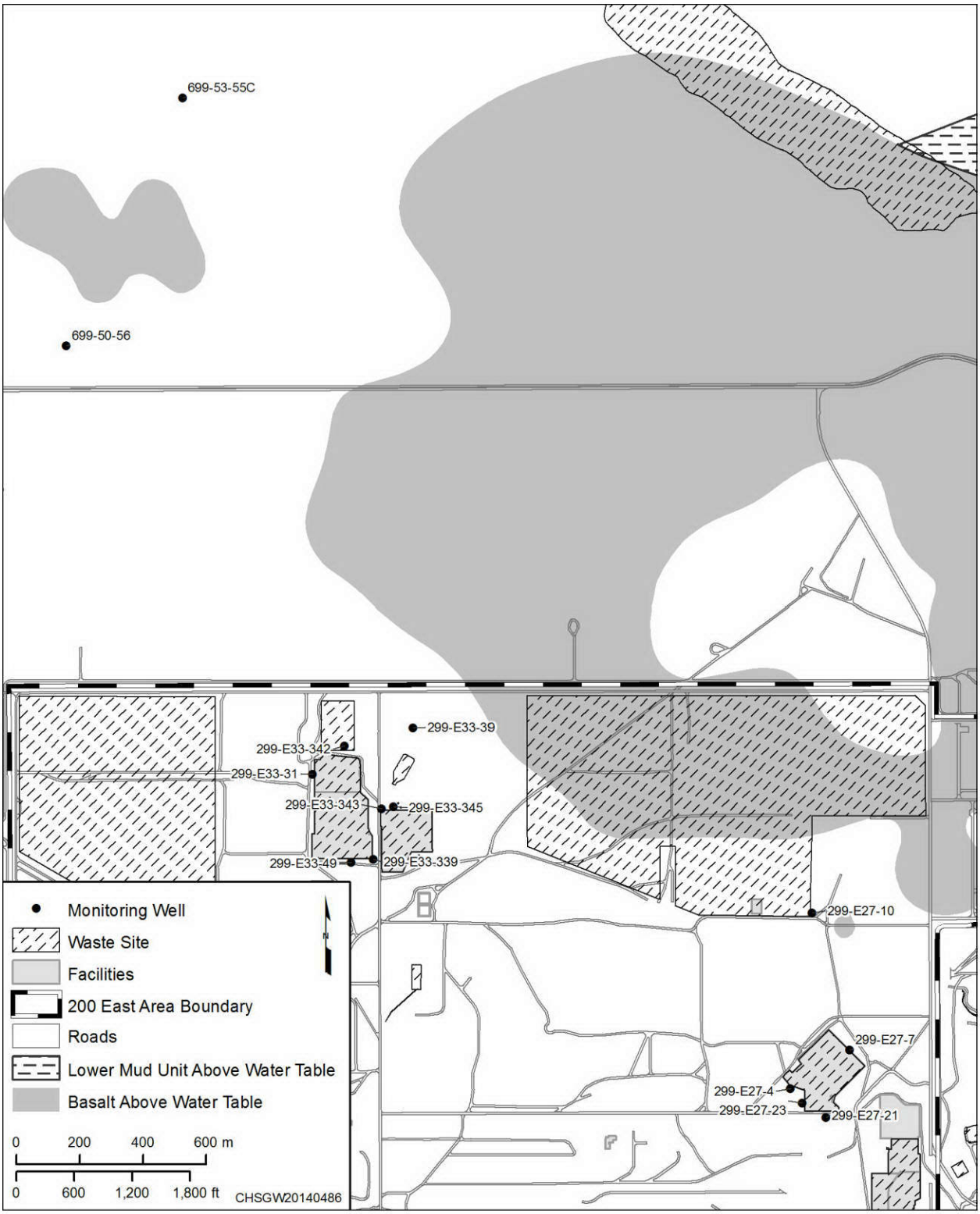

Figure 2-2. Existing Groundwater Wells in the 200-BP-5 OU Used for Depth-Discrete Groundwater Sampling in FY 2010

Hydrologic testing was planned for selected new and existing wells as part of the RI (DOE/RL-2007-18, Table A3-14). Table 2-9 presents a summary of the completed hydrologic testing.

Table 2-9. Hydrologic Tests Conducted during the RI for the 200-BP-5 OU

Type of Test	Objectives for Collecting Data	Well	Status	Documentation
Slug test, unconfined aquifer	Provide initial estimates of hydraulic properties	299-E33-345 (C6226) (“B”)	A slug test could not be conducted at Well 299-E33-345 because sufficient groundwater volume was not available.	SGW-39626
		699-52-55 (C5861) (“N”)	A slug test could not be conducted at Well 699-52-55 because the well had produced heaving sands that interfered with groundwater flow into the well through the screen, and sufficient groundwater volume was not available.	SGW-37834
Single or multiple well pumping test, unconfined aquifer	Identify aquifer parameters for evaluation of remedial alternatives	299-E33-345 (C6226) (“B”)	A single well pumping test could not be conducted at Well 299-E33-345 because sufficient groundwater volume was not available.	SGW-39626
		699-52-55 (C5861) (“N”)	A pumping test could not be conducted at Well 699-52-55 because the well had produced heaving sands that interfered with groundwater flow into the well through the screen, and sufficient groundwater volume was not available.	SGW-37834
Short-term well development pumping test, unconfined aquifer	Generate an estimate of aquifer transmissivity and evaluate well specific capacity	299-E24-25 (C7514) (“L”)	Short-term well development pumping tests were conducted as planned at all unconfined aquifer wells.	SGW-46869
		299-E27-155 (C5852) (“O”)		SGW-37834
		299-E28-30 (C7515) (“M”)		SGW-46869
		299-E29-54 (C5860) (“K”)		SGW-46869
		299-E33-205 (C5989) (“C”)		SGW-39496
		299-E33-341 (C5856) (“D”)		SGW-39626
		299-E33-342 (C5857) (“E”)		SGW-39626
		299-E33-343 (C5858) (“A”)		SGW-39626

Table 2-9. Hydrologic Tests Conducted during the RI for the 200-BP-5 OU

Type of Test	Objectives for Collecting Data	Well	Status	Documentation
		299-E33-344 (C5859) ("B") perched zone		No well development test because of low recharge SGW-39626
		299-E33-345 (C6226) ("B")		SGW-39626
		699-48-50B (C5196) ("I")		SGW-34034
		699-50-56 (C5197) ("J")		SGW-34034
		699-52-55 (C5861) ("N")		SGW-37834
Short-term well development pumping test, confined aquifer	Generate an estimate of aquifer transmissivity and evaluate well specific capacity	299-E33-50 (C5195) ("F")	Short-term well development pumping tests were conducted as planned at all confined aquifer wells.	SGW-34034
		299-E33-340 (C5853) ("G")		SGW-39626
		699-52-55B (C5862) ("H")		SGW-39626
Well tracer test, unconfined aquifer	Yield a profile of hydraulic conductivity, estimate flow velocity independent of gradient measurement and stress tests	Selected existing wells near C Tank Farm, selected existing wells northwest of BY Tank Farm, and Well 699-53-55	Well tracer tests were not conducted at existing wells. However, the groundwater flow velocity and direction in the vicinity of B-BX-BY Tank Farms, BY Cribs, and C Tank Farm were evaluated using time-series changes in the distributions of groundwater constituents. The B Tank Farm complex area was evaluated using chromium (PNNL-19277) and the C Tank Farm area was evaluated using sulfate and technetium-99/nitrate trend plots (DOE/RL-2008-01). Results of a groundwater treatability test being conducted for the B Tank Farm complex area provided field scale estimates of hydraulic conductivity (DOE/RL-2010-74).	DOE/RL-2008-01 PNNL-19277

Table 2-9. Hydrologic Tests Conducted during the RI for the 200-BP-5 OU

Type of Test	Objectives for Collecting Data	Well	Status	Documentation

Sources:

DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*.

DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

DOE/RL-2010-74, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*.

PNNL-19277, *Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and into the Upper Unconfined Aquifer Below the B Complex*.

SGW-34034, *Borehole Summary Report for the Installation of Three Groundwater Wells in the 200-BP-5 Operable Unit, FY 2007*.

SGW-37834, *Borehole Summary Report for the Installation of Two Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, FY 2007*.

SGW-39496, *Borehole Summary Report for the Installation of One Groundwater Monitoring Well at the 200-BP-5 Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells at the 200-BP-5 Operable Unit, CY 2008*.

SGW-46869, *Borehole Summary Report for the Three (3) 200-BP-5 Wells, "K," "L," and "M," Fiscal Year 2010*.

WMA = waste management area

After the new RI wells were installed for the 200-BP-5 OU, water levels were monitored to aid determining the flow direction and the estimation of groundwater velocity. Table 2-10 presents the date that water-level monitoring was initiated at each new well.

Table 2-10. Summary of Water-Level Monitoring in the New Wells Installed during the RI for the 200-BP-5 OU

Borehole	Monitoring Zone	Initial Measurement
299-E24-25 (C7514) ("L")	Unconfined aquifer	12/02/2009
299-E27-155 (C5852) ("O")	Unconfined aquifer	01/09/2008
299-E28-30 (C7515) ("M")	Unconfined aquifer	02/09/2010
299-E29-54 (C5860) ("K")	Unconfined aquifer	01/05/2010
299-E33-50 (C5195) ("F")	Confined aquifer	06/28/2007
299-E33-205 (C5989) ("C")	Unconfined aquifer	03/23/2009
299-E33-340 (C5853) ("G")	Confined aquifer	01/12/2009
299-E33-341 (C5856) ("D")	Unconfined aquifer	01/05/2009
299-E33-342 (C5857) ("E")	Unconfined aquifer	08/07/2008
299-E33-343 (C5858) ("A")	Unconfined aquifer	07/15/2008
299-E33-344 (C5859) ("B")	Perched water	07/15/2008
299-E33-345 (C6226) ("B")	Unconfined aquifer	07/15/2008

Table 2-10. Summary of Water-Level Monitoring in the New Wells Installed during the RI for the 200-BP-5 OU

Borehole	Monitoring Zone	Initial Measurement
699-48-50B (C5196) ("I")	Unconfined aquifer	05/01/2007
699-50-56 (C5197) ("J")	Unconfined aquifer	04/11/2007
699-52-55 (C5861) ("N")	Unconfined aquifer	05/05/2008
699-52-55B (C5862) ("H")	Confined aquifer	01/13/2009

In 2002 and 2003, the groundwater monitoring well networks for the 200 West and 200 East Areas were assessed through a DQO process (CP-15329, *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network*) to develop an integrated groundwater monitoring plan encompassing the various regulatory requirements. The regulatory programs that oversee activities within the 200-BP-5 OU have complementary, but not identical, purposes:

- The CERCLA groundwater monitoring program provides a routine and ongoing data for the OU.
- The RCRA detection program in WAC 173-303-400, "Dangerous Waste Regulations," "Interim Status Facility Standards," identifies whether TSD units are impacting groundwater quality and defines the rate and extent of detected contaminant migration.

The sitewide surveillance monitoring program determines baseline conditions of groundwater quality and quantity; characterizes and defines hydrogeologic, physical, and chemical trends in the groundwater system; and provides data to support decisions concerning land disposal practices and the management and protection of groundwater resources. DOE also conducts monitoring to meet the requirements of the AEA and DOE O 435.1, *Radioactive Waste Management*.

The DQO process determined that the selected groundwater constituents, sampling frequencies, and water table measurements were adequate to meet data collection and regulatory requirements for the various programs. Subsequently, the approach for ongoing groundwater monitoring of the 200-BP-5 OU was provided in DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*. The wells currently included in the 200-BP-5 OU monitoring network, the current analytical suites, and the sampling frequency are listed in the SAP (DOE/RL-2001-49). When completed, each of the new wells installed for the 200-BP-5 OU RI was added to the groundwater monitoring network.

Changes to sampling frequency and the analytical suite for selected existing wells were required to support the RI objectives and to evaluate all initial COPCs identified for sample planning during the DQO process (WMP-28945). The list of wells, associated sampling frequencies, and analytical suites to be sampled as part of the RI were provided in Appendix B of DOE/RL-2007-18.

Groundwater monitoring results from 161 wells were included in the 200-BP-5 OU risk assessment. This set represents monitoring wells for which data were available for the period from January 1, 2008, through January 31, 2014. Of these wells, 145 wells are used to monitor the unconfined aquifer and 16 wells are used to monitor the confined aquifer (Figure 2-3). These data were evaluated for use in the BRA and in the selection of COPCs; the data are discussed in further detail in Chapter 6.

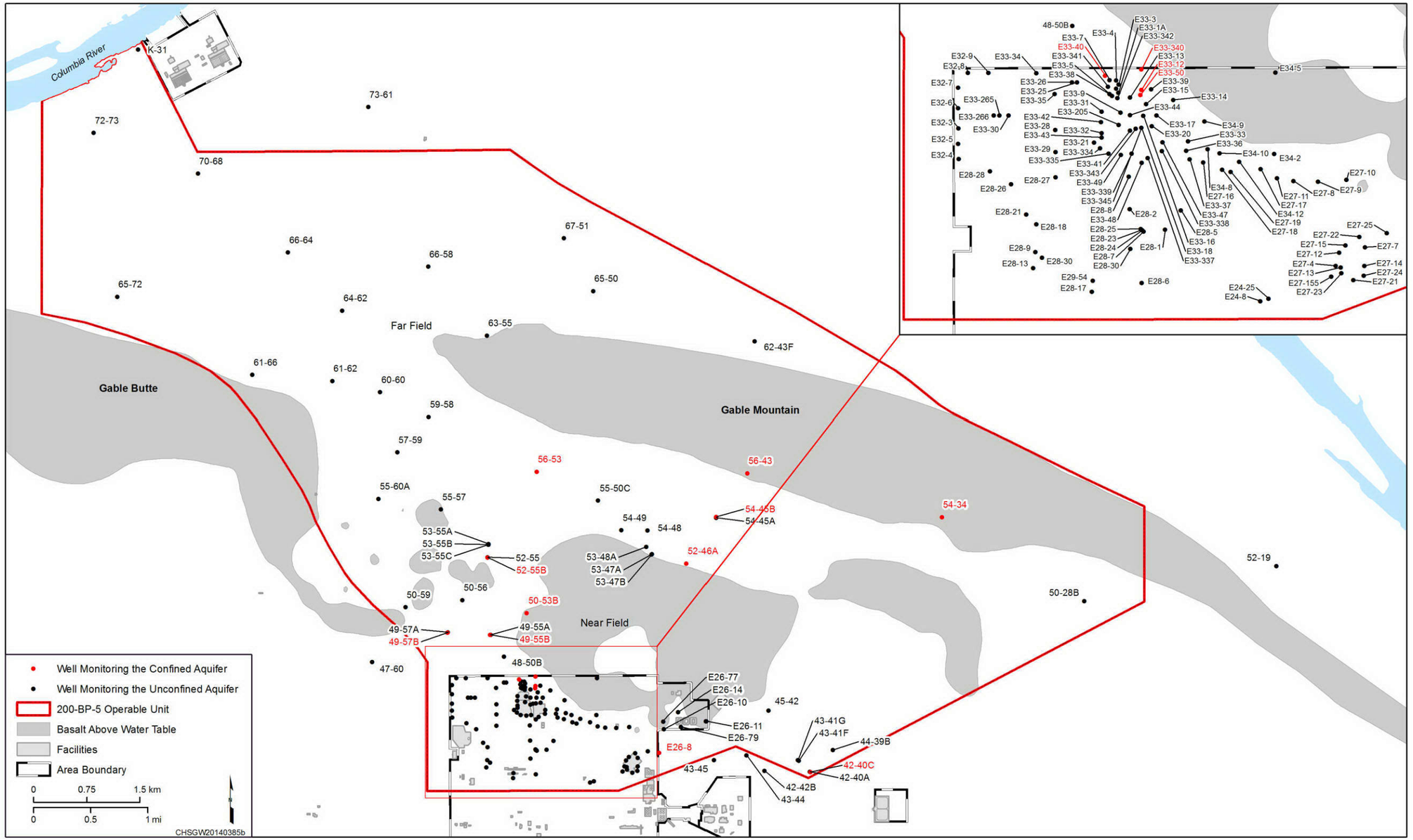

Figure 2-3. Groundwater Wells in the 200-BP-5 OU Used to Monitor the Unconfined Aquifer, Confined Aquifer, and Perched Water Zone

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Groundwater data collected in support of other onsite projects were used to supplement the data collected as part of the CERCLA RI. Groundwater sampling and analysis and water-level measurements were collected in support of RCRA and DOE O 435.1 from wells in the 200-BP-5 OU. Groundwater samples collected from RCRA wells were analyzed in the field at the time of sampling for pH, temperature, and specific conductivity. These supplemental data were used to help refine the CSM for the 200-BP-5 OU.

2.1.11 Ecological Investigations

No ecological investigations were planned or conducted during the RI for the 200-BP-5 OU. Hanford Site ecology is discussed in Section 3.8.

2.2 Field Activity Documentation

A DQA was conducted to evaluate whether the groundwater data collected from the 200-BP-5 OU are suitable for use in the BRA and for selection of remedial alternatives. The DQA process followed the general guidelines established by EPA (EPA/240/B-06/002, *Data Quality Assessment: A Reviewer's Guide*; EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners*). The results of the DQA are summarized in this section. Additional details are available in the DQA report (SGW-44071) and SGW-56758, *Supplement to the 200-BP-5 Groundwater Operable Unit Data Quality Assessment (2008 through 2013)*.

The data set included 12,217 groundwater samples and 135,562 analytical results of samples from 162 wells, which were analyzed for 362 different constituents. The samples in the data set were collected from January 1, 2008, through January 31, 2014. Within this data set, data from samples collected from 161 wells during groundwater monitoring over a 6-year period were used to support the BRA (discussed in Chapter 6).

Depth-discrete samples collected between 2006 and 2010 were used to support the CSM (discussed in Chapter 4). The number of depth-discrete groundwater samples collected from the RI wells, by well and by analyte class between November 2006 and April 2010, is shown in Table 2-11. Based on the DQA, it was concluded that the data are the correct type, quality, and quantity for direct regulatory use (e.g., in the BRA) as part of the RI/FS process (SGW-44071; SGW-56758).

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Table 2-11. Summary of Depth-Discrete Groundwater Data from the 200-BP-5 OU RI Wells, November 2006 through April 2010

Well	General Organics	Metals	Physical Properties	Radiochemistry	Semivolatile Organic Analysis	Volatile Organic Analysis	Wet Chemistry	Total (by Well)
299-E24-25 (“L”)	--	55	5	70	322	165	31	648
299-E27-155 (“O”)	--	95	10	95	321	170	55	746
299-E28-30 (“M”)	--	55	10	70	338	165	35	673
299-E29-54 (“K”)	--	64	19	70	323	169	34	679
299-E33-50 (“F”)	--	40	4	68	261	165	21	559
299-E33-205 (“C”)	8	119	10	79	271	150	61	698
299-E33-340 (“G”)	--	76	--	72	262	148	32	590
299-E33-341 (“D”)	4	76	4	42	137	76	18	357
299-E33-342 (“E”)	2	40	13	25	69	37	23	209
299-E33-343 (“A”)	2	61	24	27	64	37	46	261
299-E33-344 (“B,” perched)	--	17	2	2	--	37	7	65
299-E33-345 (“B,” unconfined)	--	19	14	6	--	--	20	59
699-48-50B (“I”)	--	20	--	36	140	66	8	270
699-50-56 (“J”)	--	10	12	23	70	33	18	166
699-52-55 (“N”)	--	--	--	--	--	--	--	--
699-52-55B (“H”)	--	--	--	--	--	--	--	--
Total (by Class)	**30**	**1,017**	**235**	**995**	**3,316**	**2,803**	**677**	**9,124**

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3 Physical Characteristics of the Study Area

This chapter describes the physical setting of 200-BP-5 OU, and the following site features are discussed: surface features, meteorology, surface water, geology, hydrogeology, water use, and ecology. The physical setting is an important component of the CSM, as it establishes the framework for understanding the nature and extent of contamination, which is described in Chapter 4. Key aspects of the physical setting that influence the movement of contaminants within the groundwater are evaluated in Chapter 5.

The Hanford Site is located in the Columbia Basin in Washington State. The Columbia Basin is an intermontane basin between the Cascade Range and the Rocky Mountains in the Pacific Northwest, and it forms the northern portion of the Columbia Plateau physiographic province and the Columbia River flood-basalt province. Most of the geologic features visible in the Columbia Basin developed during the last 18 million years of the Cenozoic era, but events as far back as the late Precambrian (2.3 billion years ago) have had significant influence on the Cenozoic history of the area.

The Hanford Site lies within the Pasco Basin (Figure 3-1), which is a smaller basin in the Yakima Fold Belt along the western margin of the Palouse Slope. The Saddle Mountains form the northern boundary of the Pasco Basin, while Rattlesnake Mountain forms part of the southern boundary. The Hanford Site's 200 East and 200 West Areas lie in the Cold Creek syncline between Yakima Ridge and Umtanum Ridge in the central portion of the Pasco Basin.

3.1 Surface Features

The physiographic setting of the Hanford Site is relatively low relief, resulting from river and stream sedimentation filling the synclinal valleys and basins between the anticlinal ridges. Surface topography has been modified within the past several million years by Pleistocene era cataclysmic flooding, Holocene eolian activity, and landslides. Cataclysmic floods during the Pleistocene eroded sediments and scoured basalt bedrock, forming "scabland" topography visible north of the Pasco Basin, and remnant large-scale erosional channels visible within the Central Plateau at the Hanford Site. In addition, branching flood channels, giant current ripples, ice-rafted erratics, and giant flood bars are among the landforms created by the floods and are readily seen on the Hanford Site. Since the end of the Pleistocene (about 10,000 years ago), prevailing winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and windblown silt around the margins of the Pasco Basin. Most sand dunes have been stabilized by vegetation. Active dunes exist north of the 300 Area near the eastern border of the Hanford Site in the Hanford Reach National Monument. An unspecified number of dunes elsewhere on the Hanford Site were temporarily reactivated by the removal of vegetation that resulted following a range fire in the summer of 2000.

Geomorphic features of the 200-BP-5 OU were created by paleoflood and ancestral Columba River erosion and deposition. Surface elevations overlying the 200-BP-5 OU range from 320 m (1,050 ft) at the top of Gable Mountain (i.e., a bedrock high) to a low of approximately 120 m (394 ft) at the Columbia River (Figure 3-2). Gable Mountain and a northwest-southeast-trending Pleistocene erosional channel (including an interior drainage) represent the primary topographic features overlying the 200-BP-5 OU (Figure 3-2). The Cold Creek bar, also known as the Central Plateau, dominates the topography overlying the southernmost portion of the OU.

PNNL-6415 describes the major features of the Hanford Site environment and provides much of the content for the following discussion on site setting and climate.

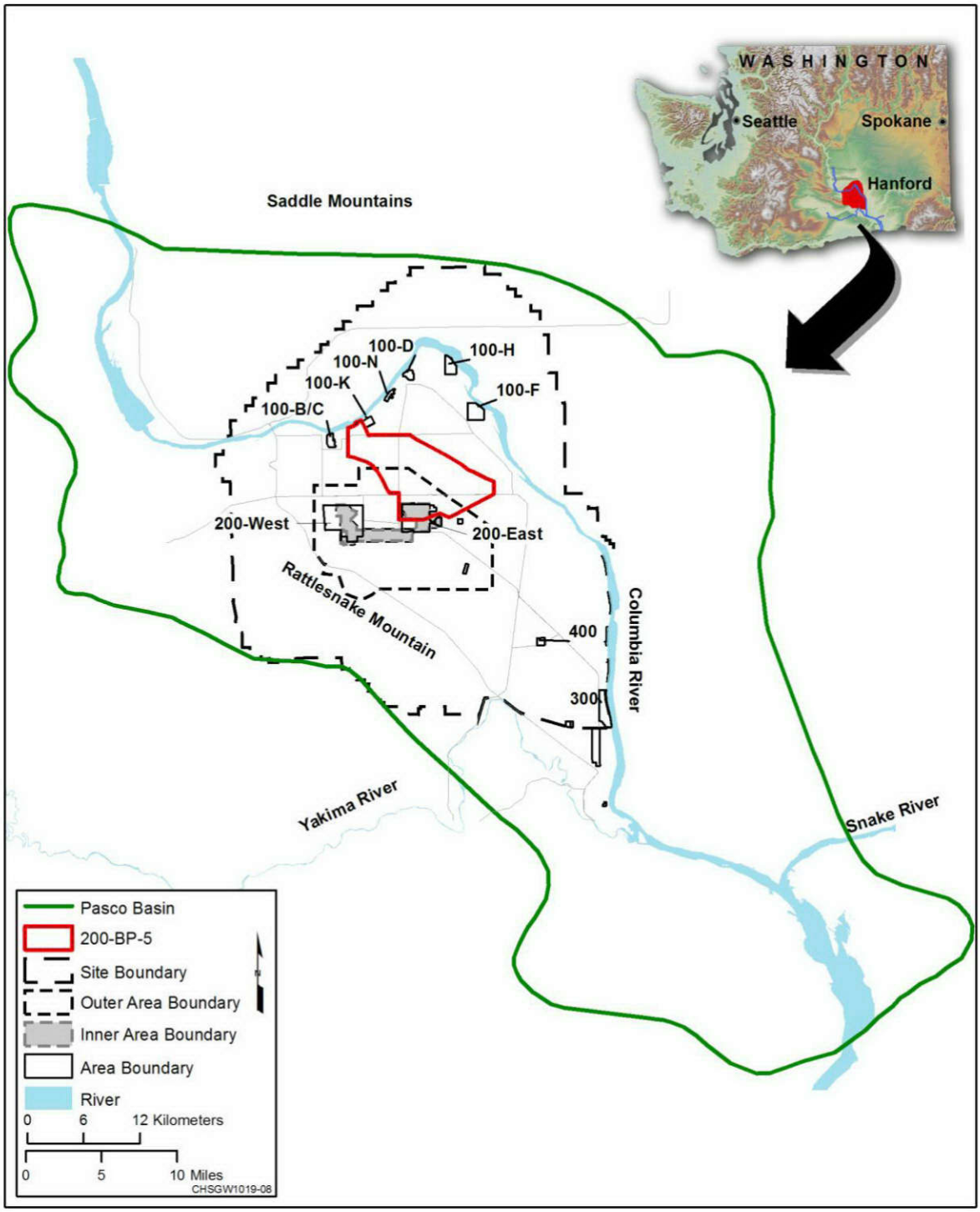

Figure 3-1. Location Map of the Pasco Basin and the 200-BP-5 OU

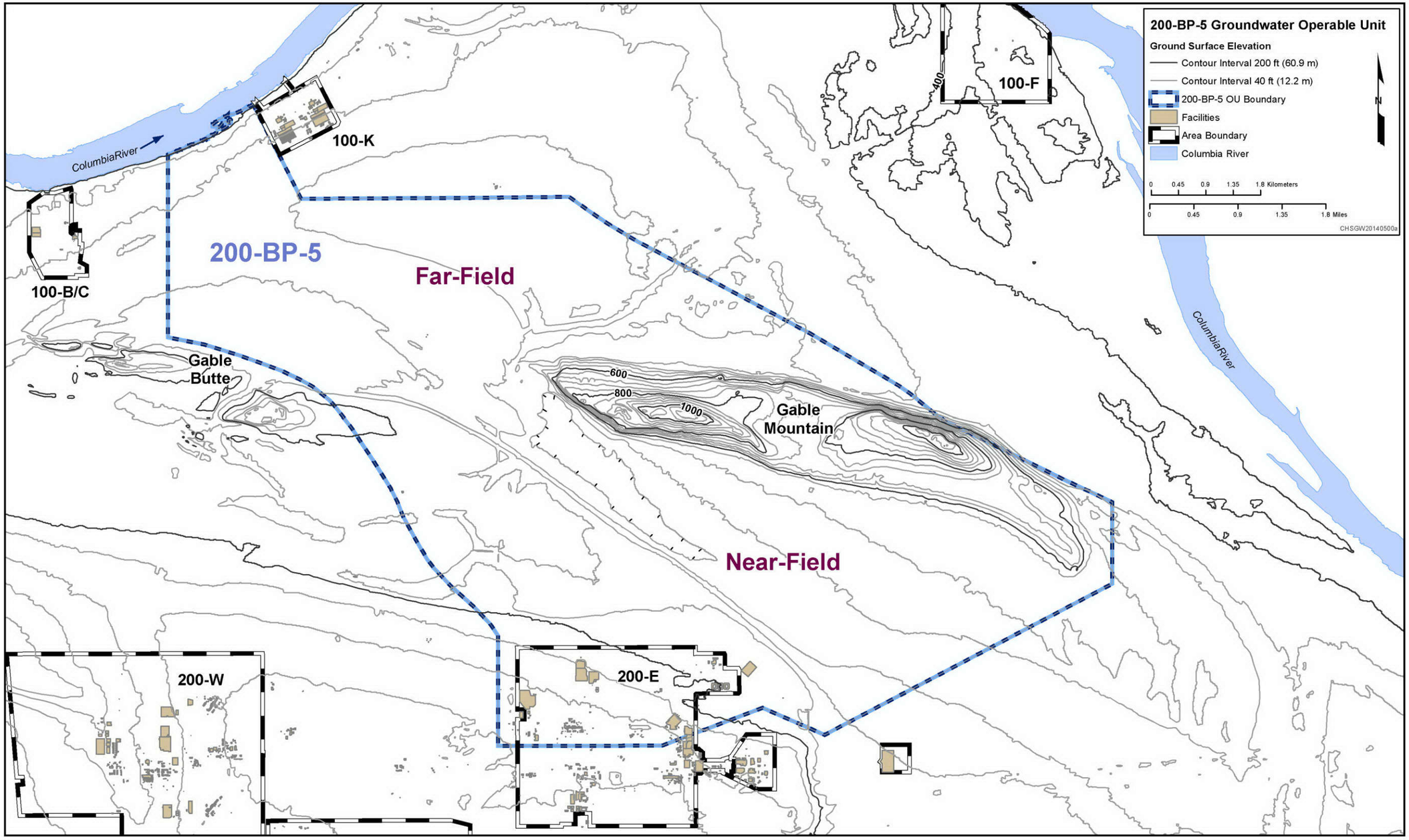

Figure 3-2. Surface Topography and Boundaries of the 200-BP-5 OU

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3.2 Meteorology

The Pacific Ocean moderates temperatures throughout the Pacific Northwest, and the Cascade Range generates a rain shadow that limits rain and snowfall in the eastern half of Washington State. The Cascade Range also serves as a source of cold air drainage, which has a considerable effect on the wind regime at the Hanford Site. The mountain ranges to the north and east of the Hanford Site shield the area from severe winter storms and frigid air masses that move south across Canada.

Climatological data for the Hanford Site are compiled at the Hanford Meteorological Station (HMS), which is located on the Central Plateau, about 4 km (3 mi) west of the 200 East Area. Meteorological measurements have been made at the HMS since late 1944. Before the HMS was established, local meteorological observations were made at the old Hanford town site (1912 through late 1943) and in Richland (1943 and 1944). To characterize meteorological differences accurately across the Hanford Site, the HMS operates a network that currently contains 30 monitoring stations (Figure 3-3). Data are collected and processed at each station, and information is transmitted to the HMS every 15 minutes. This monitoring network has been in full operation since the early 1980s.

3.2.1 Wind

The prevailing surface winds on the Central Plateau are from the northwest during the entire year (Figure 3-4). The secondary wind direction is from the southwest (DOE/RL-2013-18, *Hanford Site Environmental Report for Calendar Year 2012*). In the southeastern portion of the Hanford Site, the prevailing wind direction near the surface is from the southwest during most months, and winds from the northwest are much less common. Along the Columbia River, local winds are strongly influenced by the topography near the river (PNNL-6415).

Monthly average wind speeds are lowest during winter months, averaging about 3 m/s (6 to 7 mph), and highest during summer, averaging about 4 m/s (8 to 9 mph). The fastest wind speeds at the HMS are usually associated with flow from the southwest; however, the summertime drainage winds from the northwest frequently exceed speeds of 13 m/s (30 mph). The maximum speed of the drainage winds (and their frequency of occurrence) tends to decrease moving toward the southeast across the Hanford Site. Surface features have less influence on winds aloft than on winds near the surface.

3.2.2 Temperature and Humidity

Based on data collected from 1945 through 2012, the average monthly temperatures at the HMS range from a low of -0.5°C (31.1°F) in January to a high of 25.1°C (77.1°F) in July. Daily maximum temperatures at the HMS vary from an average of 2°C (35°F) in late December and early January to 36°C (96°F) in late July. On average, 52 days during the summer months have maximum temperatures greater than or equal to 32°C (90°F), with 12 days of maximum temperatures greater than or equal to 38°C (100°F). The largest number of consecutive days on record with maximum daily temperatures greater than or equal to 32°C (90°F) is 32 days. The record maximum temperature, 45°C (113°F), occurred at the HMS on July 23, 2006; July 13, 2002; and August 4, 1961. The recorded minimum temperature was -30.6°C (-23.1°F).

From mid-November through early March, the average daily minimum temperature is below freezing. The daily minimum in late December and early January is -6°C (21°F). On average, a daily minimum temperature of less than or equal to -18°C (approximately 0°F) occurs only 3 days per year; however, only about one winter in two experiences such low temperatures.

The annual average relative humidity at the HMS is 55 percent. It is highest during the winter months, averaging about 76 percent, and lowest during the summer, averaging about 36 percent.

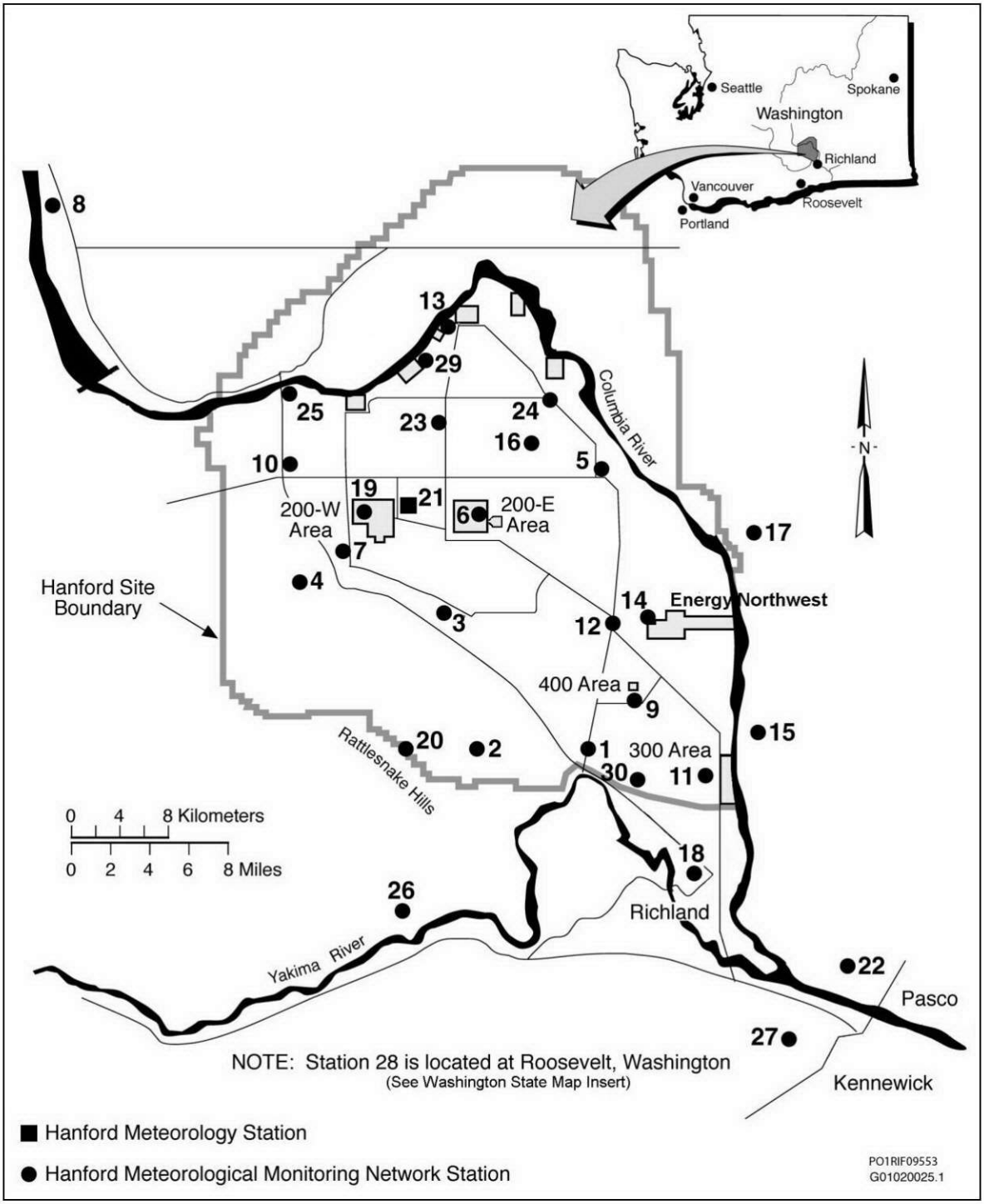


Figure 3-3. HMS Monitoring Network Location Map

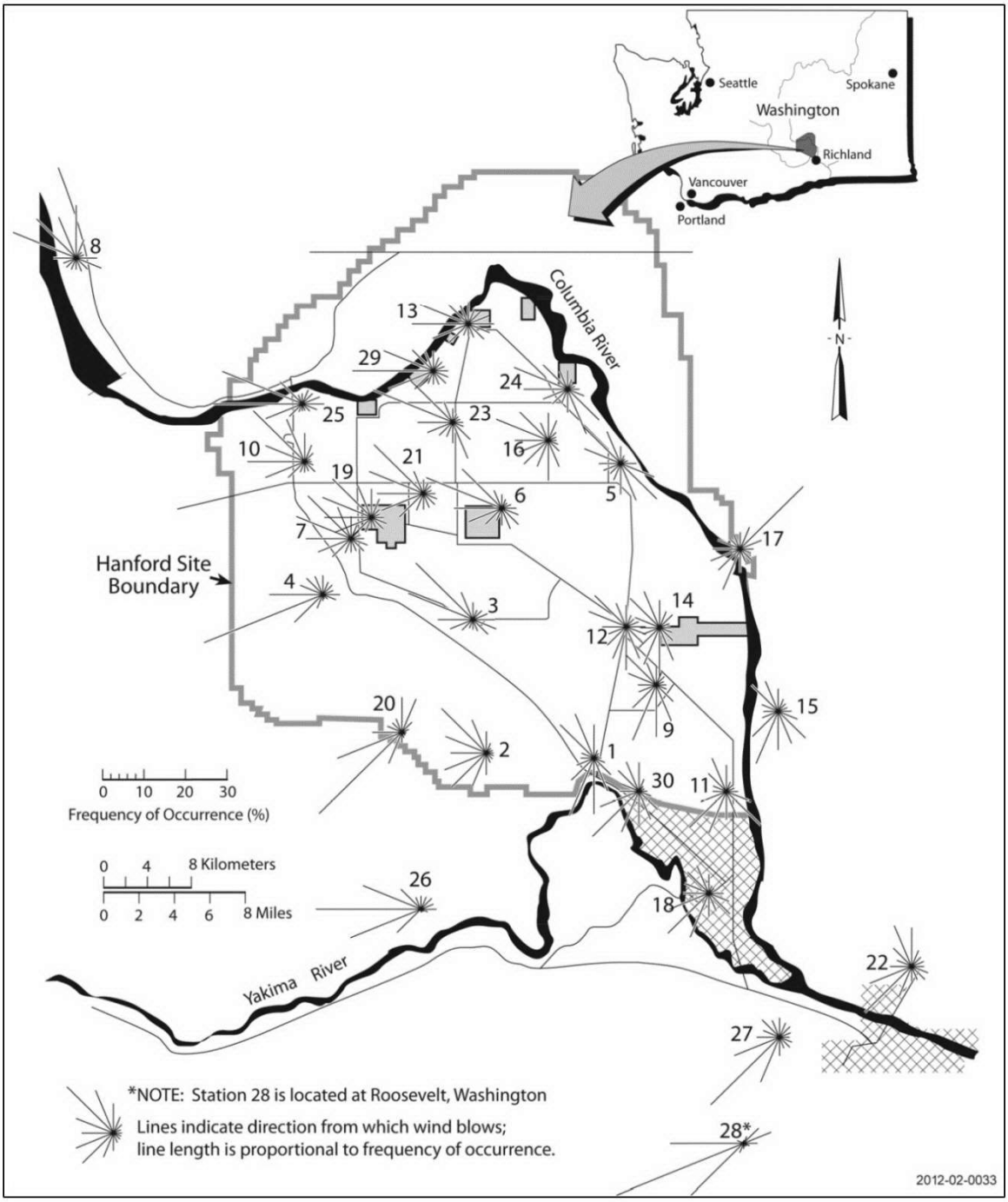


Figure 3-4. Wind Roses at the 9.1 m (30 ft) Level of the HMS Monitoring Network, 1982 through 2006

3.2.3 Precipitation

Average annual precipitation at the HMS is 18.1 cm (7.1 in.). Most precipitation occurs during the late fall and winter, with more than half of the annual total occurring from November through February. Snowfall accounts for about 38 percent of all precipitation from December through February.

3.2.4 Fog and Visibility

Fog has been recorded during every month of the year at the HMS; however, 89 percent of the occurrences are from November through February. The average number of days per year with fog (visibility less than or equal to 9.6 km [6 mi]) is 48 days, while those with dense fog (visibility less than or equal to 0.4 km [0.25 mi]) is 25 days. Other phenomena causing restrictions to visibility (i.e., visibility less than 9.6 km [6 mi]) include dust, blowing dust, and smoke from field burning and naturally occurring fires in the region.

3.2.5 Severe Weather

Concerns about severe weather usually center on hurricanes, tornadoes, and thunderstorms. Washington State does not experience hurricanes. Tornadoes are infrequent and generally small in the northwestern portion of the United States. In the counties closest to the Hanford Site, only 24 tornadoes were recorded from 1950 through November 2004. Of these, 17 tornadoes had maximum wind speeds estimated to be in the range of 18 to 32 m/s (40 to 72 mph), 4 tornadoes had maximum wind speeds in the range of 33 to 50 m/s (73 to 112 mph), and 3 tornadoes had maximum wind speeds in the range of 51 to 71 m/s (113 to 157 mph). No deaths or substantial property damage (in excess of $50,000) were associated with any of these tornadoes. The estimated probability of a tornado striking a point on the Hanford Site is 9.6×10^{-6}/yr (NUREG/CR-4461, *Tornado Climatology of the Contiguous United States*).

The average occurrence of thunderstorms in the vicinity of the HMS is 10 per year. These thunderstorms are most frequent during the summer; however, they have occurred in every month. High-speed winds at the Hanford Site are more commonly associated with strong cold frontal passages. In rare cases, intense low-pressure systems can generate winds of near hurricane force.

3.3 Surface Water Hydrology

Naturally occurring surface water at the Hanford Site (Figure 3-5) includes the Columbia River, springs, and vernal ponds. Intermittent surface streams, such as Cold Creek, may also contain water after large precipitation or snowmelt events. In addition, the Yakima River flows along a short section of the southern boundary of the Hanford Site, and surface water is associated with irrigation return flows east and north of the site.

The northern boundary of the 200-BP-5 OU is approximately 1,675 m (5,500 ft) of the Columbia River, between the 100-BC-5 and 100-KR-4 OUs. Except for the Columbia River estuary, the only unimpounded stretch of the Columbia River in the United States is the Hanford Reach, which extends from Priest Rapids Dam downstream approximately 82 km (51 mi) to Lake Wallula (south of the city of Richland). The Hanford Reach of the Columbia River was recently incorporated into the land area established as the Hanford Reach National Monument.

River flow through the Hanford Reach fluctuates substantially and is controlled primarily by operations at upstream storage dams (i.e., Grand Coulee in the United States, and Mica and Keenleyside in Canada). Flows in the Hanford Reach are directly affected by releases from Priest Rapids Dam; however, the dam operates as a run-of-the-river dam rather than a storage dam. Flows are controlled to generate power and promote salmonid egg and embryo survival.

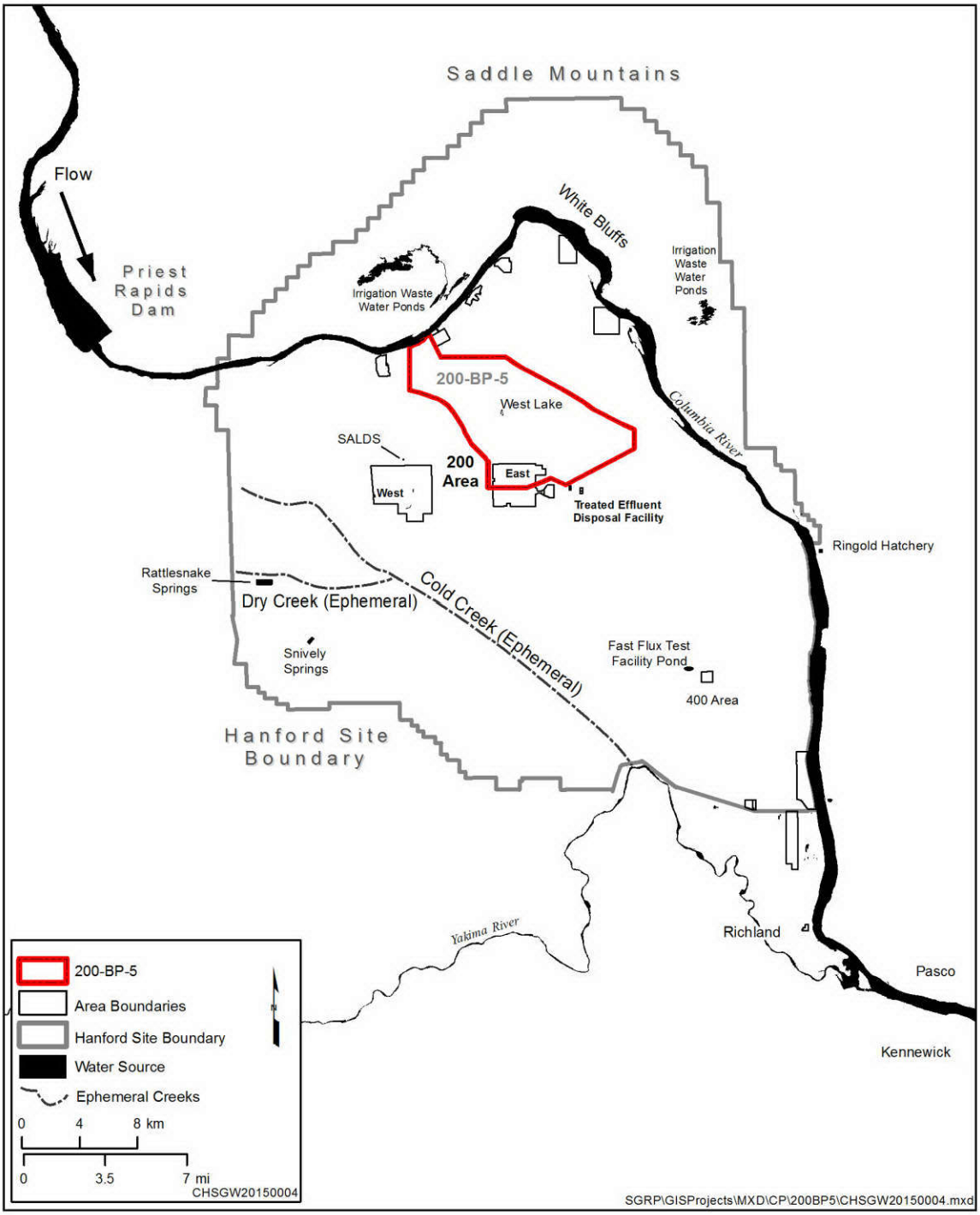


Figure 3-5. Surface Water Features of the Hanford Site

The long-term annual average flow of the Columbia River downstream of Priest Rapids Dam is approximately 3,400 m^3/s (120,000 ft^3/s). In 2012, the Columbia River exhibited above-average flows, with the average daily flow rate downstream of Priest Rapids Dam at 4,308 m^3/s (152,000 ft^3/s) (DOE/RL-2013-18). The peak monthly average flow rate occurred during July 2012 (7,813 m^3/s [276,000 ft^3/s]). The lowest monthly average flow rate occurred during October 2012 (1,982 m^3/s [70,000 ft^3/s]) on the basis of mean daily flows. Daily average flow rates varied from 1,163 to

10,021 m^3/s (41,090 to 353,990 ft^3/s) during 2012. The depth of the river varies significantly over time as a result of fluctuations in discharge. The river stage (water surface level) may change along the Hanford Reach by up to 3 m (10 ft) within a few hours. Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately one-half the magnitude of those measured near the 100 Areas due to the effect of the pool behind McNary Dam (PNL-8580, *Water Level Measurements for Modeling Hydraulic Properties in the 300-FF-5 and 100 Aggregate Area Operable Units*) and the relative distance of each area from Priest Rapids Dam. The width of the Columbia River varies from approximately 300 to 1,000 m (980 to 3,300 ft) as it passes through the Hanford Site.

West Lake is the only naturally occurring body of water within the 200-BP-5 OU (Figure 3-5). This seasonal body of water is naturally recharged from groundwater (ARH-CD-775, *Geohydrologic Study of the West Lake Basin*; PNL-7662, *An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site*). As a result of the arid climate and well-drained soils, no surface drainage pattern has developed throughout the majority of the 200-BP-5 OU. The 200 East Area is not in a designated floodplain, and calculations of probable maximum floods for the Columbia River indicate that the 200 East Area is not expected to be inundated under maximum flood conditions (RHO-BWI-C-120/PNL-4219, *Flood Risk Analysis of Cold Creek Near the Hanford Site*).

3.3.1 Water Quality of the Columbia River

The water quality of the Columbia River from Grand Coulee Dam to the Washington/Oregon border, which includes the Hanford Reach, has been designated as "Class A, Excellent" (WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington") by Washington State. Class A waters are suitable for all uses, including raw drinking water, recreation, and wildlife habitat. State and federal DWSs apply to the Columbia River.

In 2012, Columbia River water samples were collected from fixed-location monitoring stations at Priest Rapids Dam and in Richland, Washington, and from cross-river transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland. The Columbia River water sample data show results similar to those observed during recent years for tritium, nitrate, uranium, and iodine-129 in samples collected upriver of the Hanford Site at the Vernita Bridge and below (downriver) the Hanford Site at the Richland pump house (DOE/RL-2013-18).

3.3.2 Yakima River

The Yakima River, which follows a portion of the southwestern boundary of the Hanford Site, has no direct relevance to the 200-BP-5 OU.

3.3.3 Springs and Streams

Except for possible springs at the Columbia River shoreline (see Section 3.3.4), no documented springs or streams occur within the 200-BP-5 OU. The only natural surface waters in the OU are West Lake and minor ephemeral features associated with precipitation runoff.

3.3.4 Columbia Riverbank Springs

No documented springs occur in the 200-BP-5 OU, except for possible riverbank springs along the Columbia River, between the 100-BC and 100-KR-4 OUs. Seepage occurs both below the river surface and on the exposed riverbank, particularly during periods of low river stage. Riverbank springs flow intermittently and are influenced primarily by changes in river level. In many areas, water flows from the river into the aquifer at high river stage and then returns to the river at low river stage. The concentrations in seeping water along the riverbank may be lower than in groundwater because of mixing between river

water and contaminated unconfined aquifer water. Seeps and springs near the 100-BC and 100-K Areas have shown detectable levels of hexavalent chromium (Cr(VI)), strontium-90, tritium, and trichloroethene (TCE) (DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009 Volumes 1 & 2*).

3.3.5 Runoff and Net Infiltration

Total estimated precipitation over the Pasco Basin is about 9×10^8 m^3 (3.2×10^{10} ft^3) annually (DOE/RW-0164, *Site Characterization Plan: Reference Repository Location, Hanford Site, Washington*). Precipitation varies both spatially and temporally, with higher amounts generally falling at higher elevations. Mean annual runoff from the Pasco Basin is estimated at 3.1×10^7 m^3/yr (1.1×10^9 ft^3/yr), or approximately 3 percent of the total precipitation (DOE/RW-0164). Most of the remaining precipitation is lost through evapotranspiration; however, a portion of the precipitation that infiltrates the soil eventually recharges the groundwater flow system. The amount of recharge varies spatially based primarily on soil texture and vegetation (Gee et al., 1992, "Variations in Recharge at the Hanford Site"). Natural recharge also varies temporally, with the majority occurring in the winter and spring. Some evidence exists that the most significant recharge events are associated with rapid melting of relatively large snowpacks, which may occur only a few times in a decade (PNNL-14744, *Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*). Section 3.6.3 provides a discussion of artificial and natural recharge to the 200-BP-5 OU.

3.3.6 Flooding

Although large Columbia River floods have occurred in the past (DOE/EIS-0113, *Final Environmental Impact Statement Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington*, Vols. 1 through 3), the likelihood of recurrence of large-scale flooding has been reduced by the construction of several flood control/water storage dams upstream of the Hanford Site. Major floods on the Columbia River are typically the result of rapid melting of the winter snowpack over a wide area augmented by above normal precipitation. The exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 m^3/s (415,000 ft^3/s) (USGS, 2014, *USGS Water Data for the Nation*).

The probable maximum flood for the Columbia River downstream of Priest Rapids Dam has been calculated to be 40,000 m^3/s (1.4 million ft^3/s) and is greater than the 500-year flood. This flood would inundate parts of the 100 Areas adjacent to the Columbia River, but the central portion of the Hanford Site would remain unaffected (DOE/RW-0070, *Environmental Assessment: Reference Repository Location, Hanford Site, Washington*). The U.S. Army Corps of Engineers (USACE) has derived the standard project flood, with both regulated and unregulated peak discharges estimated for the Columbia River downstream of Priest Rapids Dam (USACE, 1989, *Water Control Manual for McNary Lock and Dam, Columbia River, Oregon and Washington*). The regulated standard project flood for this part of the river is 15,200 m^3/s (537,000 ft^3/s), and the 100-year regulated flood is 12,400 m^3/s (440,000 ft^3/s) (DOE/RL-97-56, *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*). Impacts to the Hanford Site are negligible and would be less than the probable maximum flood.

The USACE evaluated a number of scenarios on the effects of failures of Grand Coulee Dam, assuming flow conditions of 11,000 m^3/s (400,000 ft^3/s). The discharge or flood wave resulting from an instantaneous 50 percent breach at the outfall of the Grand Coulee Dam was determined to be 600,000 m^3/s (21 million ft^3/s). In addition to the areas inundated by the probable maximum flood, the remainder of the 100 Areas, 300 Area, and nearly all of Richland would be flooded (DOE/RW-0070). The 50 percent scenario was believed to represent the largest realistically conceivable flow resulting from

either a natural or human-induced breach (DOE/RW-0070). It was also assumed that a scenario such as the 50 percent breach would occur only as the result of direct explosive detonation and not because of a natural event such as an earthquake, and that even a 50 percent breach under these conditions would indicate an emergency situation in which there might be other overriding major concerns.

Fewer than 20 major floods have occurred on the Yakima River since 1862 (DOE/RW-0070). The most severe flooding events occurred during November 1906, December 1933, May 1948, and February 1996. Discharge magnitudes at Kiona, Washington, were 1,870 m^3/s (66,000 ft^3/s); 1,900 m^3/s (67,000 ft^3/s); 1,050 m^3/s (37,000 ft^3/s); and 1,300 m^3/s (45,900 ft^3/s), respectively. The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively. The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river.

During 1980, a flood risk analysis of Cold Creek was conducted as part of the characterization of a basaltic geologic repository for high-level radioactive waste. In lieu of 100- and 500-year floodplain studies, a probable maximum flood evaluation was performed based on a large rainfall or combined rainfall/snowmelt event in the Cold Creek and Dry Creek watershed (RHO-BWI-C-120/PNL-4219). The probable maximum flood discharge rate for the lower Cold Creek Valley was 2,265 m^3/s (80,000 ft^3/s) compared with 564 m^3/s (19,900 ft^3/s) for the 100-year flood. Modeling indicated that State Route 240 (along the Hanford Site's southwestern and western areas) would not be usable after a probable maximum flood.

3.3.7 Nonriverine Surface Water

Active ponds on the Hanford Site include West Lake, the SALDS, and the 200 Area TEDF disposal ponds (Figure 3-5). West Lake is in the 200-BP-5 OU, the SALDS is located in the 200 West Area, and the TEDF is located within the northern 200-PO-1 OU.

West Lake is a natural seasonal feature recharged from groundwater (ARH-CD-775; PNL-7662) that occurs in a closed depression between Gable Mountain and Gable Butte. West Lake has not received direct effluent discharges from Hanford Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in the topographically low area. The water levels of West Lake fluctuate with the water table elevation, which is influenced by wastewater discharge in the 200 Areas. The water level and size of the lake have been decreasing over the past several years due to reduced wastewater discharge.

The TEDF is east of the 200 East Area and consists of two unlined disposal ponds. These ponds are each 0.02 km^2 (0.008 mi^2) in size, and they receive industrial wastewater permitted in accordance with WAC 173-216, "State Waste Discharge Permit Program." The wastewater evaporates into the air or percolates into the ground from the disposal ponds. The SALDS, located west and upgradient of the 200-BP-5 OU, was activated in 1995 to handle the permitted discharge of treated wastewater from the 200 Area Effluent Treatment Facility. Liquid effluent is discharged to the ponds and is permitted to percolate into the uppermost aquifer. Groundwater monitoring for tritium and other constituents, as well as water level measurements, is required for the SALDS by Ecology, 2000, *State Waste Discharge Permit Number ST 4500.*

Several naturally occurring vernal ponds are located near Gable Mountain and Gable Butte (Soll et al., 1999, *Biodiversity Inventory and Analysis of the Hanford Site, Final Report 1994-1999*). The formation of these ponds in any particular year depends on the amount and temporal distribution of precipitation and snowmelt events. The vernal ponds range in size from about 37 to 1,400 m^2 (400 to 15,000 ft^2) and they are found in three clusters. Approximately 10 vernal ponds were documented

at the eastern end of Umtanum Ridge, 7 ponds were observed in the central portion of Gable Butte, and 3 ponds were found at the eastern end of Gable Mountain.

3.4 Geology

The subsurface geology forms the framework that affects the locations of aquifers and the release and movement of contaminants. The stratigraphy and geologic structure of the 200-BP-5 OU are described in this section. Hydrostratigraphic cross sections and descriptions of unconsolidated sediments and basalt bedrock are included to depict the nature of the aquifers and to illustrate the lateral continuity or variations that occur across the 200-BP-5 OU. The geologic discussion in this section is divided into two parts: the near-field area and the far-field area (Figure 3-2). This discussion presents the relative geology for each of these two areas, including the transition from the near-field into the far-field area of the 200-BP-5 OU near Gable Gap.

The geology of the Hanford Site has been extensively characterized as a result of various past investigations. These investigations have included the siting of nuclear reactors (WPPSS, 1981, *Final Safety Analysis Report*; PSPL, 1982, *Preliminary Safety Analysis for Skagit/Hanford Nuclear Project*), the site characterization for the BWIP (DOE/RW-0164), support for waste management operations (DOE/EIS-0113), and recent environmental restoration activities. Geologic and geophysical investigations within the 200-BP-5 OU have included regional and Hanford Site surface mapping, borehole and well sediment logging, field and laboratory sediment classification and description, surface and borehole geophysical studies (including radiological borehole logging and various seismic, magnetic, and gravity surveys), and in situ and laboratory hydrogeologic properties testing. Additional details on geologic interpretations and related maps and cross sections pertaining to the 200-BP-5 OU are available in the following sources:

- BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*
- DOE/RL-92-05, *B Plant Source Aggregate Area Management Study Report*
- DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*
- DOE/RL-95-59, *200-BP-5 Operable Unit Treatability Test Report*
- DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009 Volumes 1 & 2*
- HNF-5507, *Subsurface Conditions Description of the B-BX-BY Waste Management Area*
- PNL-6820, *Hydrogeology of the 200 Areas Low Level Burial Grounds—An Interim Report: Volume 1: Text*
- PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*
- PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*
- PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*

- RPP-10098, *Field Investigation Report for Waste Management Area B-BX-BY* (Volumes 1 and 2)
- WHC-SD-EN-TI-019, *Hydrogeologic Model for the 200 East Groundwater Aggregate Area*

Detailed geologic cross sections for the OU are provided in Appendix C.

3.4.1 General Geologic Setting of the 200-BP-5 Operable Unit

The 200-BP-5 OU is located in the central portion of the Pasco Basin. Figure 3-6 presents a generalized structural geologic map of the Pasco Basin, showing the broad structural and topographic basin that was formed by deformation of thick sequences of older basalts flows, sedimentary interbeds between basalt flows, and younger suprabasalt sediments.

The Umtanum Ridge/Gable Mountain anticline is the principal structural feature within the 200-BP-5 OU. Gable Mountain (the most prominent topographic feature overlying the 200-BP-5 OU) and Gable Butte (located northwest of the OU boundary) are basalt bedrock surface expressions of the Umtanum Ridge anticline. This anticline is asymmetrical and locally overturned, with a major high-angle reverse fault on the north side. This structural feature creates a natural groundwater divide defining the near- and far-field areas of the OU.

The Cold Creek syncline lies to the south of the Gable Mountain structural lineament, and the Wahluke syncline lies to the north. The majority of the 200-BP-5 OU near-field area lies on the northern flank of the Cold Creek syncline, adjacent to south side of Gable Mountain. Basalt bedrock in this area regionally dips to the south. However, near the northern boundary of 200 East Area smaller basalt folds trend northwest-southeast and are present above the water table, creating some localized barriers to groundwater flow toward the north and east (Figure 3-7). The basalt surface structure in this area has been refined using seismic data gathered to support the 200-PO-1 OU RI (DOE/RL-2009-85) and the 200-BP-5 RI/FS work plan (DOE/RL-2007-18) (Figure 3-8).

In the far-field area of the 200-BP-5 OU, the Wahluke syncline is the primary structural feature; the basalt surface is much deeper beneath ground surface and does not influence groundwater flow. The Wahluke syncline is an asymmetric and relatively flat-bottomed structure.

The basalt flows of the Columbia River Basalt Group were deposited during Miocene time from source vents in southeastern Washington, northern Oregon, and western Idaho. Beneath the 200-BP-5 OU, the youngest and uppermost basalt flows are members of the Saddle Mountains Basalt Formation of the Columbia River Basalt Group (RHO-BWI-ST-4, *Geologic Studies of the Columbia Plateau: A Status Report*). The Saddle Mountains Basalt is divided into the Ice Harbor, Elephant Mountain, Pomona, Esquatzel, Asotin, Wilbur Creek, and Umatilla Members. The Elephant Mountain Member is the uppermost basalt unit and ranges in thickness from 0 to 25.5 m (0 to 83 ft) beneath most of the 200-BP-5 OU.

The Rattlesnake Ridge interbed of the Ellensburg Formation is present between the Elephant Mountain Member and the underlying Pomona Member and comprises the uppermost basalt-confined aquifer beneath most of the 200-BP-5 OU. In the central portion of the Pasco Basin, the Rattlesnake Ridge interbed ranges from 1.5 to 15 m (5 to 50 ft) in thickness and is composed of clayey basalt conglomerates, fluvial floodplain deposits, and ash tuffs and tuffites (RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*).

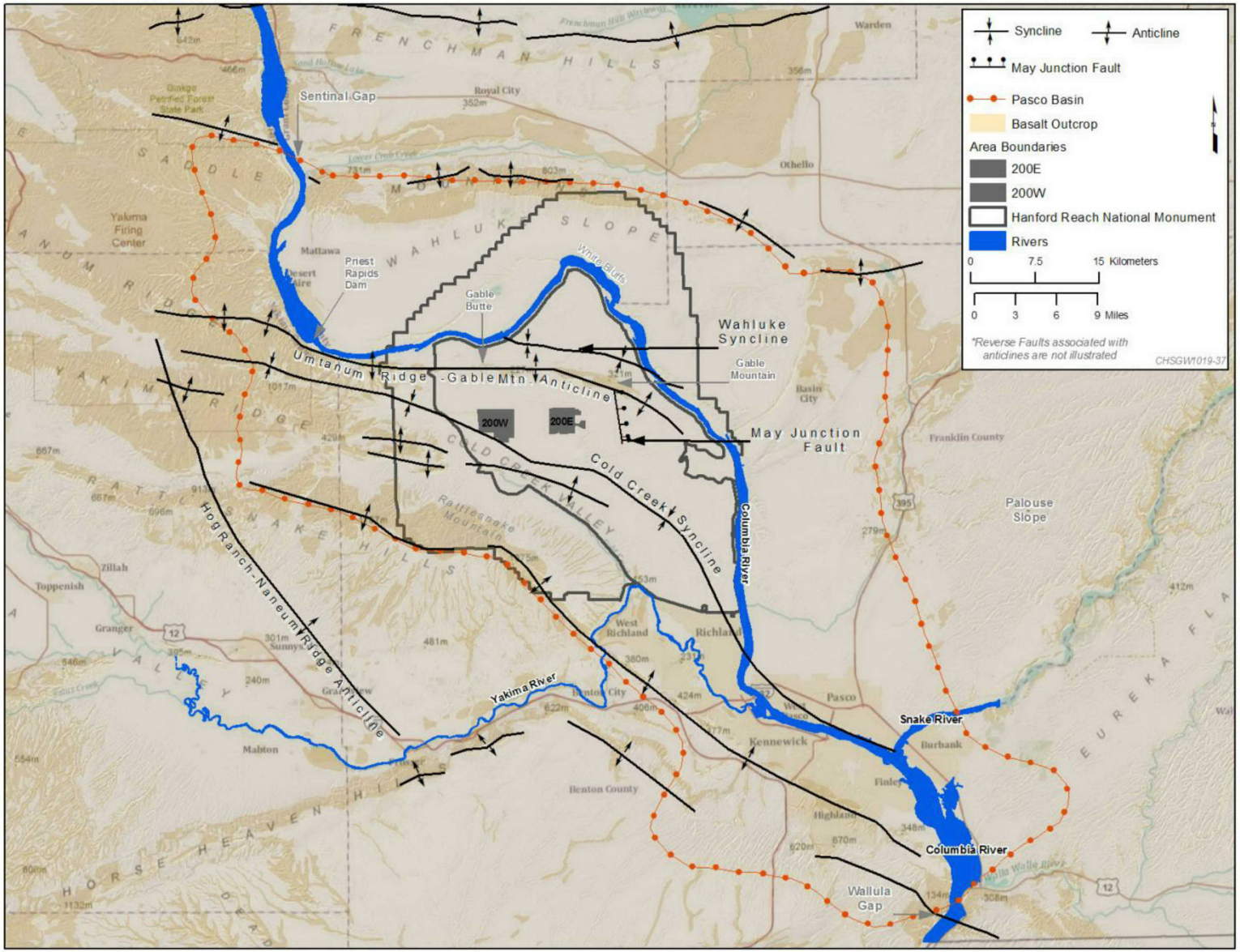


Figure 3-6. General Geologic Structures of the Pasco Basin and the Hanford Site

Unconsolidated and partly consolidated sediments of the Miocene through Holocene ages (approximately 8.5 million years to present) overlie the basalts (DOE/RL-95-100). The 200-BP-5 OU is focused on these suprabasalt sediments because they contain the uppermost unconfined aquifer system within the region. The geologic units present in the northwest far-field portion of the OU are generally continuous and extend to the Columbia River; however, in the Gable Gap region and much of the near-field area, some of the geologic units have been either removed by more recent paleoflood erosion or were locally not deposited on the uplifted basalt. In this area, the entire suprabasalt sequence thins across the uplifted basalt. The suprabasalt sedimentary sequence is thickest, ranging up to 200 m (650 ft) thick in the center of the Cold Creek syncline, southwest of 200-BP-5 OU. Figure 3-9 illustrates the pattern and location of the paleoflood erosional and depositional pathways and features.

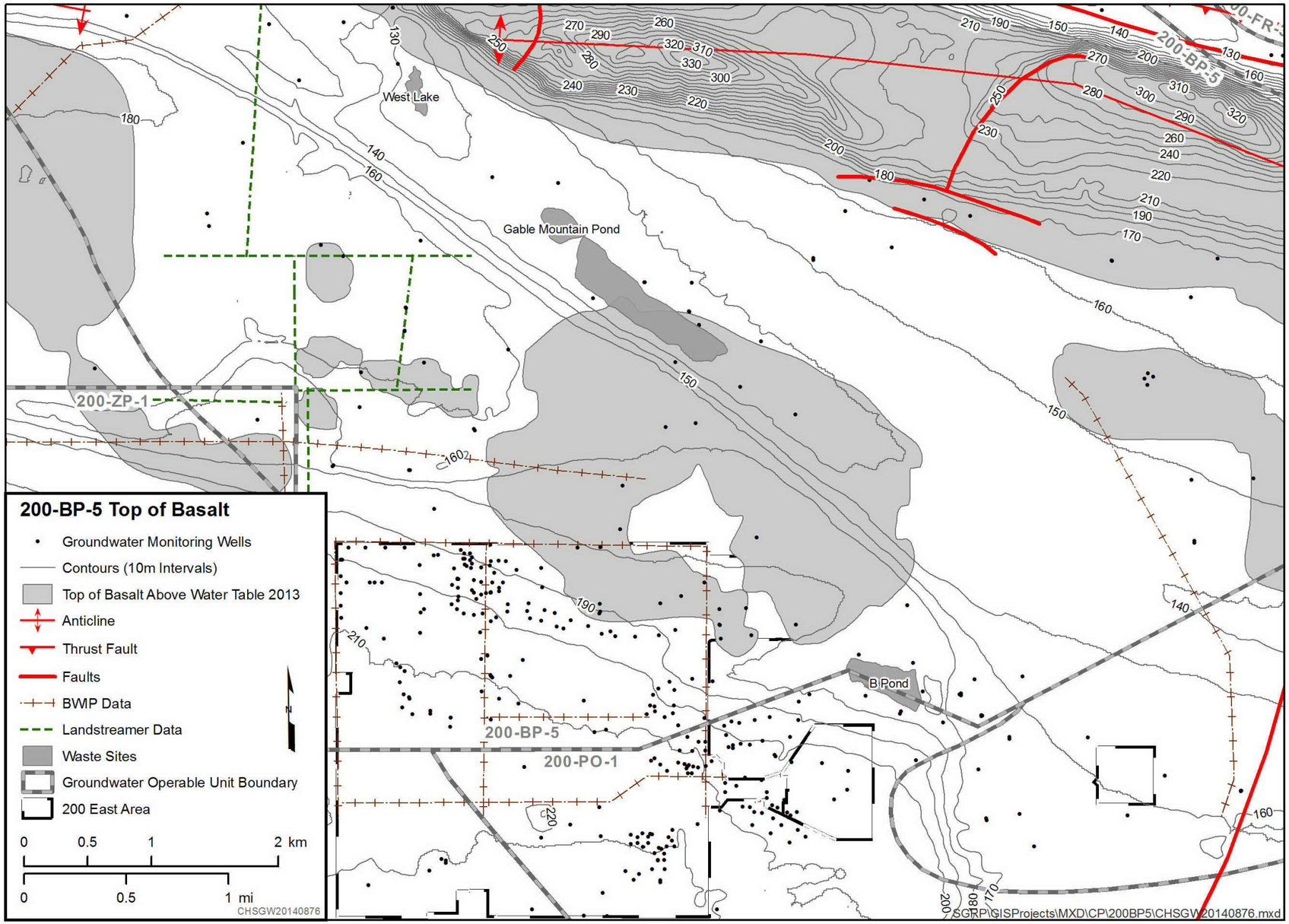
The geology of the suprabasalt sediments is relatively well defined in the 200-BP-5 OU near-field area based on the geophysical investigations and numerous boreholes drilled in support of characterization and facility monitoring of several decades. A lesser degree of confidence exists in the far-field area northwest of the 200 East Area because significantly fewer investigations have occurred. The suprabasalt sediments beneath the 200-BP-5 OU consist of extensive fluvial and slackwater deposits assigned to the Miocene- to Pliocene-age Ringold Formation, which are deposited on top of the basalt surface. The Ringold Formation is overlain in some areas by the Cold Creek unit (CCU), formerly named the pre-Missoula gravel, which is overlain with coarse-grained, Pleistocene-age, paleoflood deposits of the Hanford formation. Figure 3-10 presents a generalized stratigraphic column of the Hanford Site. Figure 3-11 presents representative photos of each major geologic unit in the OU.

3.4.2 200-BP-5 Operable Unit Near-Field Area Suprabasalt Geology

Sixteen new boreholes were drilled and completed as monitoring wells in the 200-BP-5 OU near-field area to support the RI (DOE/RL-2007-18) and to provide additional data in order to interpret the geology of the near-field area. Figure 2-1 shows the location of these boreholes, and Table 2-2 provides information on drill depths, well screen depths, and monitoring zones for the new wells.

The Ringold Formation comprises the oldest suprabasalt sediments, composed of fluvially deposited, gravel-dominated sediments designated as units A, B/D, C, and E. These high-energy deposits may be intercalated with fine-grained lake-bed (lacustrine) or overbank deposits designated as the Ringold lower mud (RLM) unit and the upper Ringold unit (Rtf). Within the 200-BP-5 OU near-field area, four sedimentary units are present (from oldest to youngest): fluvial gravel unit A (Rwia), RLM, fluvial gravel unit E (Rwie), and Rtf. These geologic units are designated as hydrostratigraphic units (HSUs) 9, 8, 5, and 4, respectively (Figures 3-10 and 3-11). Detailed lithologic descriptions of these units are provided in PNNL-12261 and PNNL-19702.

In the near-field area, Rwia (HSU 9) is the oldest Ringold Formation unit and directly overlies the Elephant Mountain Basalt. The Rwia displays a relatively flat surface that dips toward the axis of the Cold Creek syncline (southerly). The Rwia is not present in the northern portion of the near-field area where the basalt surface has been structural uplifted. This uplift created depositional thinning or exposed the older sediment to paleoflood removal (erosion) across this area (Figure 3-12). The Rwia ranges in thickness from over 30 m (100 ft) of the structure east and south of the 200 East Area to zero where it truncates within the near-field area. The position of the truncation boundary is approximate and is identified as the erosional limit of the post-Ringold fluvial incision from Pleistocene-age cataclysmic flooding that traversed the uplifted area. For the near-field area, Figure 3-12 depicts the stratigraphy and general structural and erosional relationships of the Ringold Formation and overlying Hanford formation sediment.



Source: Based on PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*.

Figure 3-7. Top of Basalt Structure Map, 200-BP-5 OU Near-Field Area in 2009

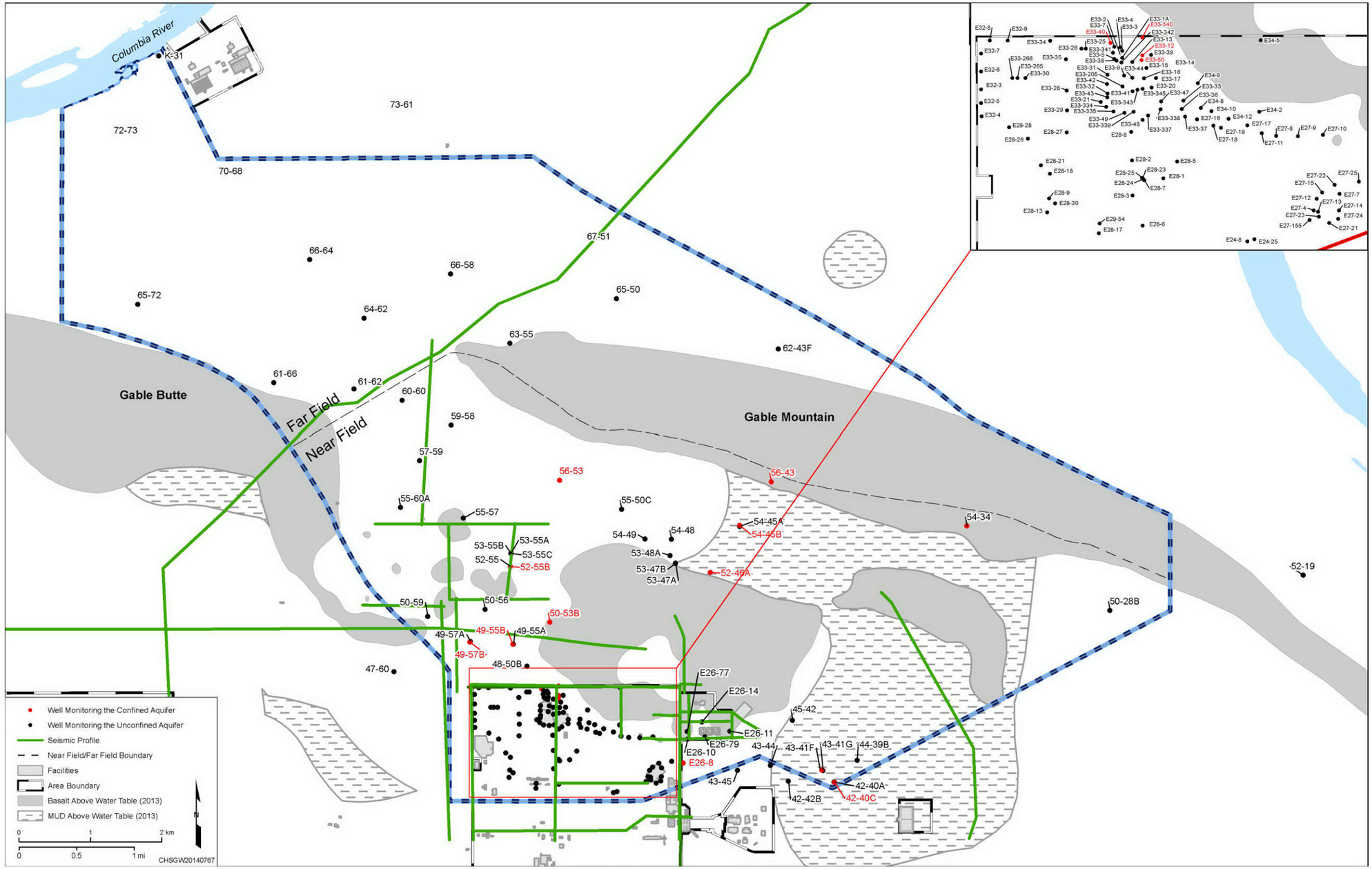
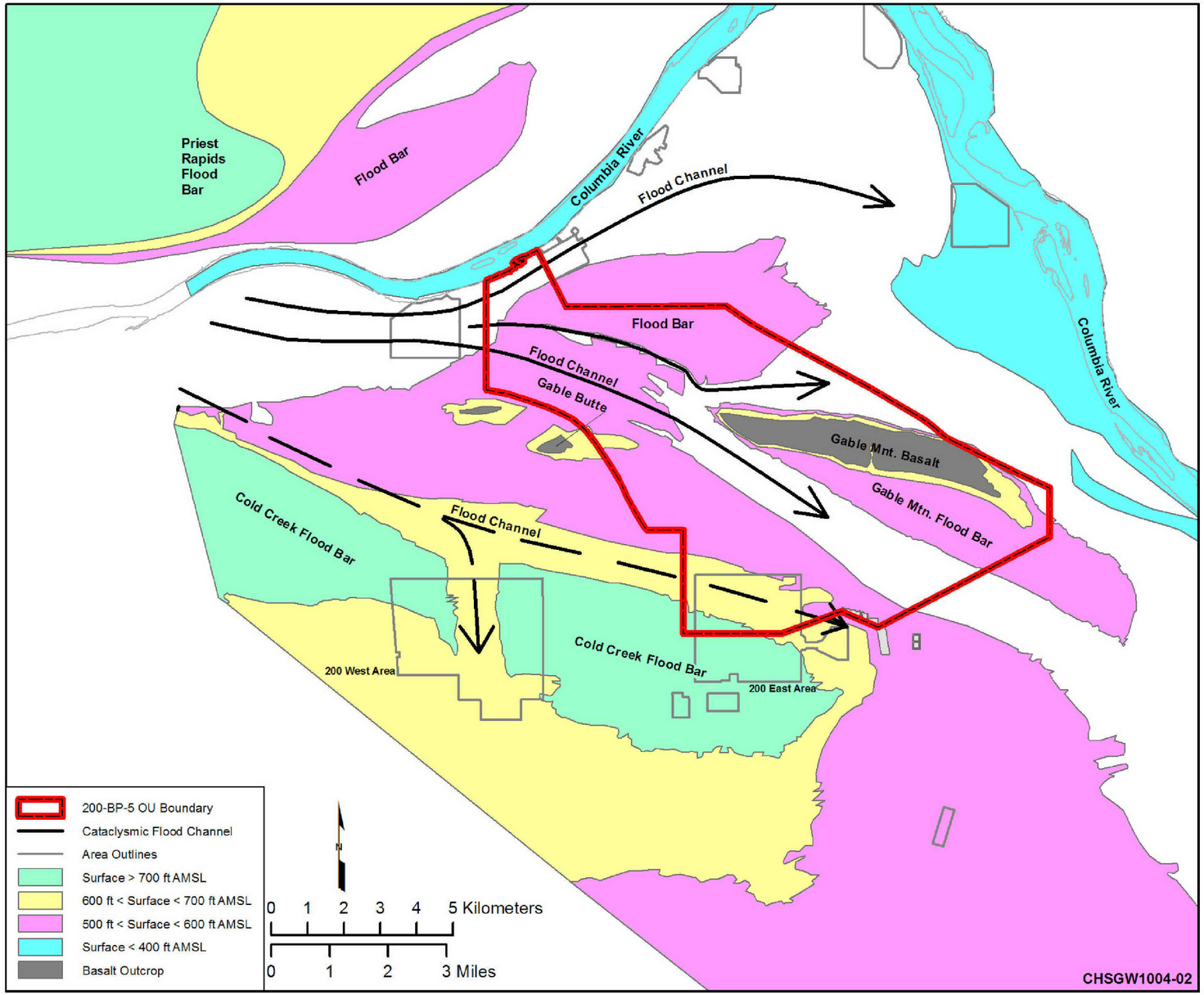


Figure 3-8. Seismic Profiles in the 200 East Area



Source: Based on PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*.

Figure 3-9. 200-BP-5 OU Pleistocene Paleo-Erosional Surface Topography

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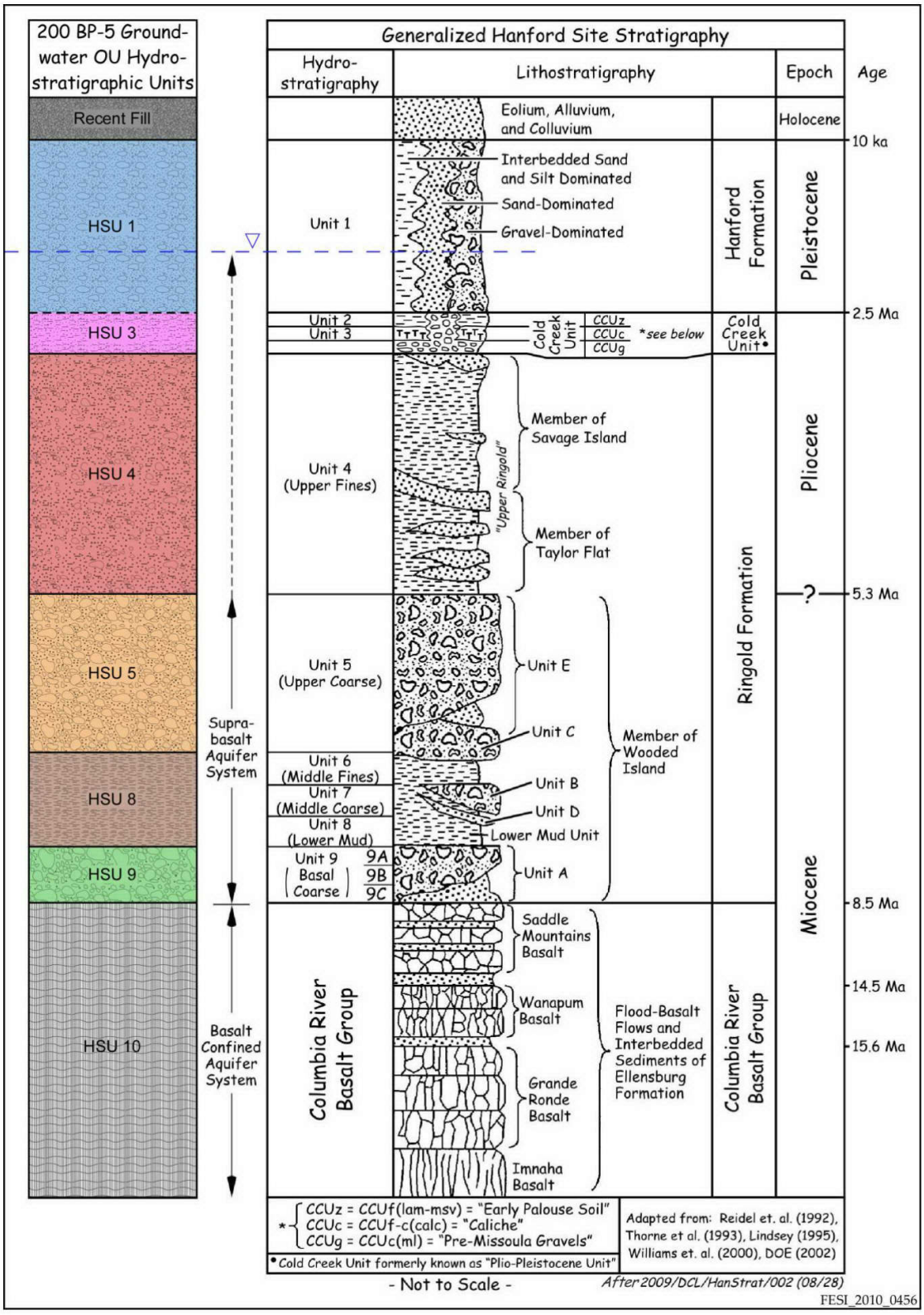
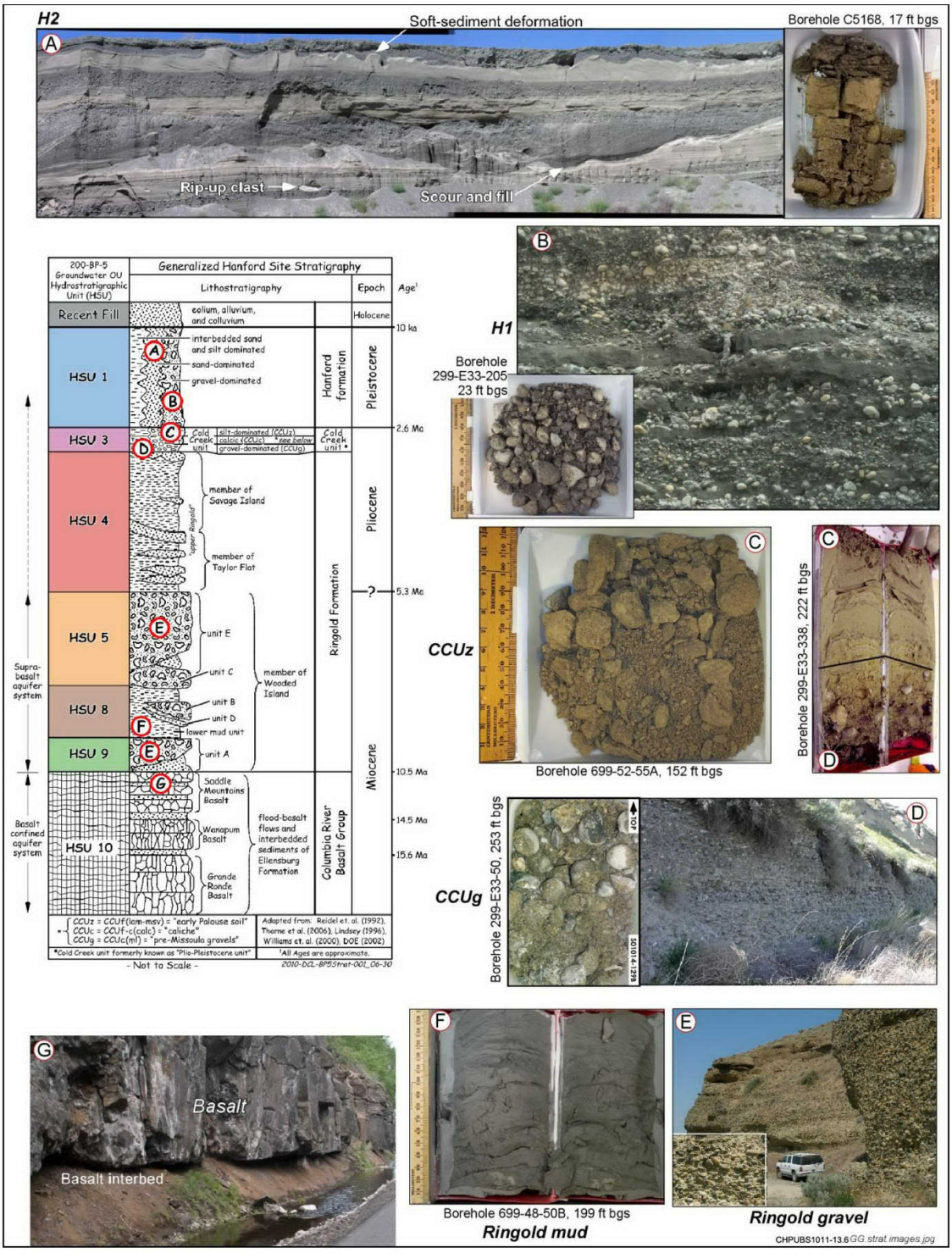
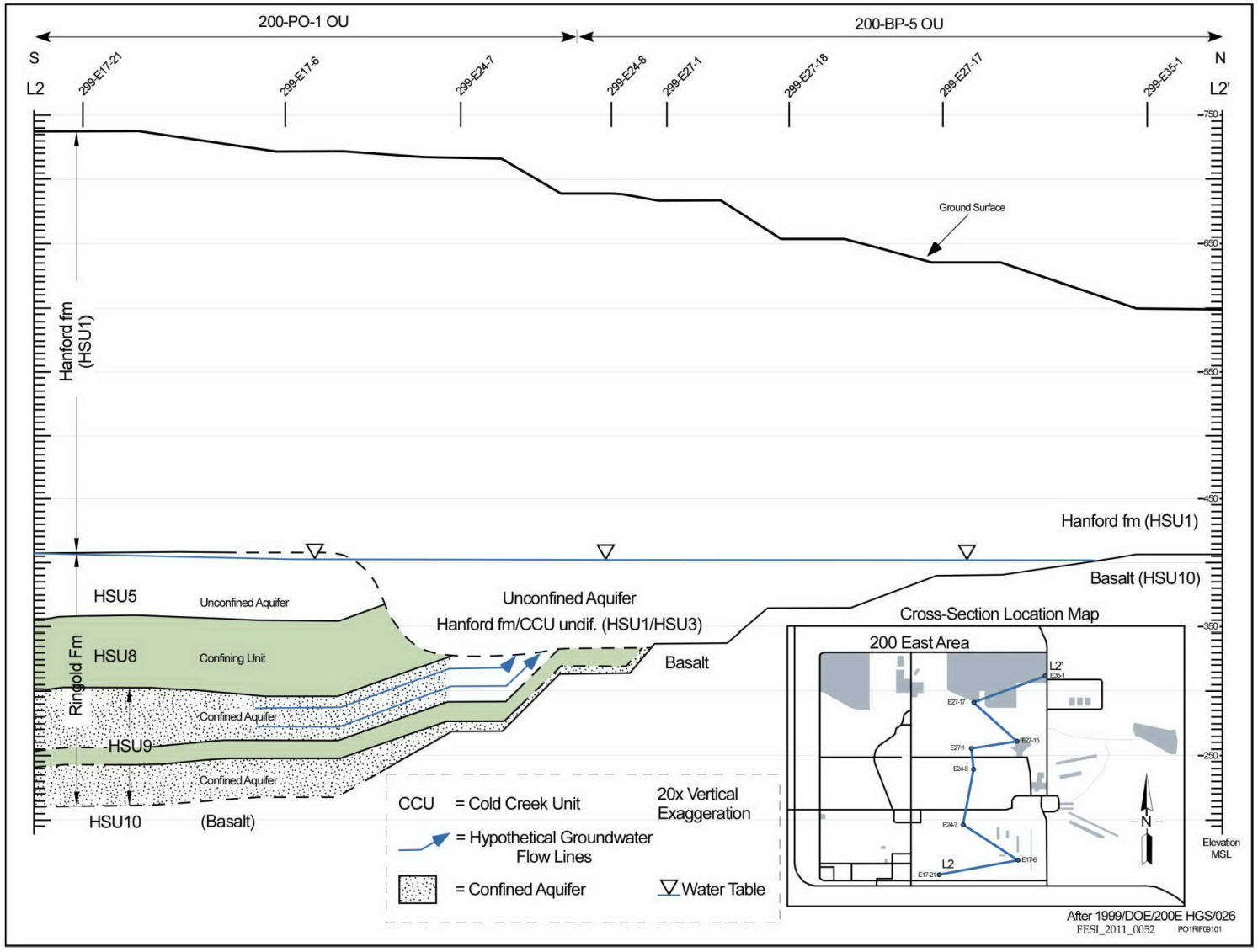


Figure 3-10. Comparison of 200-BP-5 OU Hydrostratigraphy to Hanford Site Stratigraphy



Source: Based on PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*.

Figure 3-11. Representative Photos of the Hanford Formation, CCU, Ringold Unit E, RLM, and Basalt



Source: Based on PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*.

Figure 3-12. 200-BP-5 OU Near-Field Area Hydrogeology Depicting Truncation of Ringold Units on Uplifted Basalt

Within the synclinal Cold Creek and Wahluke basins, the RLM (HSU 8) is a regionally extensive, relatively thick, low-permeability, fine-grained sequence of overbank, paleosol, and lacustrine silt and clay with minor sand and gravel, but it occurs within a relatively small area within the southeastern portion of the 200-BP-5 OU. Where the RLM occurs below the water table, it forms a confining unit within the suprabasalt aquifer system, separating the lower saturated unit Rwia (HSU 9) from the overlying saturated Ringold unit E (HSU 5). Where the RLM is at or above the water table, it creates a relative aquitard, a "no-flow" groundwater boundary. The uppermost unconfined aquifer is contained within the geologic units overlying the RLM (i.e., Rwie and saturated Hanford formation or Cold Creek sediments) where present or the top of basalt where the RLM is absent. The RLM sequence thickens and dips to the southeast into the syncline, similar to the underlying Rwia. As with the Rwia, the RLM is absent throughout much of the 200-BP-5 OU near-field area, including the northern portion of the 200 East Area, and to the north and northwest of the 200 East Area. The RLM is interpreted to underlie most of the far-field area, ranging in thickness from 0 m to more than 69 m (0 to 226 ft) thick.

Within the 200-BP-5 OU near-field area, the Rwie (HSU 5) is the uppermost coarse-grained Ringold unit and is composed of fluvial gravel that grades upward into interbedded fluvial sand and silt. Unit E overlies the RLM and is present is a relatively small area in the western portion of the OU and in the eastern part of the OU. Its up-dip limit is interpreted to be the same as that of the RLM (Figure 3-12). Unit E is present under most of the southern half of the 200 East Area (south of the 200-BP-5 OU) but has been mainly removed by uplift and subsequent erosion or depositional thinning in the northern and eastern portion of the 200 East Area (southern near-field area). The Rwie ranges from 0 m to more than 54 m (0 to 177 ft) thick.

Where present, the Rtf (HSU 4) overlies Rwie. The Rtf occurs as discontinuous deposits throughout the near-field area. The Rtf ranges in thickness from 0 m to more than 25 m (0 to 80 ft). The Rtf is a silty, sandy, fine-grained unit, and data indicate that it is less permeable than the underlying Rwie silty, sandy gravel.

The CCU (HSU 3) represents both coarse-grained and fine-grained facies. The coarse-grained facies typically underlies the fine-grained facies and is a clast-supported, sandy pebble/cobble gravel that sharply truncates the underlying Ringold Formation (HSU 4, and/or HSU 5, or HSU 9) or basalt. This highly permeable, gravelly unit is present as discontinuous deposits throughout the 200-BP-5 OU near-field area, occurring mainly in the southern half of the near-field area of the OU. The CCU fine-grained (CCU_z) facies is composed of fluvial and eolian fine sands and silt. The CCU ranges from 0 m to more than 41 m (0 to 135 ft) thick.

The Hanford formation (HSU 1) is the youngest geologic sequence within the 200-BP-5 OU. This unit consists of glaciofluvial sediment deposited during cataclysmic Ice Age flooding. HSU 1 is subdivided into three main facies (silt-, sand-, and gravel-dominated) that vary vertically and laterally across the region and are difficult to correlate from area to area. In the southern portion of the near-field area (southern 200 East Area), the Hanford formation sediments unconformably overly the older Ringold Formation units (Rwie, RLM, and Rwia) and may only comprise the very uppermost portion of the unconfined aquifer. In the other portions of the 200-BP-5 OU near-field area, the Hanford formation sediments were mainly deposited unconformably on top of basalt and form part or all of the sediment in the unconfined suprabasalt aquifer. The vadose zone in the 200-BP-5 OU near-field area is primarily composed of the Hanford formation. The thickness of the Hanford formation ranges from 0 m to more than 109 m (0 to 357 ft).

Clastic dikes are not known to exist in great numbers within the Hanford formation sediments of the 200-BP-5 OU but have been mapped extensively at the Hanford Site south of the 200-BP-5 OU

(PNNL-14224, *Influence of Clastic Dikes on Vertical Migration of Contaminants in the Vadose Zone at Hanford*). Clastic dikes normally occur as cross-cutting, vertically oriented cracks or fissures in the formation that are typically filled with sand, silt, clay, and minor coarser debris. Their origin is not well understood but is likely associated with hydraulic ejection during or immediately following Pleistocene cataclysmic flooding, mass wasting, earthquakes, and other geologic processes. Clastic dikes occurring in vadose zone sediments have the potential to influence the movement of soil moisture and contaminants (BHI-01103, *Clastic Injection Dikes of the Pasco Basin and Vicinity*), but no data exist about the potential influence of clastic dikes within the aquifer.

Holocene surficial deposits in the 200 East Area are dominated by very fine-grained to medium-grained, and occasionally silty, eolian sheet sands. These deposits have been removed or reworked over much of the area by past construction activities.

3.4.3 200-BP-5 Operable Unit Far-Field Area Suprabasalt Geology

The 200-BP-5 OU far-field area monitoring wells are shown in Figure 2-3. Locations of the hydrogeologic cross sections presented in this section are illustrated in Figure 3-13. The geologic nomenclature developed during the past several decades for the area north of Gable Mountain (100 Areas) is simpler, and informal, resulting in a slightly different nomenclature than the near-field area south of Gable Gap. The 100 Area geologic units are grouped into four main HSU intervals: (1) HSU 9, consisting of geologic unit Rwia; (2) HSU 8, designated informally as the RUM, which is composed of a thick, undifferentiated, fine-grained sequence of sediment consisting of the RLM, with Ringold Formation units B/D stratigraphically included within the RLM interval, and the younger Ringold Formation upper fine unit; (3) HSU 5, consisting of Rwie; and (4) HSU 1, which is the undifferentiated Hanford formation. Some of the geologic units are combined to define the primary HSUs needed to facilitate groundwater modeling efforts. The geologic units were combined based on similarities in hydraulic properties, to incorporate units that are not continuous, or areas where uncertainty exists about the correlation and extent of the geologic units.

In the 200-BP-5 OU far-field area, the suprabasalt aquifer thickness is significantly greater than in the near-field area on the Central Plateau (Figure 3-14). This is mainly because of the structural differences in elevation of the basalt surface between these areas. In the far-field area, the Ringold Formation is the oldest suprabasalt sediment and is the primary sequence of units that make up the suprabasalt aquifer system. The relatively widespread Rwia and Rwie sediments are gravel-dominated units (from oldest to youngest). These high-energy deposits are separated by a thick, undifferentiated sequence of fine-grained lacustrine and overbank deposits designated as the RUM. The RUM consists of the RLM and younger sediments composed of predominantly fine-grained sequences of fine sand to silt and clay and represents relatively low-permeability units. The RUM has not been correlated south of Gable Mountain. Limited geologic mapping of units B/D and C indicates that these units may not be continuous or extend across the entire 100 Areas. Units B and D are relatively thin or isolated by the deeper, low-permeability RUM. The RUM is relatively thick and persists throughout most of the far-field area of the 200-BP-5 OU.

The Rwia (HSU 9) is the oldest suprabasalt sediment and directly overlies the Elephant Mountain Basalt. Within the far-field area, the Rwia thickens to greater than 15 m (50 ft) in the northern portion of the OU. This unit truncates (i.e., is not present) beneath the central portion of the 200-BP-5 OU, near Gable Gap (Figure 3-14).

The RUM (or HSU 8) forms a semiregional confining unit within the suprabasalt aquifer system, separating the lower saturated Rwia (HSU 9) sediment from the overlying saturated Rwie (HSU 5) or Hanford formation sediment (whichever is present). In the far-field area, the uppermost unconfined aquifer within the suprabasalt sedimentary sequence is contained within the geologic units overlying

the RUM (i.e., Rwie and saturated Hanford sediments). The RUM (HSU 8) is more than 90 m (300 ft) thick in the northwestern and northeastern portion of the OU. This unit truncates beneath the central portion of the OU near Gable Gap due to structural uplift of the basalt and historical cataclysmic flood erosional events through Gable Gap.

Within the 200-BP-5 OU far-field area, the Rwie (HSU 5) overlies the RUM, where present. The Rwie thickens to greater than 45 m (150 ft) in the northwestern and northeastern portions of the OU. This unit truncates beneath the central portion of the OU near Gable Gap and the Gable Mountain reverse fault.

The upper Ringold unit (HSU 4) is not differentiated from other units within the far-field area. The CCU (HSU 3) is not known to be present in the 200-BP-5 OU far-field area.

The Hanford formation (HSU 1) forms the youngest geologic sequence within the 200-BP-5 OU far-field area. The Hanford formation sediments are generally the most permeable of all the suprabasalt sediments. In the far-field area, the Hanford formation (HSU 1) sediments are deposited unconformably above HSU 5 and HSU 8, where these sediments are present. Where the HSU 5 is not present, the HSU 1 is deposited unconformably on top of HSU 8 or basalt (HSU 10). In the far-field area, HSU 1 typically comprises the vadose zone interval above the suprabasalt aquifer.

3.5 Soils

Within the Central Plateau, the groundwater OUs are administratively separated from vadose zone OUs where contaminant sources are located. This RI report discusses groundwater conditions in the saturated zone of the 200-BP-5 OU. Characterization of the unconsolidated sediments and soils of the vadose zone over the 200-BP-5 OU saturated zone is not part of the scope of this document and is addressed in documents pertaining to the vadose zone OUs.

3.6 Hydrogeology

Groundwater migration is the primary contaminant transport pathway for this OU. This section describes the basalt and suprabasalt aquifer systems in the 200-BP-5 OU, as well as the influence of geologic structures, aquifer parameters, and aquifer recharge on groundwater flow and contaminant transport through the OU.

3.6.1 200-BP-5 Operable Unit Hydrostratigraphy

The hydrostratigraphic column for the 200-BP-5 OU presented in Figure 3-10 defines the geologic units included in each HSU. The following two major aquifer systems include these HSUs:

- Basalt-confined aquifer system (HSU 10)
- Suprabasalt aquifer system (HSU 9, HSU 8, HSU 5, HSU 4, HSU 3, and HSU 1)

The vadose zone comprises all sediments above the water table and is not administratively part of the 200-BP-5 OU; however, the vadose zone is considered the pathway for contaminant migration to the groundwater and, thus, the 200-BP-5 OU. The vadose zone is mainly composed of HSU 1 and HSU 3, and perched water has been identified in some boreholes in the vicinity of WMA B-BX-BY near the water table within HSU 3. In a few areas, HSU 4, HSU 5, and HSU 8 may also occur within the vadose zone.

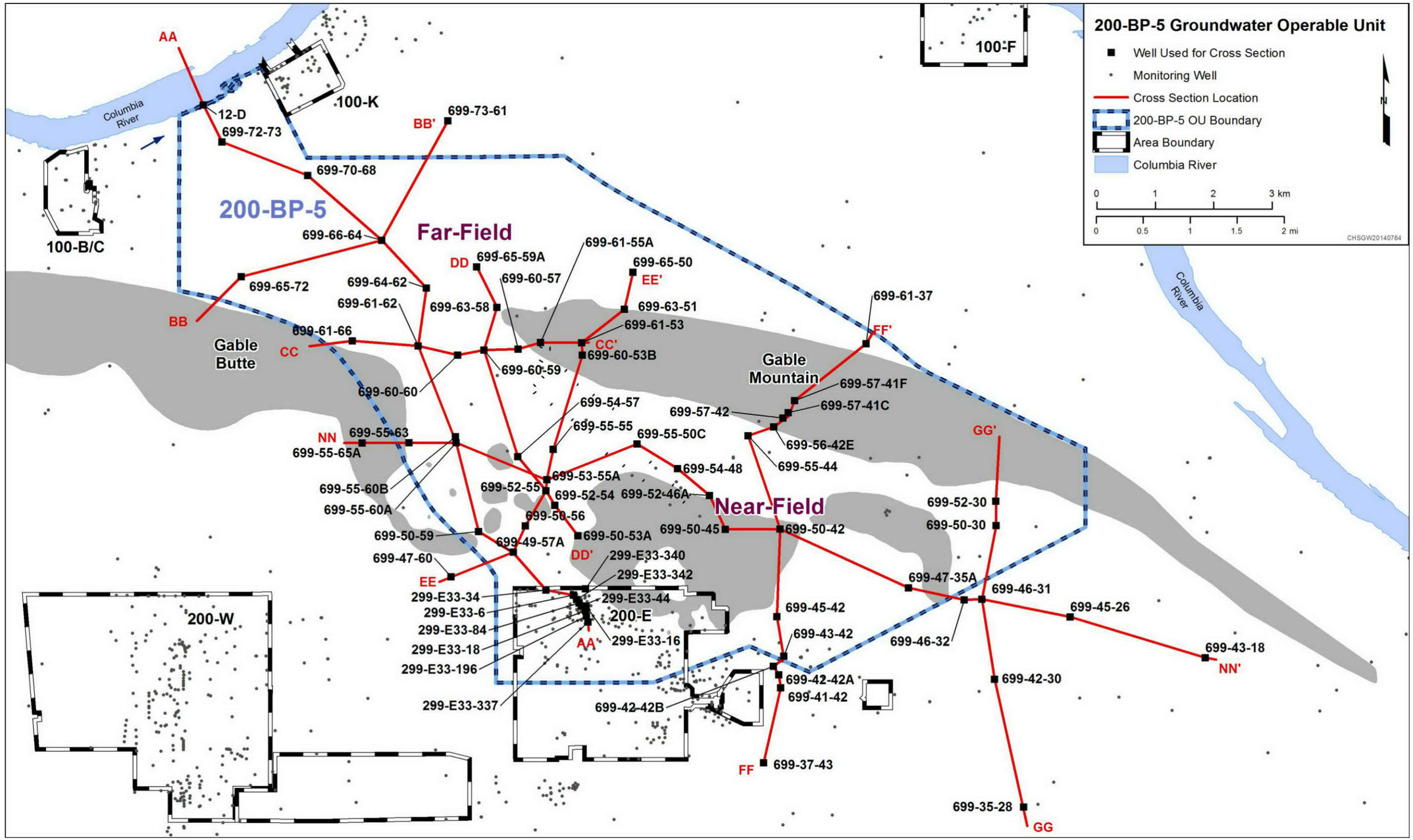
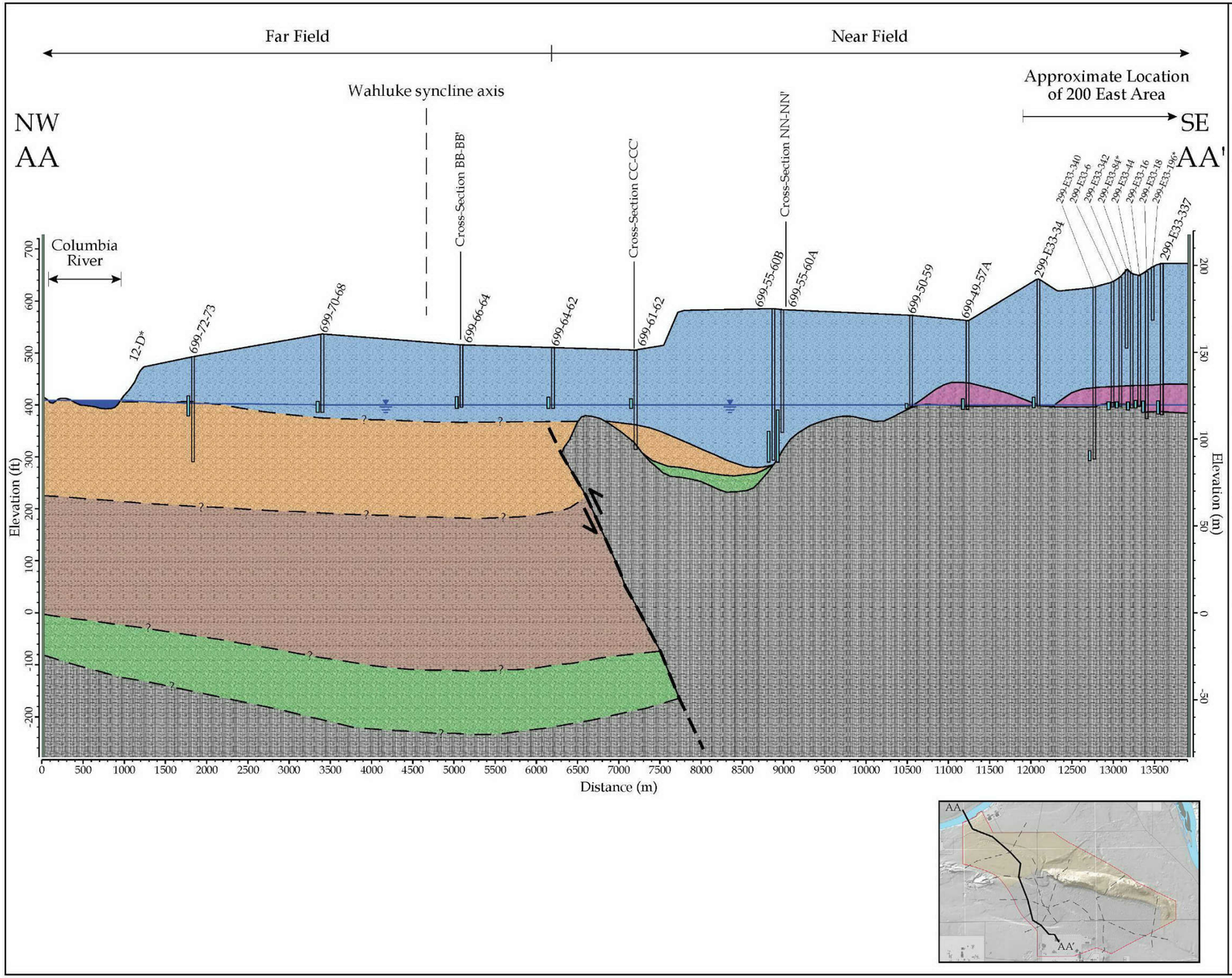


Figure 3-13. Hydrogeologic Cross-Section Location Map, 200-BP-5 OU



Hydrostratigraphic Unit	Associated Lithologic Units
HSU 1	Undifferentiated Hanford fm. Recent Fill - H1 - H2 - H3
HSU 3	Undifferentiated Cold Creek Unit - CCU g (gravel dominated) - CCU z (silt dominated)
HSU 5	Undifferentiated Ringold - Ringold Unit E - Ringold Unit C
HSU 8	Undifferentiated Ringold Upper Mud - RUM, upper - Rwib&d - RUM, lower
HSU 9	Undifferentiated Ringold Unit A - Rwia, upper - Rwia, mud - Rwia, lower
HSU 10	Basalt (undifferentiated, including sedimentary interbeds)

Contact dashed where inferred

Water level from March 2009 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Wells with no screen data available

20X Vertical Exaggeration

CHSGW20140725

Figure 3-14. 200-BP-5 OU Hydrogeologic Cross-Section AA-AA'

3.6.1.1 Upper Basalt-Confined Aquifer

The HSU 10 (the Columbia River Basalt Group) includes numerous basalt flows (members) interlayered with sedimentary interbeds of the Ellensburg Formation (Section 3.4). Figure 3-15 is a conceptual drawing of the upper basalt-confined aquifer. The flow top of the lower Pomona Basalt Member, the Rattlesnake Ridge interbed (Ellensburg Formation), and the flow bottom of the upper Elephant Mountain Basalt Member comprise the upper basalt-confined aquifer within the OU. In most parts of the 200-BP-5 OU, the interior of the Elephant Mountain Basalt flow is intact and acts as an aquitard to confine water beneath it (upper basalt-confined aquifer). A description of where leakage occurs through erosional windows in the Elephant Mountain Basalt is included in Section 3.6.5.3. Three of the recent RI wells targeted the upper basalt-confined aquifer to characterize this aquifer more accurately in the near-field area. These wells include 299-E33-340, 299-E33-50, and 699-52-55B.

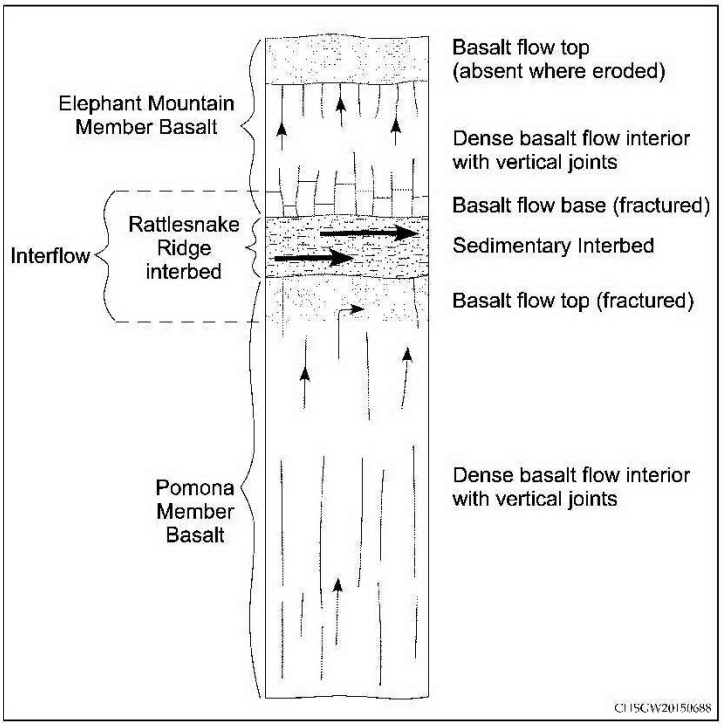


Figure 3-15. Conceptual Diagram of Relative Magnitude and Direction of Groundwater Flow in the Elephant Mountain/Pomona Basalt Interflow Zone in the 200-BP-5 OU

Within the 200-BP-5 OU, the Elephant Mountain Basalt ranges in thickness from 0 to 25 m (0 to 82 ft), the Rattlesnake Ridge interbed ranges in thickness from 0 to 16 m (0 to 52 ft), and the total thickness of the underlying Pomona Member Basalt is estimated to range from 0 to 60 m (0 to 197 ft) (PNNL-15955, *Geology Data Package for Single-Shell Tank Waste Management Areas at the Hanford Site*). Beneath the Pomona Basalt is the Selah interbed.

3.6.1.2 Suprabasalt Aquifer System

The suprabasalt aquifer system is composed of six different HSUs within the 200-BP-5 OU. This aquifer system includes an unconfined aquifer (also called the water table aquifer), a confining unit, and a confined to semiconfined aquifer (called the Ringold confined aquifer). Figure 3-16 provides an aquifer thickness map for the suprabasalt aquifer system in the near-field area based on borehole and recent geophysical data and illustrates the large variability of suprabasalt aquifer sediment thickness.

The Ringold Formation in the 200-BP-5 OU includes four HSUs (in order of oldest to youngest): HSU 9, HSU 8, HSU 5, and HSU 4. HSU 8 has relatively low permeability and is considered to be an aquitard. The geologic units that comprise these HSUs are described in Section 3.4. General hydrogeologic properties of the Ringold Formation HSUs, as they occur within the OU, are summarized as follows:

- HSU 9 (Rwia) is a silty, sandy gravel that typically is confined by HSU 8 (RLM). If the overlying RLM is thin or absent nearby (because of erosion), then HSU 9 may occur as a semiconfined (leaky) aquifer. If the overlying RLM is completely absent, then HSU 9 occurs as part of the unconfined aquifer. Saturated thickness of HSU 9 ranges from 0 to 22 m (0 to 71 ft) in the OU.
- HSU 8 (RLM) is a silt-rich mud unit that acts as an aquitard separating HSU 9 from the overlying Ringold and Hanford unconfined aquifer sediments. HSU 8 thickness ranges from 0 to 69 m (226 ft) in the OU.
- HSU 5 (Rwia and Rwie) comprises sandy gravel units with moderate permeability and, where saturated, part of the unconfined aquifer. Saturated thickness of HSU 5 ranges from 0 to 51 m (0 to 167 ft) in the OU.
- HSU 4 (Rtf) is a silty-sandy gravel to silty sand with moderate permeability and, where saturated, part of the unconfined aquifer. HSU 4 comprises the uppermost Ringold sediments. The saturated thickness of HSU 4 ranges from 0 to 24 m (0 to 80 ft) in the OU.

The water table represents the upper boundary of the unconfined aquifer. As described in Section 3.6.2, the composition of the unconfined aquifer varies spatially within the OU. In much of the near-field area, the unconfined aquifer is mainly composed of very permeable sediments defined by HSU 1 and HSU 3. In the far-field area, significant thicknesses of HSU 5 and HSU 1 contain the unconfined aquifer. In the southeast portion of the near-field area where HSU 8 has been eroded but some older Ringold deposits remain, the unconfined aquifer can consist partly of HSU 9 sediments (Figure 3-12).

The HSU 8 or HSU 10 (when HSU 8 is not present) represents the base of the unconfined aquifer in the OU. Where porous basalt flow-top features occur within the top surface of basalt, the groundwater within the flow top may be hydraulically connected with the unconfined aquifer (PNNL-17675, *BP-5 Remedial Investigation Slug-Test Characterization Results for Well 699-52-55A*; Section 2.10 of DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). However, in most of the near-field area, the top surface of basalt has relatively low permeability and is considered to be the base of the suprabasalt aquifer.

3.6.1.3 Perched Water within the Vadose Zone

Contaminated perched groundwater occurs within a localized CCU silt facies of HSU 3 (CCU_z) in several borings drilled near WMA B-BX-BY. The perched zone is above the regional water table and is administratively included within the 200-DV-1 OU, which was created in 2010 to support remedy selection for waste sites with deep vadose zone contamination. An update to the perched zone CSM, remedial approach, and a discussion of recommendations for ongoing and future field activities are presented in SGW-53604, *Path Forward Recommendations Report for the Uranium Contamination in the B Area*.

3.6.2 Hydraulic Head, Flow Direction, and Aquifer Extent

Significant differences in hydraulic head and aquifer extent exist among the upper basalt-confined aquifer, the Ringold confined aquifer, and the unconfined aquifer. Water level contour maps for each aquifer derived from 2013 water level data are presented, and hydraulic head and the horizontal extent of each aquifer are described in the following subsections.

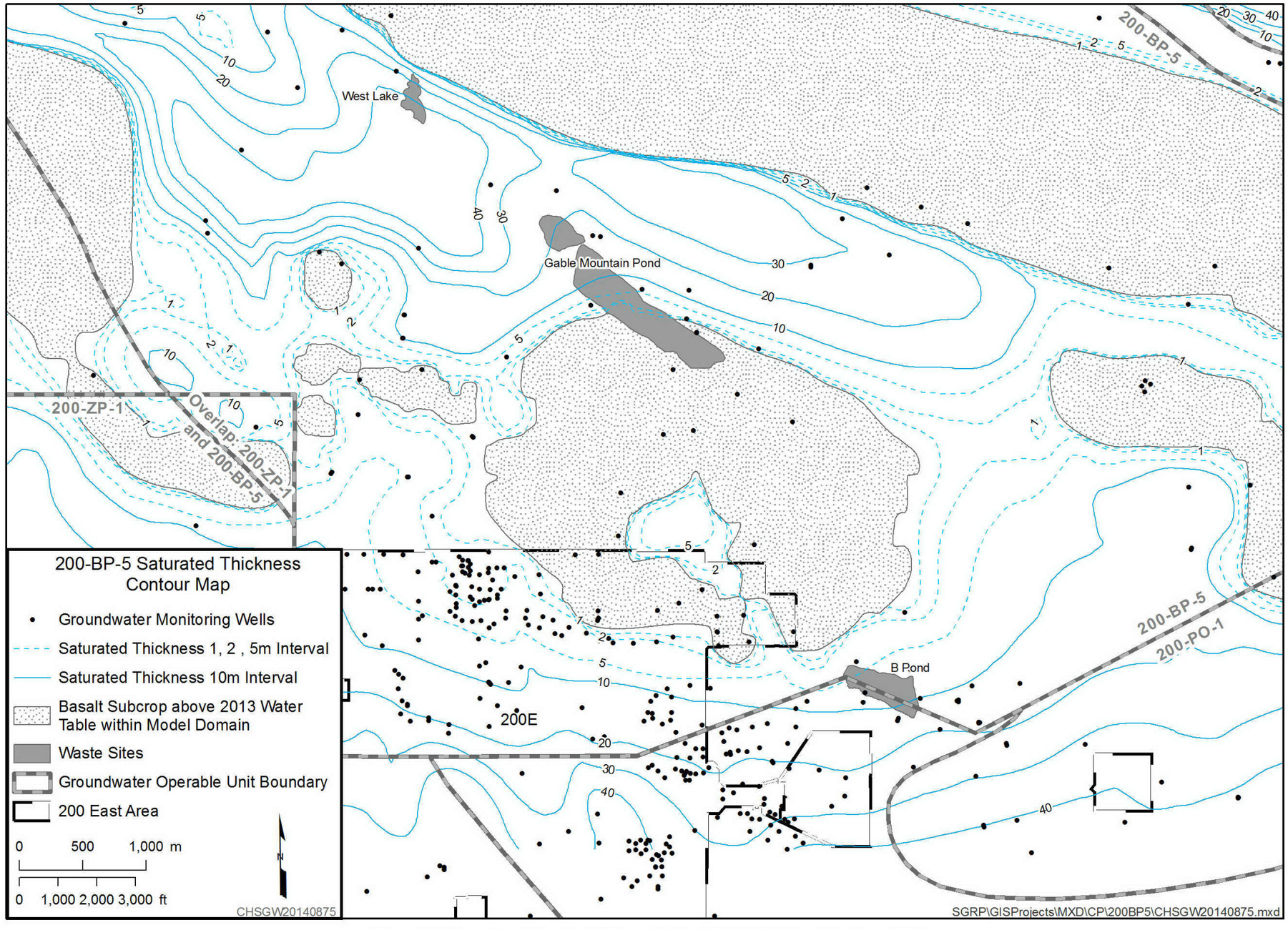


Figure 3-16. Suprabasalt Aquifer Thickness in the 200-BP-5 OU Near-Field Area, 2009

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3.6.2.1 Upper Basalt-Confined Aquifer

A 2013 potentiometric map for the upper basalt-confined aquifer is presented in Figure 3-17. The groundwater contours suggest a northeast groundwater flow into the Central Plateau within the upper basalt-confined aquifer. No groundwater contours are drawn north of Gable Gap because of the limited number of deep monitoring wells in the far-field area between Gable Gap and the Columbia River (DOE/RL-2010-11).

The upper basalt-confined aquifer, located within the Rattlesnake Ridge and underlying interbeds, is an important factor for determining the potential for offsite migration of contaminants. The horizontal extent of the upper basalt-confined aquifer (within the Rattlesnake Ridge) is interpreted to occur in all areas of the OU, except in the structurally uplifted and eroded region near Gable Gap, where the Rattlesnake Ridge interbed has been removed by erosion.

3.6.2.2 Ringold Confined Aquifer

A potentiometric map for the Ringold confined aquifer (HSU 9) is presented in Figure 3-18, which illustrates the limited extent of this aquifer in the near-field area. Figure 3-18 illustrates the boundary of the HSU 9 confined aquifer and the interpreted groundwater flow directions (mainly northeast, and some southwest flow) into regions where intercommunication with the unconfined aquifer may occur (i.e., where HSU 8 is absent and only the unconfined aquifer is present). This intercommunication between aquifers is discussed further in Section 3.6.5.3.

In the far-field area, the Ringold confined aquifer is located deep beneath the unconfined aquifer within HSU 9, although little mapping of the Ringold confined aquifer exists in the far-field area due to a lack of deep boreholes in this area. Hydrogeologic cross-section AA-AA' (Figure 3-14) shows the occurrence of the HSU 9 confined aquifer in the far-field area.

3.6.2.3 Unconfined Aquifer

Figure 3-19 provides a 2013 water table map showing the extent of the unconfined aquifer across the Hanford Site and the 200-BP-5 OU. Historically, high-volume wastewater releases to ponds near the 200 East Area (i.e., Gable Mountain Pond and B Pond) created large groundwater recharge mounds that produced radial groundwater flow away from the discharge points. These mounds interacted hydraulically with large mounds produced by discharges to T Swamp, U Pond, and S Pond in 200 West Area, as well as the mounding generated by cooling water discharges in the 100 Areas. These recharge mounds were largely responsible for defining the historical groundwater gradient (both direction and magnitude) within the 200-BP-5 OU. Due to the elevated groundwater near Gable Mountain Pond during operations north of the 200 East Area and the mound generated by cooling water discharges at the 100-K Area during reactor operations, groundwater beneath the 200 East Area was prevented from migrating rapidly north toward the Columbia River until the early 1970s. Following the discontinuation of cooling water discharges in the 100-K Area, the mound beneath Gable Mountain Pond became the dominant groundwater hydraulic feature near the 200 East Area. The reduction in groundwater disposal near the 100-K Area and increases in disposal in the Central Plateau increased the gradient across the 200-BP-5 OU near-field area, increasing the velocity of contaminated groundwater migrating northward toward the Columbia River. As the magnitude of the recharge mound beneath Gable Mountain Pond diminished, the recharge mound beneath B Pond became the dominant feature in 200 East Area.

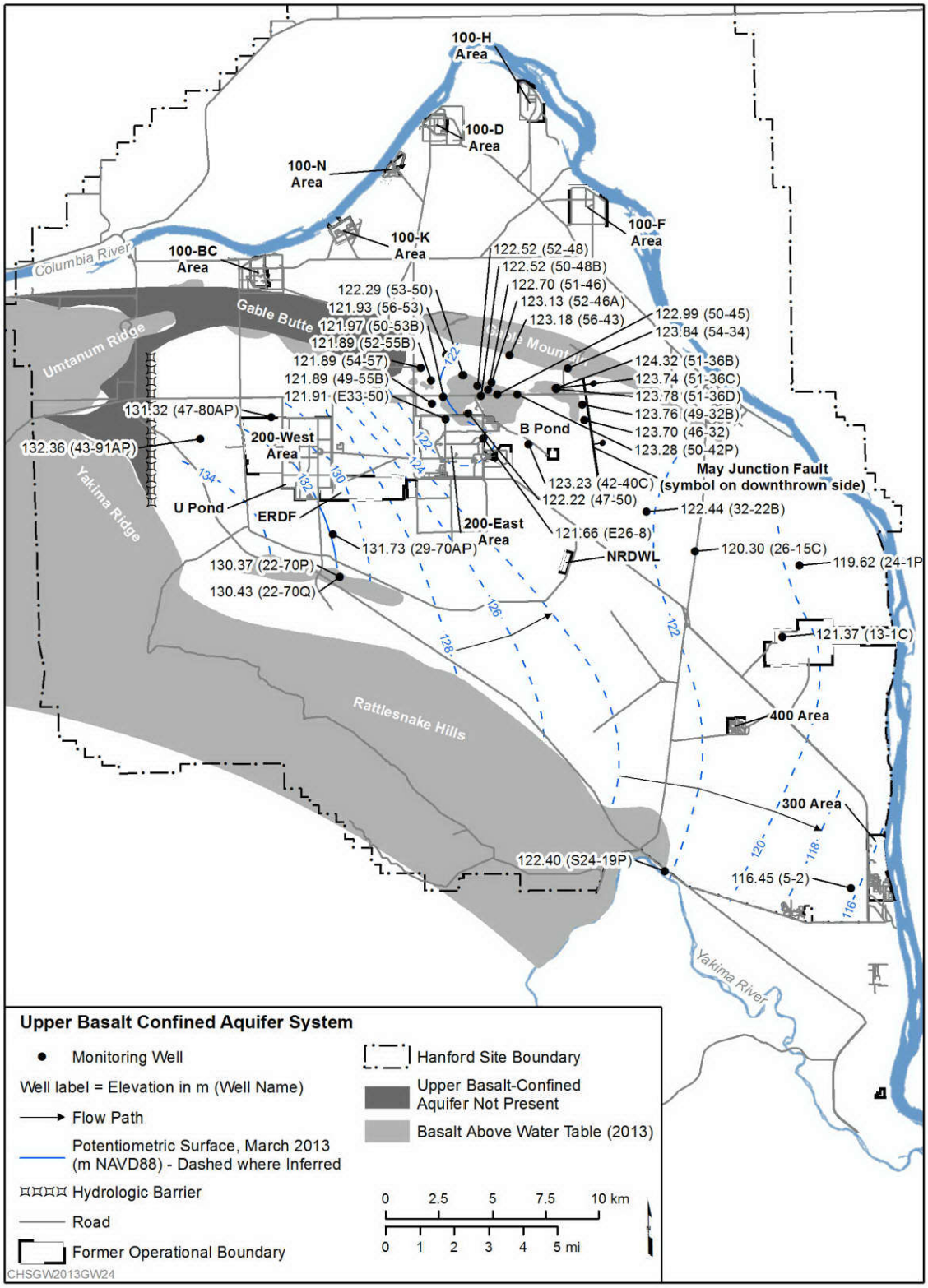


Figure 3-17. Potentiometric Surface Map of the Upper Basalt-Confined Aquifer, March 2013

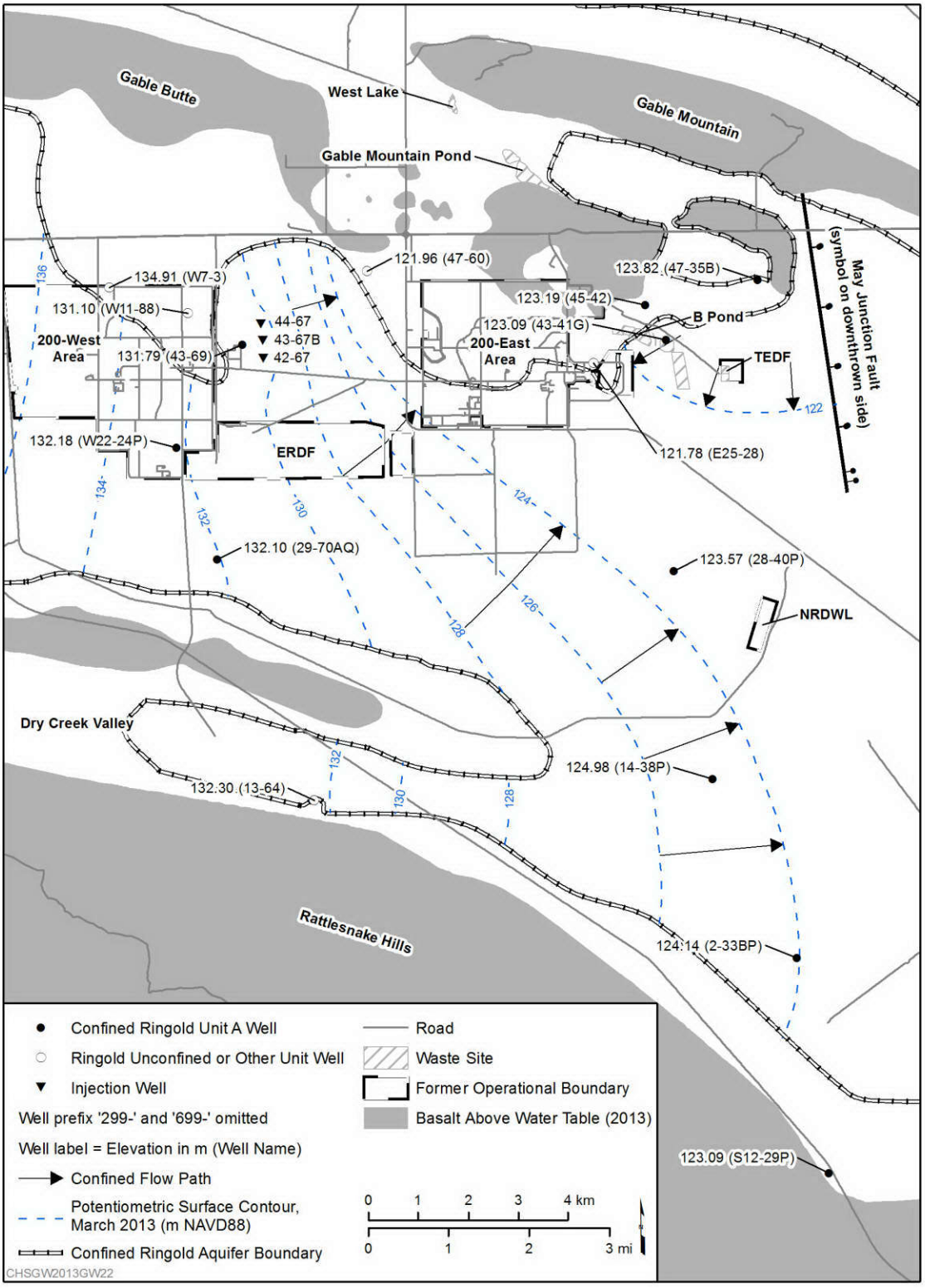


Figure 3-18. Potentiometric Surface Map of the Confined to Semiconfined Ringold Aquifer, March 2013

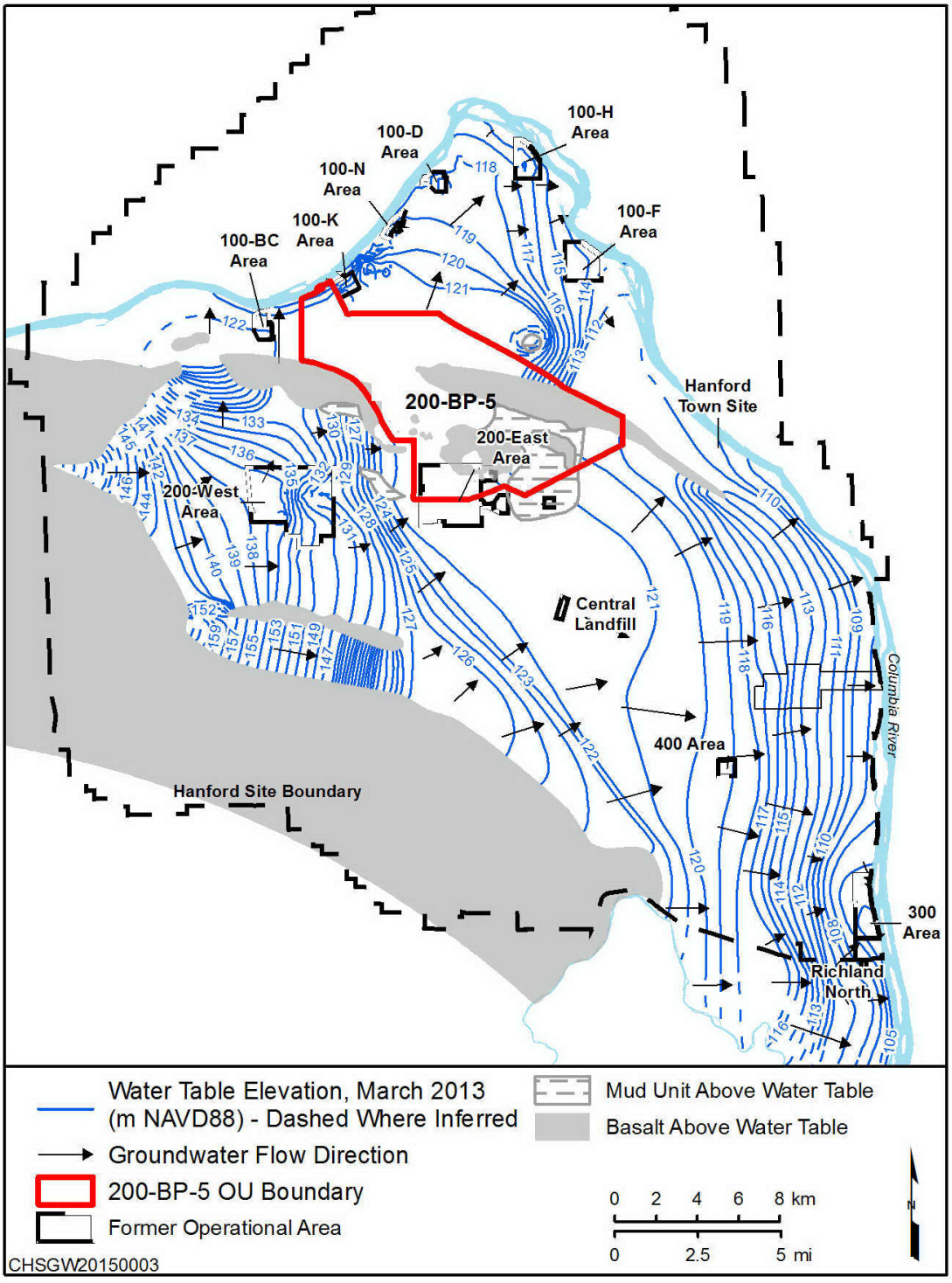


Figure 3-19. Hanford Site Water Table Map, March 2013

With cessation of discharges to B Pond, the northward migration of contaminated groundwater from the 200 East Area slowed as the gradient decreased. By 2009, a broad relatively flat water table and groundwater divide within the unconfined aquifer was identified near the northern half of the 200 East Area within the OU. The exact location of this divide is variable and not well understood because the water table in the 200 East Area is nearly flat and measurement uncertainties are greater than actual water level differences between wells (DOE/RL-2010-11). In July 2011, groundwater flow within the unconfined aquifer in the southern portion of the 200-BP-5 OU (south of Gable Mountain) changed flow direction by 180 degrees due to ongoing water table declines in the 200 East Area and temporal Columbia River stage changes. Since July 2011, the flow has maintained a south-southeast direction from the southern portion of Gable Gap into the northwest quarter of the 200 East Area (DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*).

The unconfined aquifer extends throughout most of the 200-BP-5 OU. The unconfined aquifer is absent where the top of basalt occurs above the regional water table (Figure 3-19). The unconfined aquifer is also absent in the near-field area where HSU 8 occurs at or above the regional water table, east and northeast of the 200 East Area (Figure 3-19).

Groundwater gradients and flow direction through Gable Gap currently vary with Columbia River stage and are discussed in Sections 3.6.4 and 3.6.5.

3.6.3 Aquifer Recharge

Sources of recharge to the suprabasalt aquifer system include the following:

- Disposal of liquid wastewater to the soil column
- Injection of water from upgradient pump-and-treat operations (e.g., 200-UP-1 and 200-ZP-1)
- Precipitation and irrigation runoff from elevated areas along the western boundary of the Hanford Site (primarily the Cold Creek and Dry Creek Valleys)
- Infiltration of precipitation
- Upwelling from the underlying Ringold confined (HSU 9) and upper basalt-confined (HSU 10) aquifer systems
- Influent water from the Columbia River west of 100-BC during high river stage
- Leakage from water lines (PNNL-13021, *Water-Level Monitoring Plan for the Hanford Groundwater Monitoring Project*)

Temporal elevation increases in the Columbia River create bank storage in the far-field area, where the OU intersects the Columbia River. The volume of bank storage that occurs along the shoreline of the river is small.

The influence of offsite precipitation and irrigation runoff is discussed in WRIR-88-4108, *Estimates of Ground-Water Recharge to the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho for Predevelopment and Current Land Use Conditions*. Recharge that occurs outside of the 200-BP-5 OU (e.g., offsite Hanford irrigation) influences groundwater levels, groundwater gradients, and flow rates but does not directly influence contaminant migration in the vadose zone above the OU. Increases and decreases in recharge from outside of the OU can influence the rate of contaminant movement in groundwater due to changes in groundwater levels (PNL-10285, *Estimated Recharge Rates at the Hanford Site*; PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*;

PNNL-14744; and PNNL-16688, *Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas*). PNNL-14702 estimated the maximum recharge rate to be no more than the total of winter precipitation, which over the 58-year period of records at the HMS network has averaged 101 mm/yr (3.98 in./yr). The undisturbed areas of the 200-BP-5 OU have Ephrata sandy loam-type soils, with variable amounts of shrub vegetation; the highly disturbed areas generally have gravelly surfaces with little to no vegetation. Vegetated Ephrata sandy loam soils are estimated to have mean recharge equal to 2.8 mm/yr (0.11 in./yr), and unvegetated gravel surfaces are estimated to have mean annual recharge equal to 92 mm/yr (3.62 in./yr) (PNNL-16688; PNNL-19277).

Recharge to the upper basalt-confined aquifer likely occurs from upland areas along the margins of the Pasco Basin, where basalt and interbeds are exposed at or near ground surface, including possibly the Yakima River. Recharge also occurs to the upper basalt-confined aquifer from overlying aquifers where downward vertical gradients occur and from underlying basalt aquifers where upward vertical gradients occur (DOE/RL-2010-11).

Upward vertical flow or upwelling from the upper basalt-confined aquifer system to the suprabasalt system occurs where hydraulic head is greater in the underlying confined aquifer. Figure 3-20 illustrates that an upward vertical gradient exists in most of the near-field area, except for a small area near B Pond. Upwelling is most likely to occur in the Gable Gap vicinity, where both the Elephant Mountain and Pomona Member Basalts were removed by erosion exposing the confined aquifer within the basalt interbed to the unconfined aquifer.

In the far-field area, recharge to the unconfined aquifer can occur during periods of high Columbia River stage when the water level in the unconfined aquifer is lower than the river stage. This recharge has been documented to occur west of the 100-BC Area (PNNL-13021; DOE/RL-2010-11) (and eastward movement) and influences the unconfined aquifer elevation in the northern portion of the 200-BP-5 OU. The amount of recharge that occurs from the Columbia River during high river stage has not been quantified.

Currently, the water table (unconfined aquifer) beneath liquid disposal sites within the 200 East Area ranges from 76 to 91 m (250 to 300 ft) bgs. Historical artificial groundwater recharge from effluent disposal at B Pond, Gable Mountain Pond, various cribs, ditches, and reverse well waste sites generated local mounds in the water table and generally elevated the water table throughout the 200 East Area. The groundwater mound under B Pond caused an estimated additional 10 m (35 ft) of hydraulic head to the suprabasalt aquifer in the late 1980s. Gable Mountain Pond discharges were suspended in 1985 and effluent disposal at B Pond ceased in 1993.

Figure 3-21 shows the annual discharges of water at B Pond and Gable Mountain Pond; this effluent infiltrated the vadose zone and led to massive artificial mounding of the water table during the 1940s through the early 1990s. Groundwater mounds beneath the 200 East Area subsided very quickly as most Central Plateau effluent discharges ceased in the early 1990s. The rapid decline in the water table in the 200 East Area is due to the occurrence of highly permeable and transmissive aquifer sediments within the region that extends from approximately 100-B/C Area southeast through Gable Gap and across the 200 East Area. Currently, only the TEDF contributes effluent releases to the unconfined aquifer within the 200 East Area. Artificial recharge also occurs via pump-and-treat injection wells located between the 200 East and 200 West Areas. The 2013 water table map of the Hanford Site (Figure 3-19) illustrates a lack of significant groundwater gradient or mounding in the unconfined aquifer beneath most of the 200-BP-5 OU, indicating that the current recharge, natural and artificial, does not significantly affect the water table elevation.

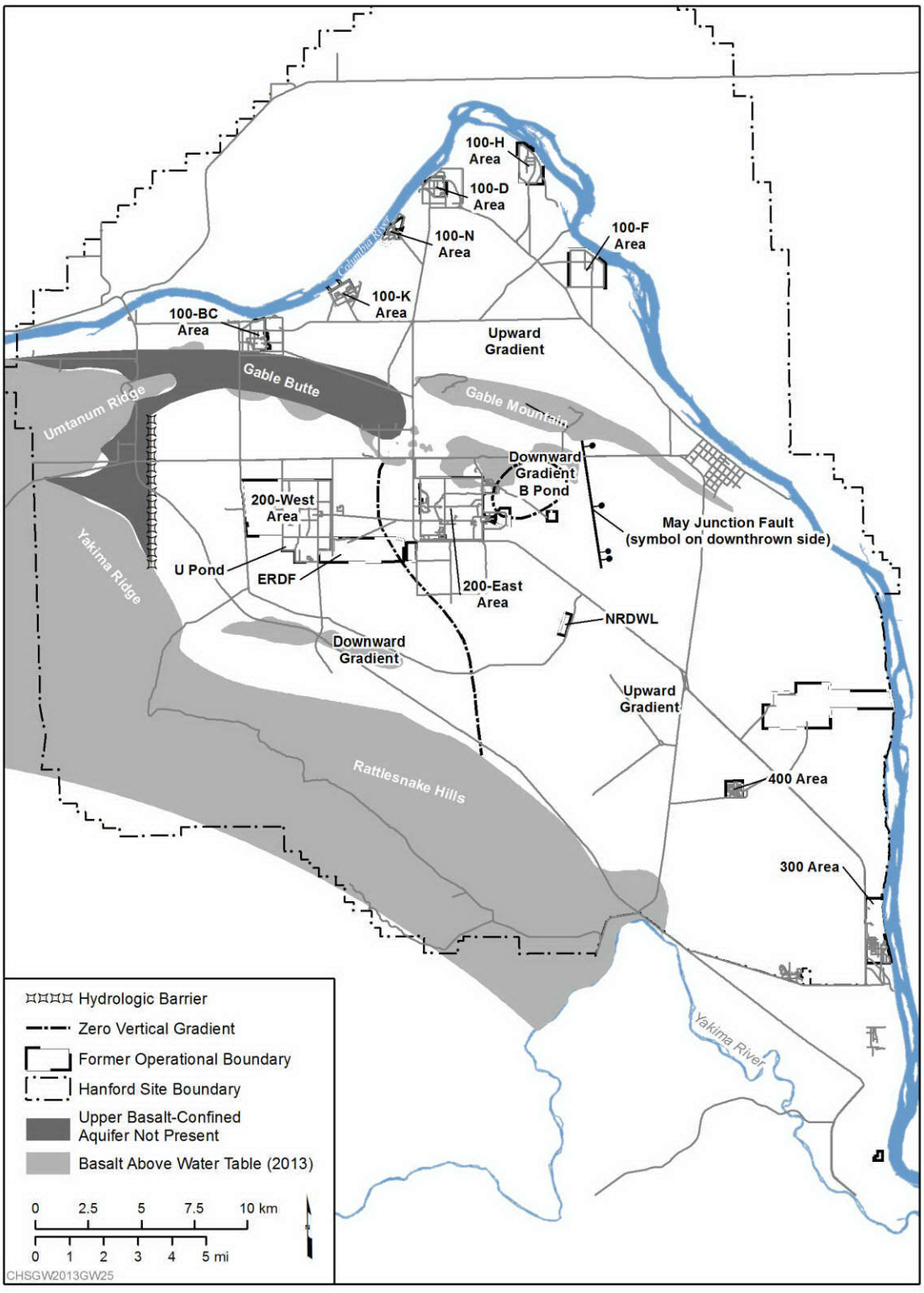


Figure 3-20. Comparison of Observed Heads for Upper Basalt-Confined Aquifer and Overlying Unconfined Aquifer, March 2013

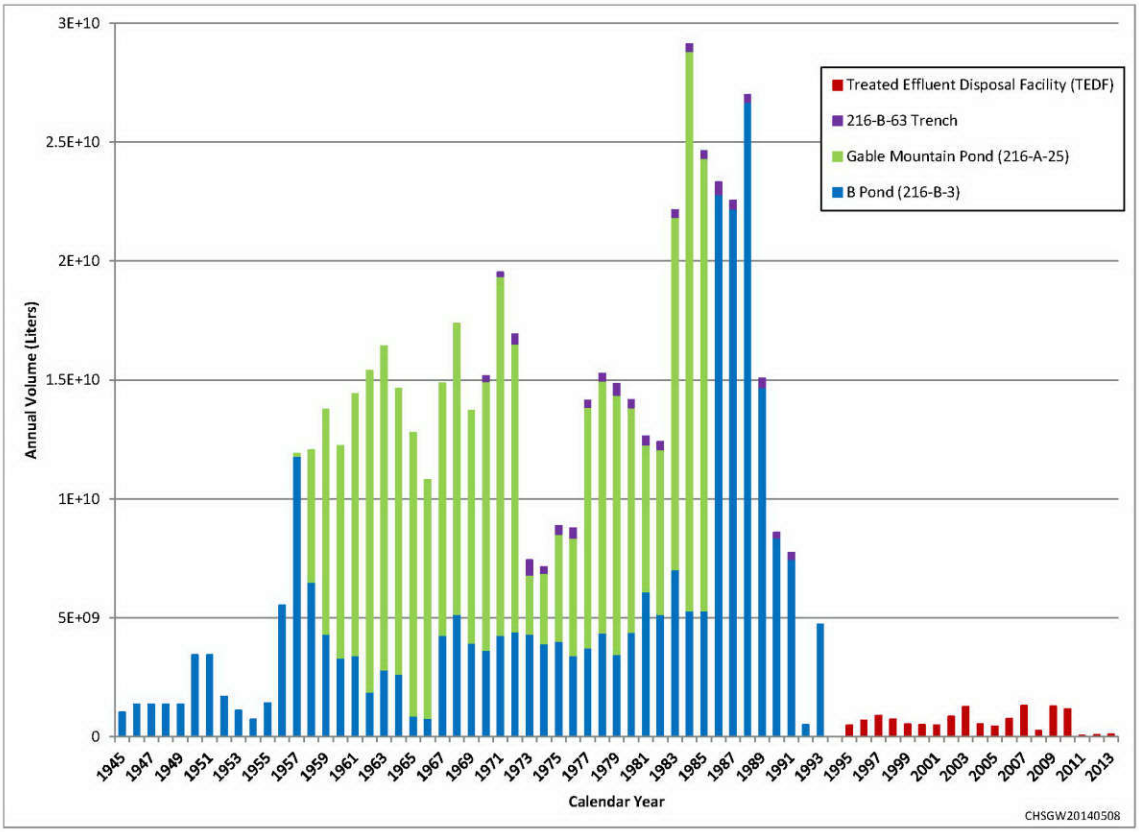


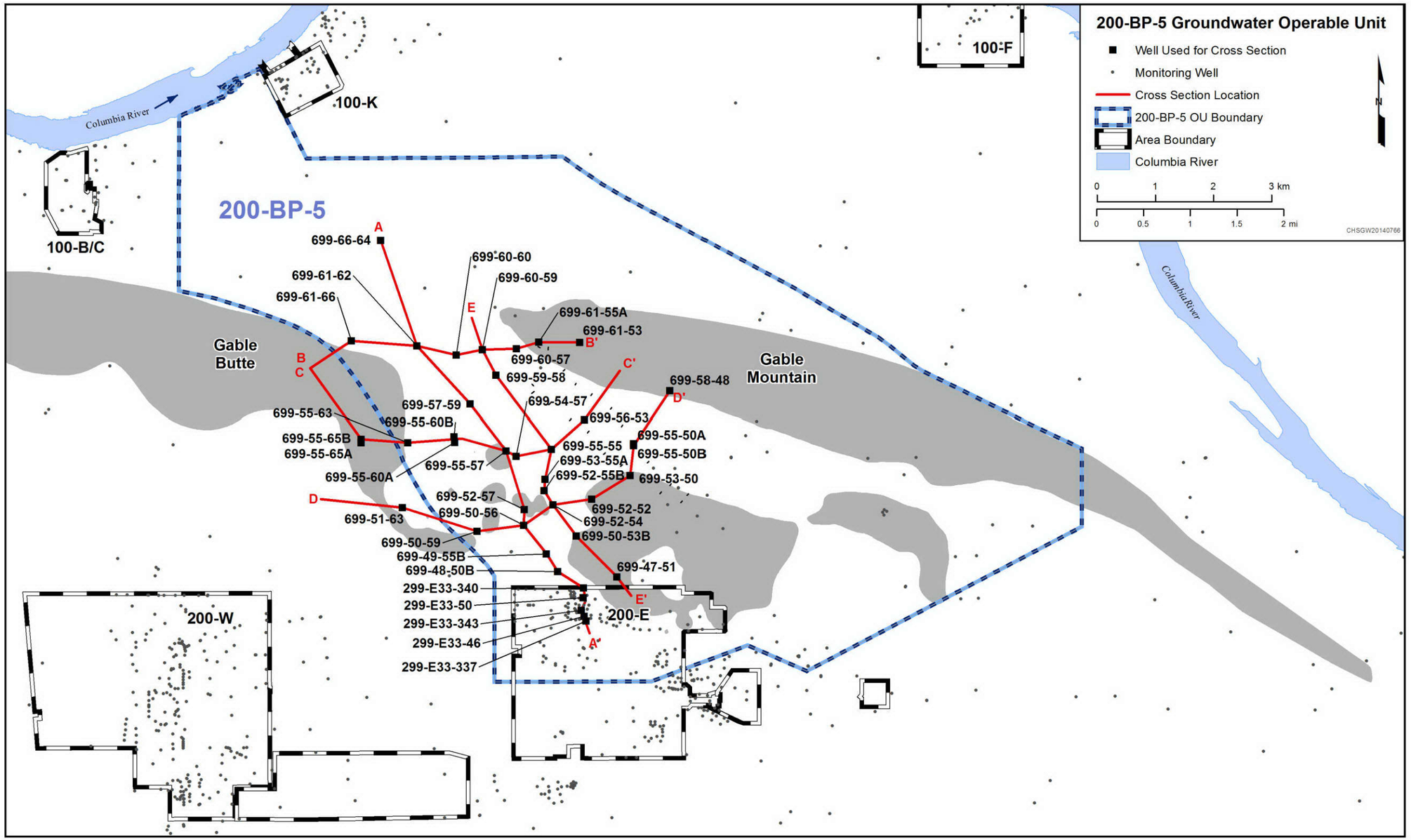
Figure 3-21. Discharge History for B Pond, Gable Mountain Pond, 216-B-63 Trench, and TEDF

3.6.4 Hydrogeologic Cross Sections

Hydrogeologic cross sections illustrate the variability of the suprabasalt aquifer system and the basalt bedrock surface in the 200-BP-5 OU. These cross sections show the spatial variability of aquifer conditions and illustrate how geologic structures influence groundwater flow paths within the OU. Figure 3-13 shows the locations of the hydrogeologic cross sections. Figure 3-22 shows the locations of geologic cross sections that illustrate complex structures interpreted within the underlying basalt and also the suprabasalt intervals. The aquifer thickness map (Figure 3-16), along with the cross sections, are used to present the hydrogeological conditions in the 200-BP-5 OU. Specific hydrogeologic features are summarized for five of the near-field focus areas and the far-field area (Figure 3-23).

3.6.4.1 Focus Area 1: Waste Management Area B-BX-BY

The unconfined aquifer is relatively thin beneath the WMA B-BX-BY and north, approximately 2 km (1.2 mi) of the 200 East Area (Figure 3-16). Within this area, the uppermost basalt member, Elephant Mountain Basalt, has been partially eroded. The unconfined aquifer thickness currently ranges from 0.3 to 4.5 m (1 to 15 ft). Numerous boreholes in this area have demonstrated a high-permeability unconfined aquifer (typically HSU 1 and/or HSU 3) above an eroded basalt surface (cross-section AA-AA' [Figure 3-14] and cross-section A-A' [Figure 3-24]).



Source: PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*.

Figure 3-22. Geologic Cross-Section Location Map, 200-BP-5 OU

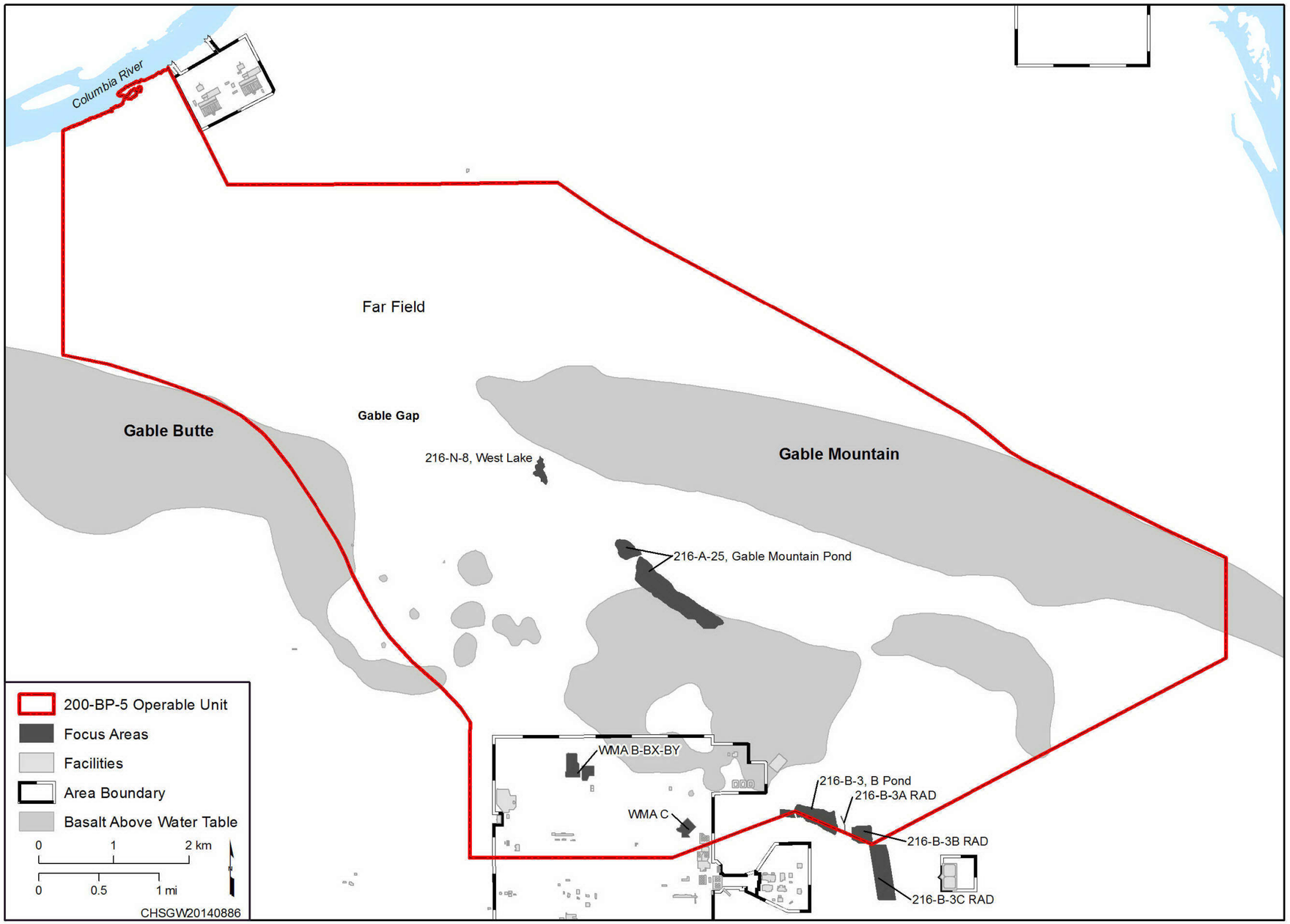
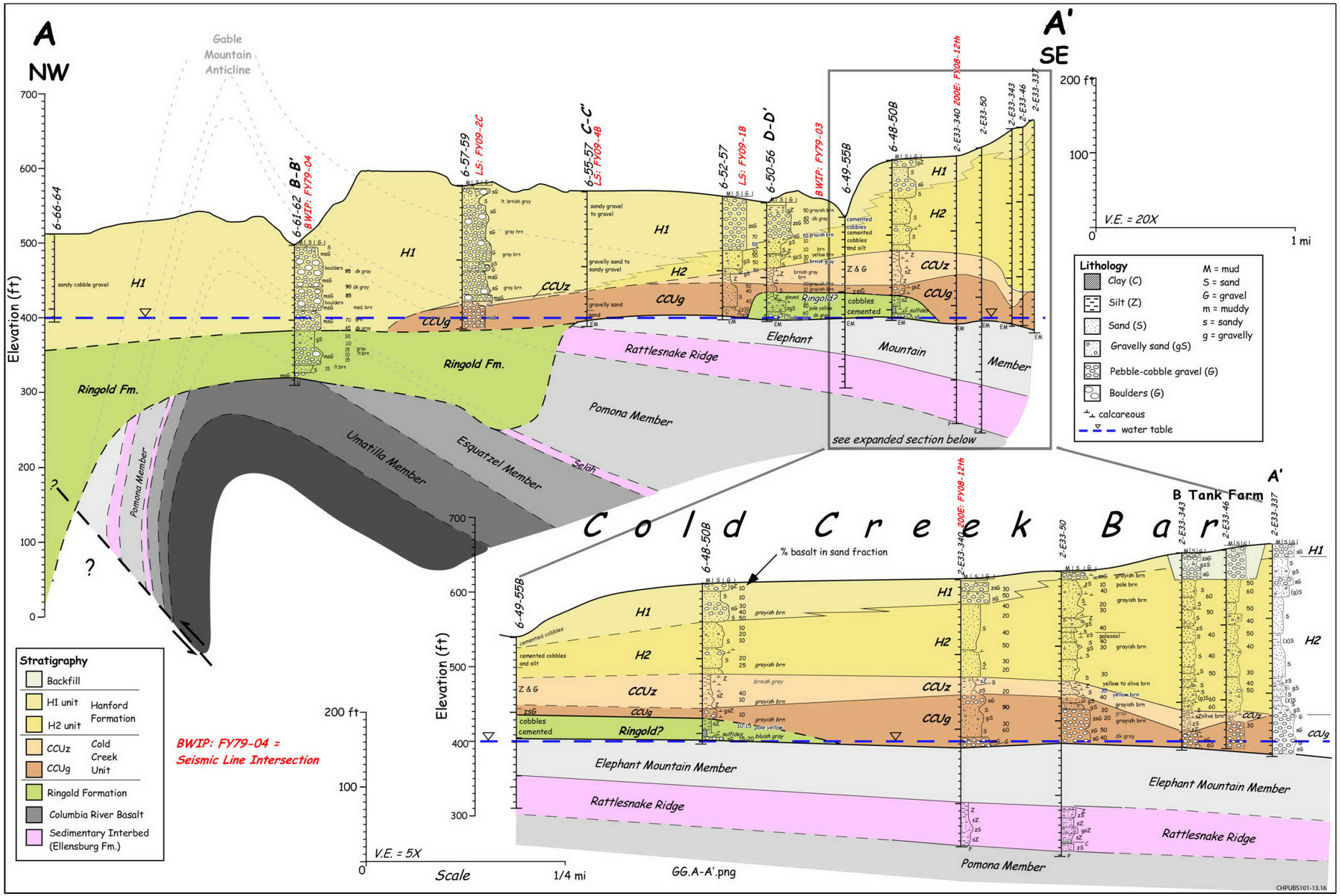


Figure 3-23. Vicinities of Major Features Described in the 200-BP-5 OU Conceptual Model



Source: PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*.

Figure 3-24. 200-BP-5 OU Geologic Cross-Section A-A'

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3.6.4.2 Focus Area 2: Vicinity of B Pond

The unconfined aquifer is absent beneath B Pond in an area where the Ringold confined aquifer (HSU 9) is overlain by HSU 8 sediments that are above the current water table. This sequence lies adjacent to the unconfined aquifer and is composed of high-permeability HSU 1 and 2 sediments that form preferential pathways to groundwater flow where present. South of B Pond, the unconfined aquifer thickness increases and extends into older Rwie sediment that is not present further north. The main B Pond lobe is located above the northern and western limit of HSU 8. Figure 3-12 and cross-section FF-FF' (Figure 3-25) illustrate these relationships and show that the total saturated thickness of the suprabasalt aquifer system ranges from 0 m (0 ft) north of B Pond to approximately 67 m (220 ft) south of B Pond.

3.6.4.3 Focus Area 3: Vicinity of Gable Mountain Pond

Gable Mountain Pond is located in the northern portion of the near-field area. Gable Mountain Pond previously acted as a recharge pond for dilute wastewater effluent disposal and was located above a shallow basalt subcrop in a topographic low area north of the 200 East Area. During active disposal, the shallow, permeable sediment that made up the vadose zone and the shallow basalt surface created rapid recharge and mounding on the unconfined aquifer. The hydrogeology in this area is presented in cross-section NN-NN' (Figure 3-26). The current, unconfined aquifer thickness near Gable Mountain Pond ranges from 0 to 46 m (0 to 150 ft).

3.6.4.4 Focus Area 4: Vicinity of Gable Gap and West Lake

The hydrogeology for the area between Gable Gap and West Lake is presented in north-south cross-section DD-DD' (Figure C-5, Appendix C), cross-section EE-EE' (Figure C-6, Appendix C), and east-west cross-section NN-NN' (Figure 3-26). Appendix C contains additional cross sections of the Gable Gap area (from PNNL-19702). The vicinity of Gable Gap coincides with the interpreted erosional windows in the Elephant Mountain Basalt (RHO-RE-ST-12P; PNNL-19702), which is filled with suprabasalt sediment that greatly increased the vertical thickness of the unconfined aquifer in some areas. Between the 1970s and 2011, Gable Gap was the contaminant and groundwater flow pathway northward from the 200 Areas. Currently, the unconfined aquifer thickness in this area is variable and ranges from 0 to 46 m (0 to 150 ft). High transmissivity sediments within the thin unconfined aquifer south of Gable Gap (Figures 3-14 and 3-16) control the amount of groundwater flow through Gable Gap.

3.6.4.5 Focus Area 5: Vicinity of Waste Management Area C

Beneath WMA C, the Elephant Mountain Basalt dips gently to the south into the Cold Creek syncline and is the base of the unconfined aquifer (PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*). The thickness of the unconfined aquifer beneath WMA C ranges from 11 to 18 m (36 to 59 ft) and is composed of relatively high-permeability HSU 1 and HSU 3 sediment. The unconfined aquifer in this area is also very flat and has little measureable gradient, but it is generally believed to flow south-southeastward out of the area.

3.6.4.6 Far-Field Focus Area: 200-BP-5 Operable Unit

The 200-BP-5 OU far-field area includes the area north of the Gable Mountain-Gable Butte structural lineament to the Columbia River and is illustrated by hydrogeologic cross-section BB-BB' (Figure 3-27). The aquifer within the far-field area is approximately 61 m (200 ft) thick. The unconfined aquifer in this location includes the lower saturated portion of HSU 1 and HSU 5 overlying HSU 8 (confining unit). In this area, preferential groundwater flow may occur in some areas where the HSU 1 is within the unconfined aquifer. The Ringold confined aquifer (HSU 9) in this vicinity ranges from 0 to 61 m (0 to 200 ft) in thickness, based partly on logs for boreholes located outside the OU.

3.6.5 Aquifer Properties and Groundwater Plume Movement

Groundwater is the primary pathway for the transport of contaminants within the 200-BP-5 OU. The magnitude and direction of plume movement is controlled by the hydraulic conductivity distribution within the aquifer, the configuration of the water table, the presence of contaminant sources, and the geometry of flow pathways within the aquifer systems. These factors control groundwater velocity, which drives plume movement (Domenico and Schwartz, 1990, *Physical and Chemical Hydrogeology*). The distribution of geologic units and structural features within the 200-BP-5 OU create corresponding variations in aquifer parameters, groundwater, and plume movement, and these changes and variations are discussed below.

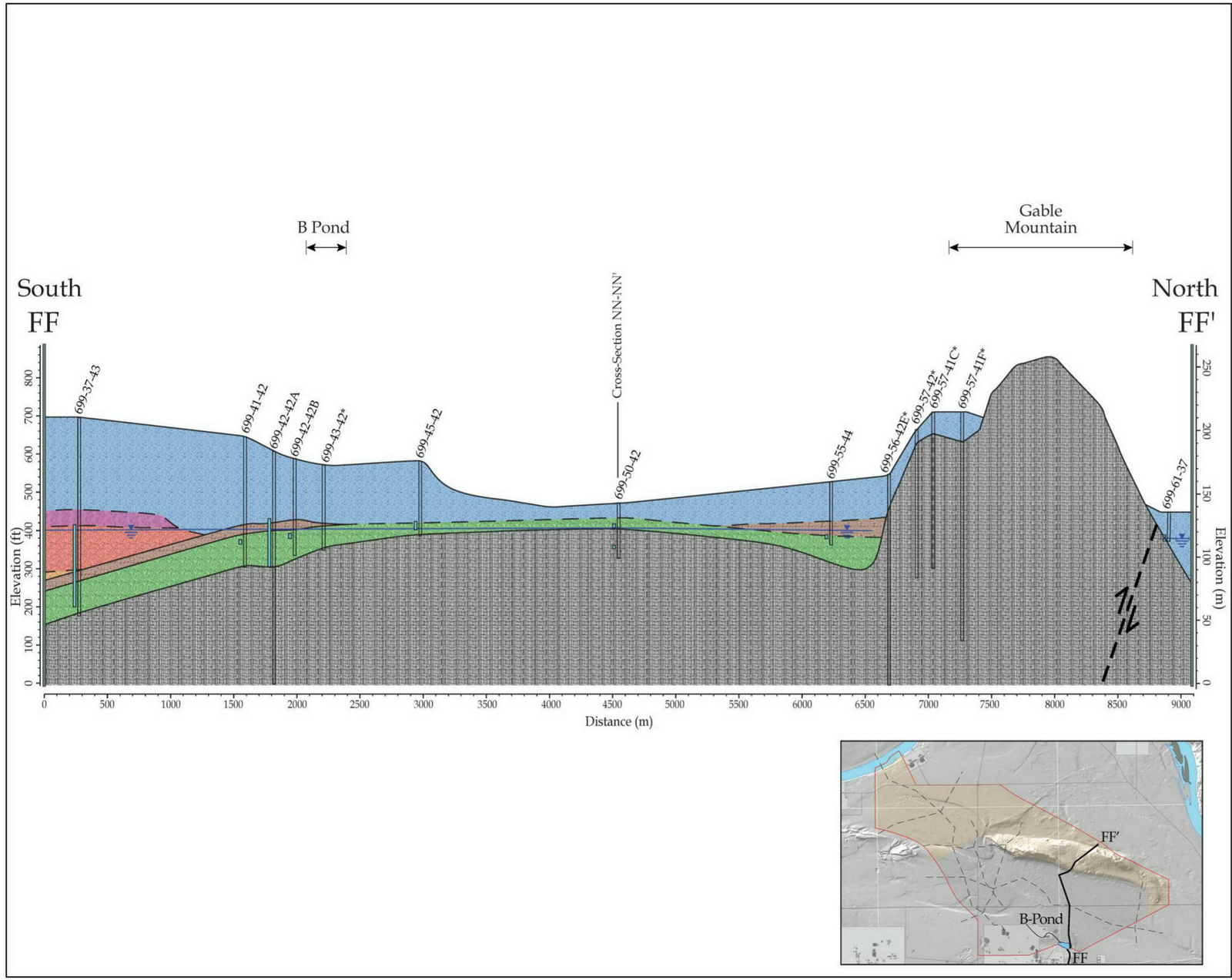
3.6.5.1 Effects of Site Geology on Groundwater and Plume Movement

Several geologic features influence groundwater flow and contaminant plume movement in the 200-BP-5 OU. The aquifer systems in the OU are heterogeneous and anisotropic (i.e., high contrasts in permeability and thickness). The unconfined aquifer has decreased significantly in thickness over the past 25 years due to discontinued large-volume effluent disposal on the Central Plateau; groundwater levels continue to decline (discussed in Section 3.6.3).

The distribution of hydrogeologic units within the unconfined aquifer is a result of Miocene-Pliocene-age geologic uplift, structural folding and faulting, and subsequent ancestral Columbia River and Pleistocene cataclysmic flooding, and erosion of those older geologic units. Maps showing which HSUs intersect the water table are useful for understanding groundwater flow paths since preferential flow paths occur in the more permeable, generally shallower HSUs 1 and 3. Figure 3-28 depicts the best estimate for the distribution of HSUs at the water table before Hanford Site operations began. Figure 3-29 depicts the distribution of HSUs at the water table during the late 1980s, when maximum water table elevations were observed during Hanford Site operations. Figure 3-30 depicts the 2009 distribution of HSUs at the water table after most large-volume effluent disposal to ground ceased.

Plumes moving in the unconfined aquifer are influenced (i.e., slowed or altered) by low-permeability geologic structures such as basalt subcrops and low-permeability sediment units within or above the aquifer (i.e., HSU 8) and maybe redirected along preferential flow paths in high-permeability channel-fill deposits (i.e., HSUs 1 and 3).

Structural uplift, fluvial erosion, and paleoflooding have shaped the top surface of basalt in much of the OU, most notably in the area between the 200 East Area and Gable Mountain, where the surface of the basalt has been severely folded/faulted and eroded (Figure 3-7). Where the basalt surface was eroded by paleoflooding, the uppermost Elephant Mountain Basalt was thinned or removed, and direct contact is likely between the Hanford formation or CCU and the upper basalt-confined aquifer. Preferential flow occurs within the aquifer materials, which have greater hydraulic conductivity. In those areas where both the Hanford formation and Ringold Formation occur in the unconfined aquifer, the hydraulic conductivity of the Hanford formation gravel-dominated facies (HSU 1) is generally magnitudes higher than the Ringold unit E gravel-dominated facies (HSU 5). The RLM (HSU 8) represents an aquitard and has very low hydraulic conductivity. The hydraulic conductivity of the Hanford formation is several orders of magnitude higher than that of the RLM (HSU 8).



Hydrostratigraphic Unit	Associated Lithologic Units
HSU 1	Undifferentiated Hanford fm. Recent Fill - H1 - H2 - H3
HSU 3	Undifferentiated Cold Creek Unit - CCU g (gravel dominated) - CCU z (silt dominated)
HSU 4	Upper Ringold - Member of Taylor Flat
HSU 5	Undifferentiated Ringold - Ringold Unit E - Ringold Unit C
HSU 8	Undifferentiated Ringold Lower Mud - Rlm, upper - Rwib&d - Rlm, lower
HSU 9	Undifferentiated Ringold Unit A - Rwia, upper - Rwia, mud - Rwia, lower
HSU 10	Basalt (undifferentiated, including sedimentary interbeds)

Contact dashed where inferred

Water level from March 2009 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Well with no screen data available

10X Vertical Exaggeration

CHSGW20140726

Figure 3-25. 200-BP-5 OU Hydrogeologic Cross-Section FF-FF'

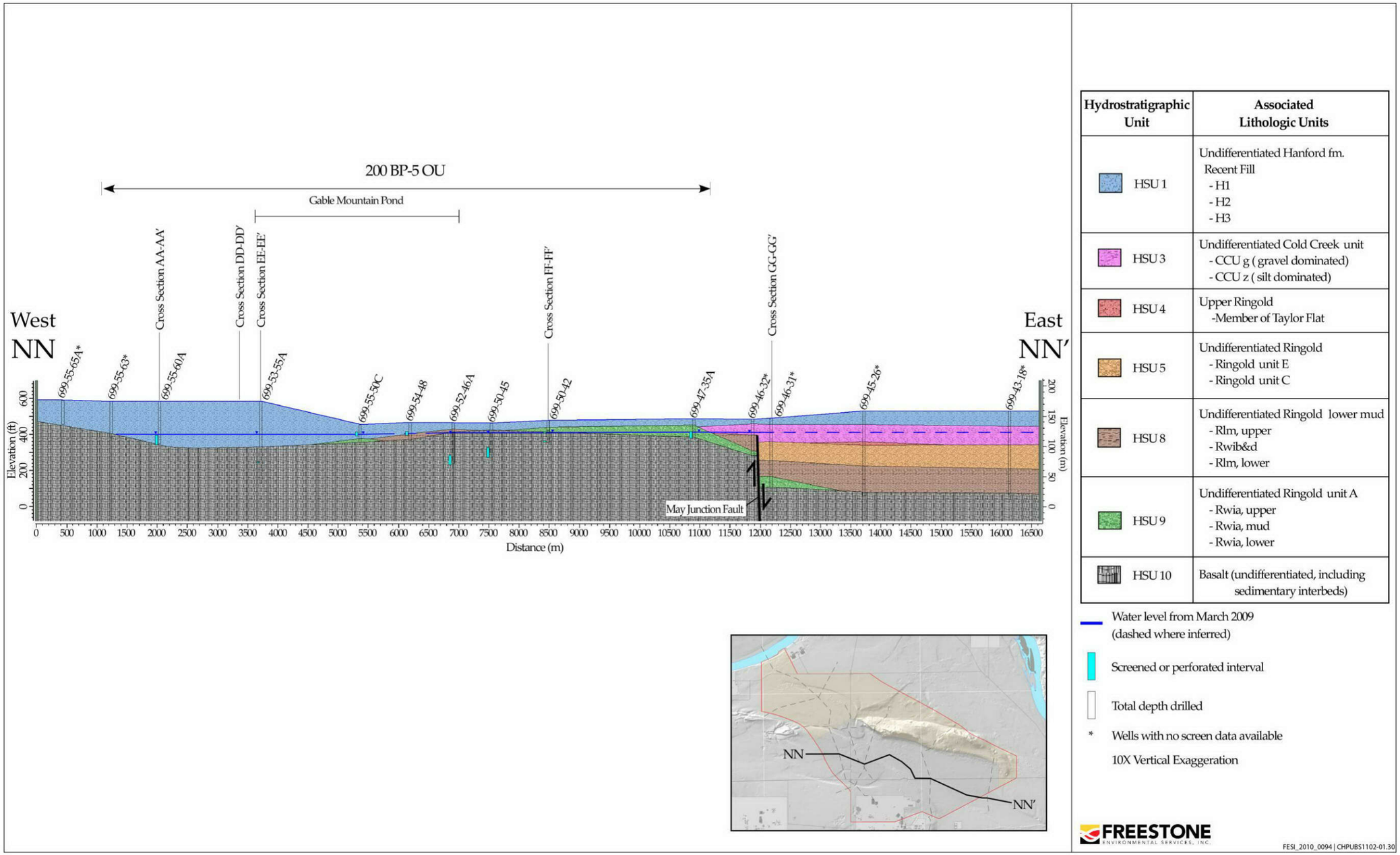


Figure 3-26. 200-BP-5 OU Hydrogeologic Cross-Section NN-NN'

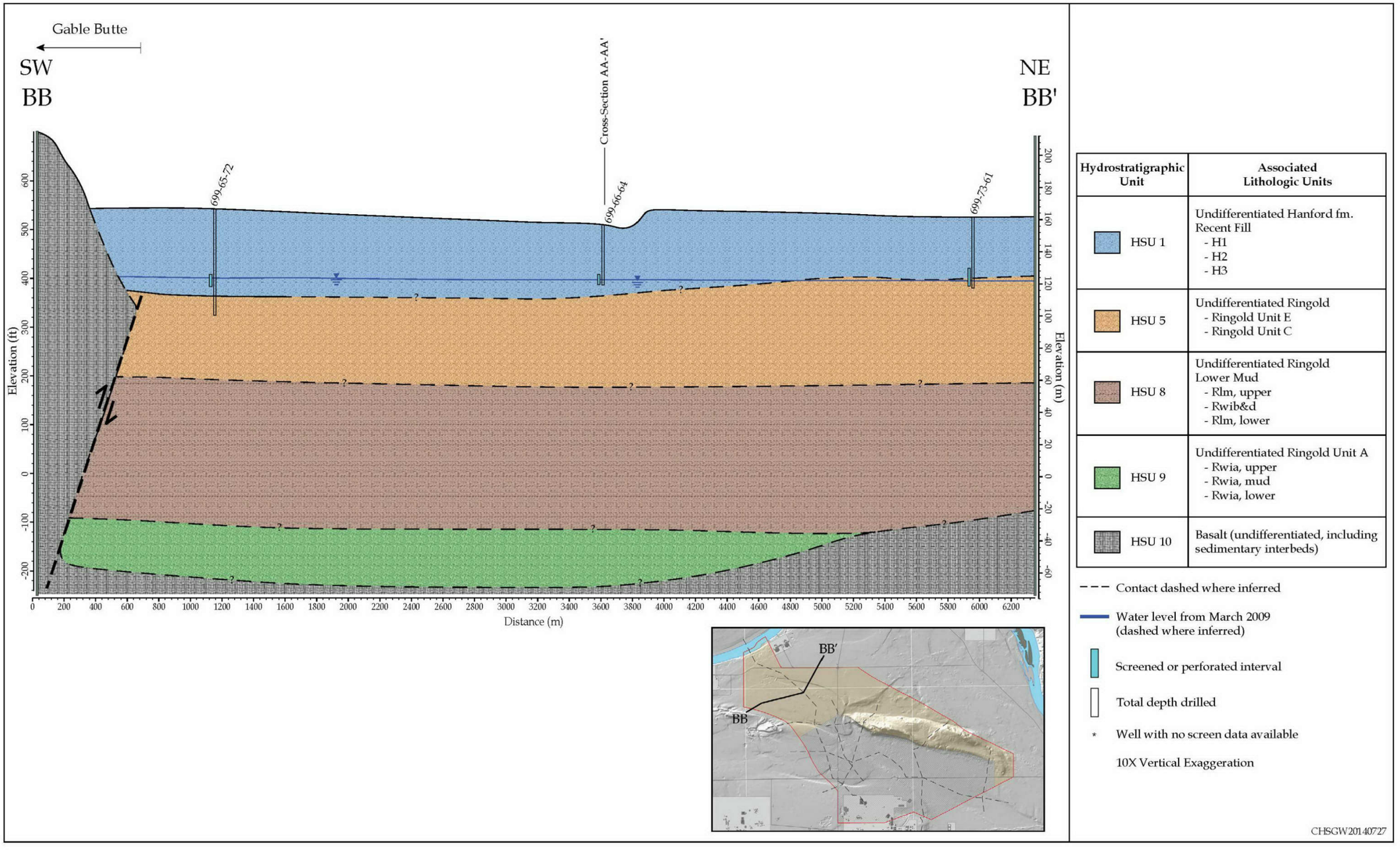


Figure 3-27. 200-BP-5 OU Hydrogeologic Cross-Section BB-BB'

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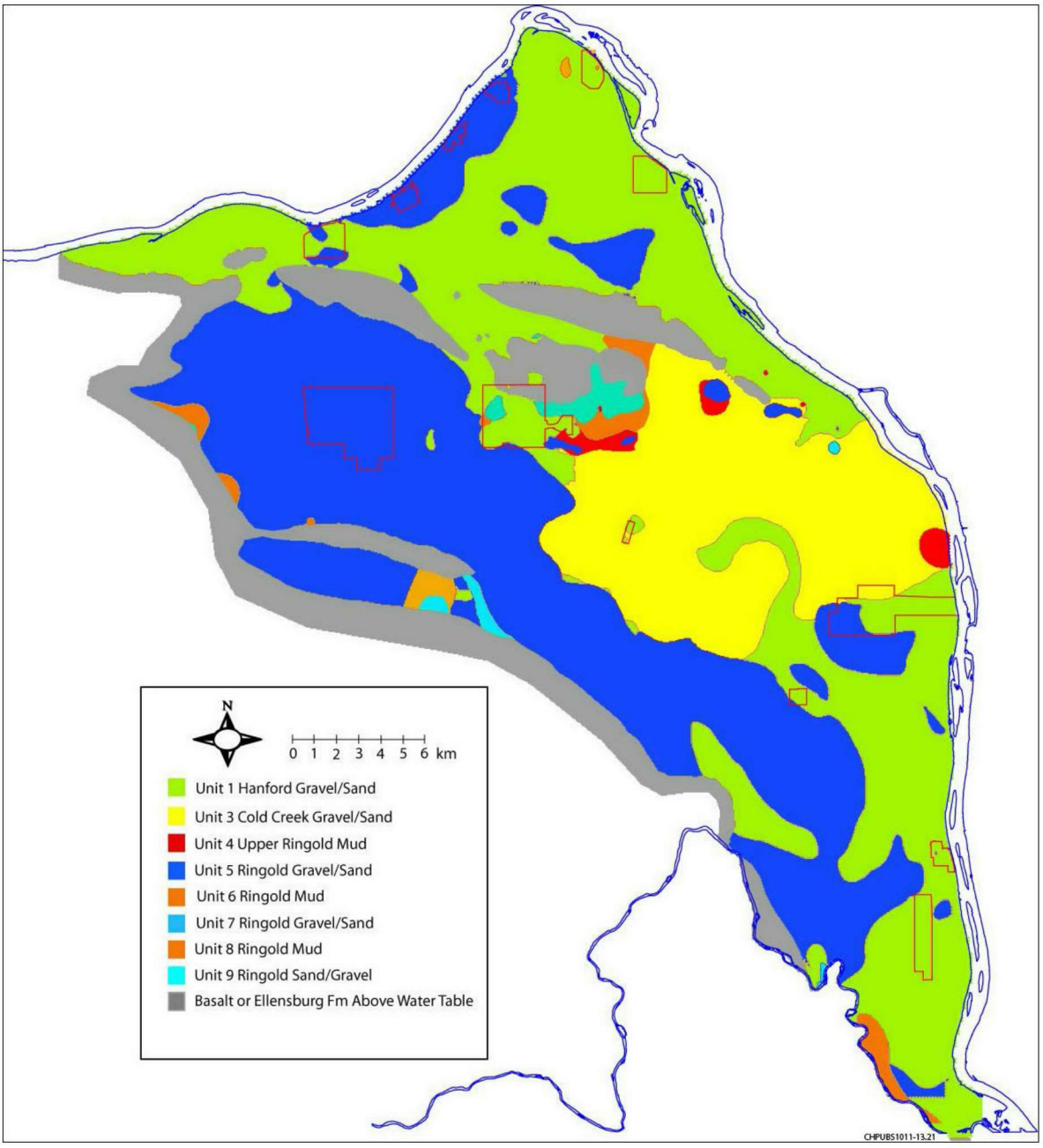

Figure 3-28. Distribution of Hydrogeologic Units at the Water Table, Pre-Hanford Operations

An example of preferential groundwater and contaminant flow through higher permeability sediments occurs east of the 200 East Area near B Pond, in an area where low-permeability sediments composing HSU 8 occur at the water table. Groundwater moving eastward downgradient in the southern portion of the 200-BP-5 OU is diverted south and then east around the exposed HSU 8 low-permeability region. The hydraulic constraints imposed by the HSU 8 create this change in flow direction. The region downgradient of the May Junction fault contains less structural and geologic constraints, and groundwater flows across the region following the path of least resistance, flowing downgradient toward the Columbia River through the 200-PO-1 OU.

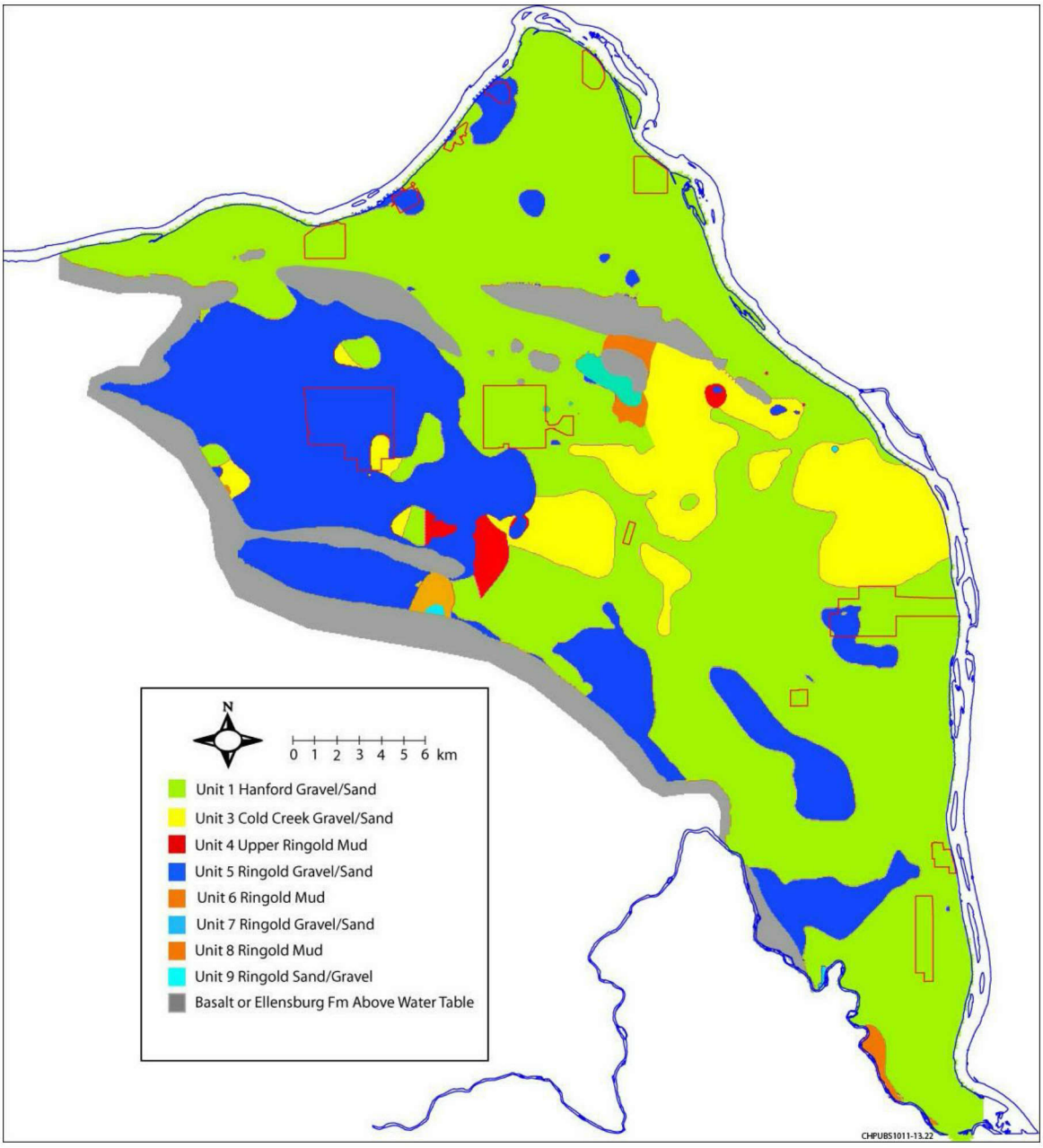

Figure 3-29. Distribution of Hydrogeologic Units at the Water Table during Hanford Operations

3.6.5.2 Aquifer Properties

Aquifer properties were obtained in situ at the new RI wells by performing short-term pumping tests at 11 of the 12 wells. Aquifer slug testing was performed at a single RI well (PNNL-17675). Aquifer properties were also derived from laboratory tests on sediment split-spoon samples obtained from the boreholes.

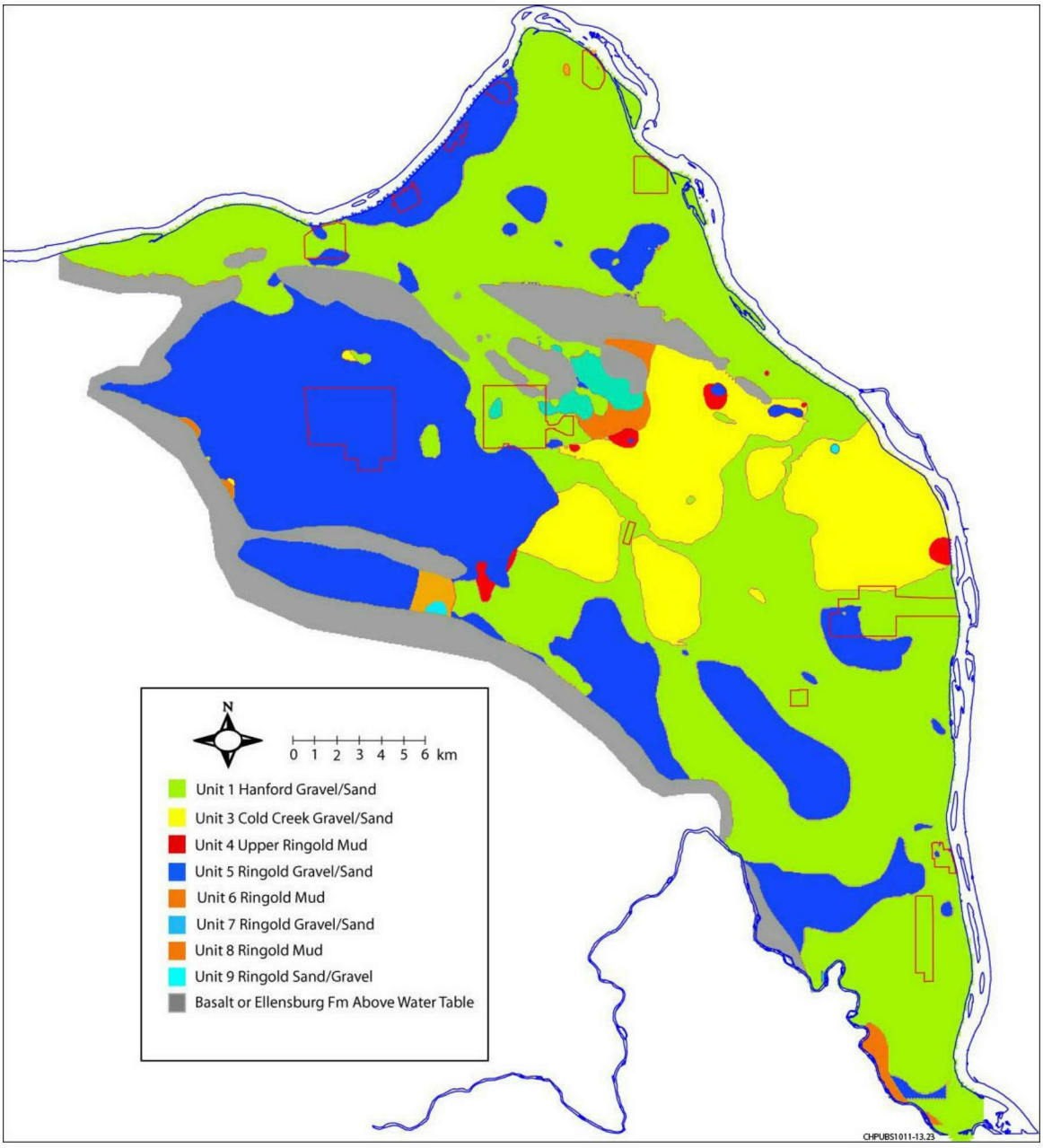

Figure 3-30. Distribution of Hydrogeologic Units at the Water Table, 2009

Pumping rates for the three Rattlesnake Ridge interbed wells ranged from 4.0 to 13 L/min (1.5 to 5 gallons per minute [gpm]); pumping rates for the suprabasalt aquifer system were significantly higher, ranging from 30 to 79 L/min (11.5 to 30 gpm). The results of these tests are summarized in Table 3-1. Transmissivity for the different wells was estimated from specific-capacity data using an empirical method (PNNL-19277). Transmissivity estimates for the new RI Rattlesnake Ridge interbed wells are significantly lower than those measured in the unconfined aquifer (Table 3-1), ranging from 2 to 5.5 m^2/d (22 to 59 ft^2/d), whereas estimates for the new RI unconfined aquifer wells ranged from 10 to 18,600 m^2/d (107 to more than 200,000 ft^2/d).

Estimates of hydraulic conductivity derived from the RI well pumping tests are based on estimates of aquifer transmissivity. A map of hydraulic conductivity values for Hanford Site wells is presented in Figure 3-31. A map of hydraulic conductivity values for wells near WMA B-BX-BY is provided in PNNL-19277. Other estimates of hydraulic conductivity are based on slug tests. Estimates of hydraulic conductivity and porosity from recent RI boreholes are also included in PNNL-19277. As saturated thickness of the unconfined aquifer declines (which is ongoing in most of the near-field area of the 200-BP-5 OU), aquifer transmissivity also declines. For this reason, transmissivity values obtained from the new RI wells drilled from 2007 through 2009 may be more informative in support of flow and transport modeling than transmissivity values obtained in previous decades when the water table was elevated. A decline in transmissivity is expected to be the most pronounced in areas such as the north portion of the 200 East Area, where aquifer thickness is only 1 to 2 m (3 to 7 ft). In areas such as WMA C where unconfined aquifer thickness is tens of meters, the declining groundwater level is expected to have much less effect on aquifer transmissivity.

The variable sediments that comprise the different HSUs are depicted in Figure 3-11. Various physical properties of the unconfined aquifer were obtained from well drilling and borehole characterization activities conducted within the 200-BP-5 OU, including total and effective porosity, field capacity, and bulk density (summarized in PNNL-19277). Laboratory tests for unconfined aquifer sediments demonstrated effective porosities in the range of 0.11 to 0.31.

3.6.5.3 Aquifer Intercommunication

At least four mechanisms are thought to account for groundwater flow between the unconfined aquifer and the upper basalt-confined/Rattlesnake Ridge interbed aquifer (RHO-RE-ST-12P), including the following:

- Erosional unconformities
- Framework of the Elephant Mountain Basalt flows
- Structural deformation or rupture
- Human induced pathways (i.e., open boreholes)

For groundwater movement to occur between different aquifers, a difference in potentiometric head must exist. Figure 3-20 shows the relative difference in head between the upper basalt-confined aquifer and the suprabasalt unconfined aquifer, where the difference in head can be compared at nearby monitoring wells. Figure 3-20 shows that head is generally higher in the upper basalt-confined aquifer throughout most of the near-field area of the 200-BP-5 OU, indicating the potential for upward flow. A downward vertical gradient persists near B Pond.

Erosional unconformities that place overlying younger sediment adjacent to underlying basalt interbeds are considered the principal mechanism for direct physical interconnection between the aquifers. Several logs for boreholes located within Gable Gap, and between Gable Gap and the 200 East Area, show the uppermost Elephant Mountain Basalt to be absent, which is the result of anticlinal uplift, deformation, and subsequent erosion. For instance, the Rattlesnake Ridge interbed sediments are believed to be encountered directly beneath Hanford formation in Well 699-53-55C. In other areas, erosion has greatly thinned the basalt, which separates the Hanford formation from the Rattlesnake Ridge interbed, increasing the potential for leakage between the two aquifer systems. The erosional area of the paleochannel south and southeast of Gable Gap (including Borehole 699-53-55C) is an example of an erosional unconformity mechanism allowing hydraulic communication between two aquifers (RHO-RE-ST-12P).

Table 3-1. Summary of 200-BP-5 OU RI Well Aquifer Pumping Tests

Well Name	Test Date	Depth to Water (m [ft] bgs)	Depth to Top of Basalt (m [ft] bgs)	Saturated Thickness (m [ft])	Top of Screen (m [ft] bgs)	Bottom of Screen (m [ft] bgs)	Well Diameter (cm [in.])	Pumping Rate L/min (gpm)	Drawdown (m [ft])	Pumping Duration (minutes)	Specific Capacity (L/min/m [gpm/ft])	Aquifer Transmissivity (m^2/d [ft^2/d])*
299-E27-155	11/12/2007	85.62 (280.92)	101.2 (332)	15.57 (51.08)	91.58 (300.46)	102.25 (335.46)	10.2 (4)	113.6 (30)	0.001 (0.002)	60	186,270 (15,000)	>18, 581 (>200,000)
299-E33-205	8/21/2008	79.14 (259.65)	81.4 (267.2)	2.30 (7.55)	78.49 (257.5)	81.53 (267.5)	10.2 (4)	71.9 (19)	0.027 (0.09)	45	2,620 (211)	3,902 (42,000)
299-E33-340	10/15/2008	66.22 (217.27)	Interbed	4.57 (15.0)	93.93 (308.18)	98.50 (323.17)	10.2 (4)	15.1 (4)	5.425 (17.8)	50	3 (0.22)	5 (59)
299-E33-341	6/10/2008	69.14 (226.85)	70.9 (232.5)	1.72 (5.65)	67.96 (222.98)	71.01 (232.97)	10.2 (4)	103.3 (27.3)	0.009 (0.03)	45	11,300 (910)	17,001 (183,000)
299-E33-342	6/9/2008	71.98 (236.17)	73.9 (242.5)	1.93 (6.33)	70.90 (232.6)	73.94 (242.6)	10.2 (4)	102.2 (27)	0.015 (0.05)	21	6,706 (540)	10,126 (109,000)
299-E33-343	3/10/2008	76.85 (252.14)	79.5 (260.9)	2.67 (8.76)	76.17 (249.9)	79.22 (259.9)	10.2 (4)	75.7 (20)	0.006 (0.02)	59	12,418 (1,000)	18,674 (201,000)
299-E33-344	—	68.55 (224.90)	Perched water	3.72 (12.2)	66.42 (217.9)	72.27 (237.09)	10.2 (4)	—	—	—	—	—
299-E33-345	6/5/2008	77.23 (253.38)	79.3 (260.3)	2.11 (6.92)	76.10 (249.68)	79.15 (259.68)	15.2 (6)	60.6 (16)	0.600 (1.97)	100	101 (8.1)	149 (1,600)
299-E33-50	3/28/2007	68.47 (224.64)	Interbed	4.57 (15.0)	96.34 (316.06)	100.91 (331.06)	10.2 (4)	18.2 (4.8)	10.363 (34)	150	2 (0.14)	3 (37)
699-48-50B	12/5/2006	63.44 (208.14)	63.9 (209.5)	0.41 (1.36)	62.24 (204.2)	65.38 (214.5)	10.2 (4)	5.7 (1.5)	0.869 (2.85)	412	7 (0.53)	10 (107)
699-50-56	12/15/2006	46.14 (151.39)	49.1 (161)	2.93 (9.61)	46.09 (151.2)	49.13 (161.2)	10.2 (4)	43.5 (11.5)	0.023 (0.077)	60	1,850 (149)	2,787 (30,000)
699-52-55A	1/18/2008	46.86 (153.75)	54.0 (177.2)	7.15 (23.45)	51.76 (169.8)	54.80 (179.8)	10.2 (4)	—	—	—	—	—
699-52-55B	8/20/2008	52.91 (173.60)	Interbed	4.57 (15.0)	69.63 (228.46)	74.21 (243.46)	10.2 (4)	18.9 (5)	18.4 (60.4)	91	1 (0.083)	2 (22)

* Estimates of aquifer transmissivity were calculated using specific-capacity data method in accordance with Driscoll, 1986, *Groundwater and Wells*, for unconfined and confined aquifers.
bgs = below ground surface
gpm = gallons per minute

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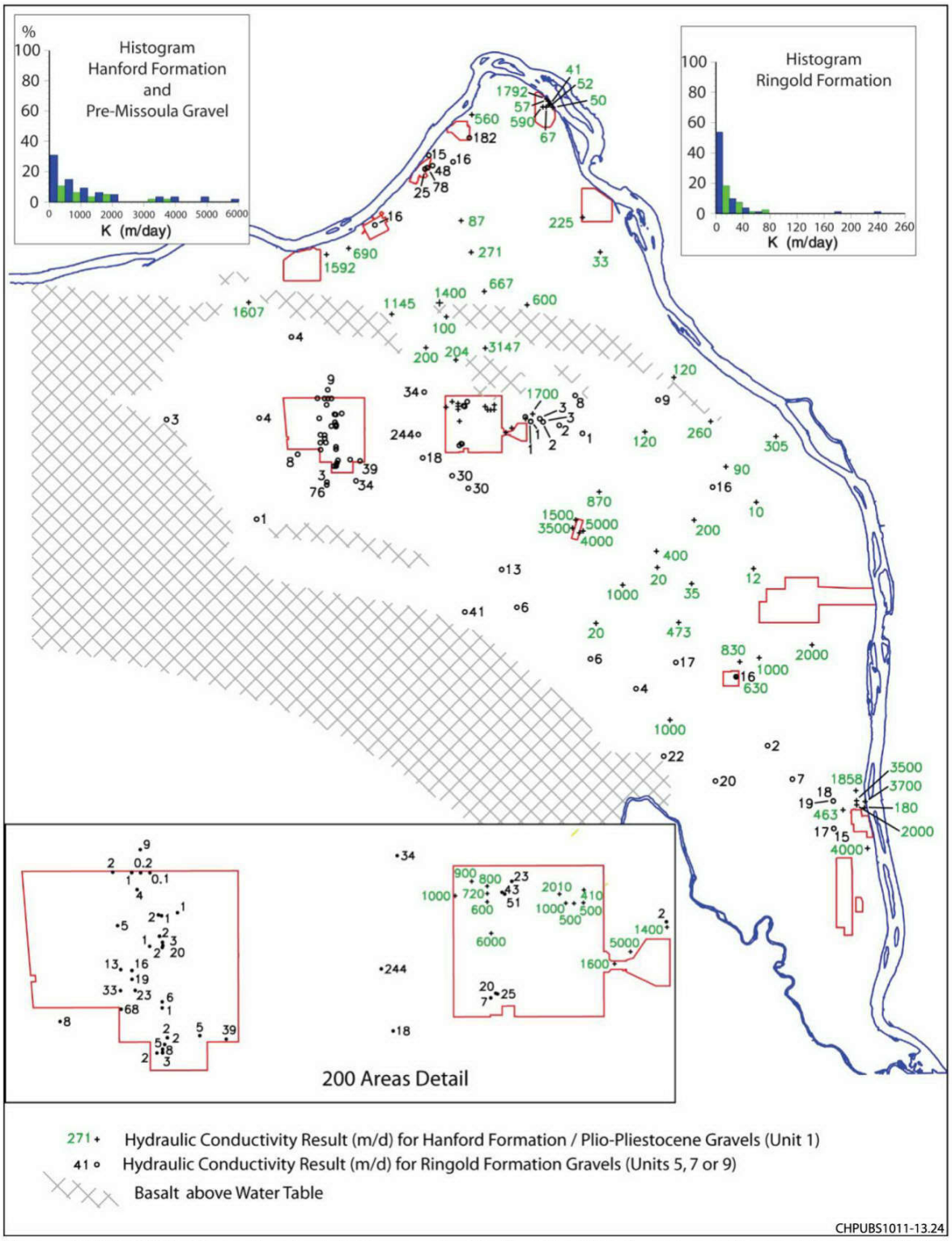


Source: PNNL-13641, *Uncertainty Analysis Framework – Hanford Site-Wide Groundwater Flow and Transport Model.*

Figure 3-31. Distribution of Hydraulic Conductivity from Pumping Tests

The framework of the Elephant Mountain Basalt can include the presence of vertical and horizontal cooling joints, typical of all Saddle Mountain Basalt flows. This jointing, if not sealed with secondary mineralization or forced together by tectonic forces, can provide a network of interconnecting pathways between aquifers. This jointing is considered a negligible pathway for groundwater and contaminants (compared to more direct pathways described below) unless the Elephant Mountain Basalt is extremely thin and fractured (RHO-RE-ST-12P).

Anticlinal folding and deformation of the Elephant Mountain Basalt, may act to enhance the fracturing along the tightest folds and within any zone of cooling joints. This may induce secondary permeabilities through the confining unit.

Faulting (another type of structural deformation) can provide a much more direct connection between the aquifers, by displacing older confined aquifer beds adjacent to younger aquifers. However, inactive fault zones can be filled with low-permeability (clay-dominated) fault gouge that, as with secondary mineralization within basalt cooling joints, inhibits the flow of groundwater. Nevertheless, faulting can provide a connection between the aquifers in two ways: (1) by providing a vertical fracture zone pathway through the dense basalt interior confining layer, and (2) by vertical displacement or offset of older confined aquifer beds adjacent to the unconfined aquifer.

Intercommunication between suprabasalt aquifers at the Hanford Site is well documented (RHO-RE-ST-12P; PNNL-12261). Near B Pond, an erosional window exists between the lower confined aquifer system and the uppermost unconfined aquifer system along the margins of buried paleochannels that extend approximately northwest to southeast across the 200 East Area and to the north. Such paleochannels cut through or eroded all of the Ringold Formation in some areas, allowing the lower confined portions of the Ringold Formation (HSU 9) to come into direct contact with the overlying saturated Hanford formation (HSU 1) sediments (Figure 3-24). During active B Pond disposal, the gradient was higher in the overlying unconfined aquifer, and contaminated groundwater was driven locally beneath the HSU 8 and into the underlying Ringold confined aquifer (HSU 9) near B Pond. Currently, the B Pond effluent disposal mound has dissipated, and because the hydraulic conductivity of the Hanford formation sediments in the channel fill is generally higher than that of the Rwia (HSU 9), the higher potentiometric head continues to decline as preferential flow into overlying Hanford sediments is returning to pre-Hanford conditions. Groundwater from the confined or semiconfined HSU 9 slowly discharges into the highly transmissive HSU 1 channel-fill sediment; this mixing of groundwater occurs at the intersection of the unconfined and confined aquifers.

3.6.5.4 Groundwater and Surface Water Interactions

The Columbia River and West Lake are two natural surface water bodies known to interact with groundwater in the 200-BP-5 OU. Groundwater in the unconfined aquifer flows toward and discharges into the Columbia River across most of the Hanford Site. Figure 3-32 provides a detailed water table map showing groundwater contours from Gable Gap to the Columbia River during late March 2010, when flow was toward the Columbia River. The volume of water leaving the unconfined aquifer and flowing into the river varies temporally based on river stage elevation, relative permeability along the shoreline sediments that form the unconfined aquifer, and relative gradient at the aquifer/river interface.

Substantial changes in groundwater levels and localized flow reversals can occur near the Columbia River during high river stages, which can vary up to 4 m (13 ft) during the year. When river stage is high (usually in the spring and early summer), water moves into the banks along the river, resulting in bank storage. When the river stage drops, water moves back toward the river, often appearing as riverbank seepage. The distance that water moves into the aquifer from the river depends on the magnitude and duration in the river stage above groundwater elevation and the hydraulic properties of the intervening

aquifer (PNNL-13080). Seasonal river-stage fluctuations can also result in a pressure pulse (i.e., a rise in groundwater elevation) in the aquifer that can extend long distances, depending on the duration and amplitude of the river-stage change and the aquifer transmissivity. This phenomenon was recently observed as far south as the northernmost portion of the 200 East Area (DOE/RL-2010-11). The seasonal high river pulse is clearly illustrated in Figure 3-33, which compares hydrographs for four wells (located in Gable Gap) with the river stage. The well responses are delayed with respect to the time of river stage increase, but the pattern is very clear. Figure 3-34 shows the effect of seasonal river-stage changes on groundwater gradient and direction of groundwater flow in the unconfined aquifer.

Shoreline aquifer tube monitoring stations are used to evaluate groundwater interaction between the suprabasalt aquifer and the Columbia River. Aquifer tubes along the southern shore of the Columbia River bordered by the 200-BP-5 OU include 11-D, 12-D, 13-S, and 14-D.

West Lake is a natural ephemeral lake located southeast of Gable Gap (ARH-CD-775; PNL-7662) in a topographically low area located within an ancient erosional channel. As an ephemeral lake, the water surface is a reflection of the water table position. During periods of high precipitation, the level of West Lake may be slightly higher than the regional water table. During dryer months, evaporation causes the water in the lake to become supersaturated with certain minerals, including calcium carbonate. The water level in West Lake was higher when Gable Mountain Pond (located near the lake) was receiving water, and the water table was subsequently several meters higher than at present.

3.6.6 Groundwater Velocity

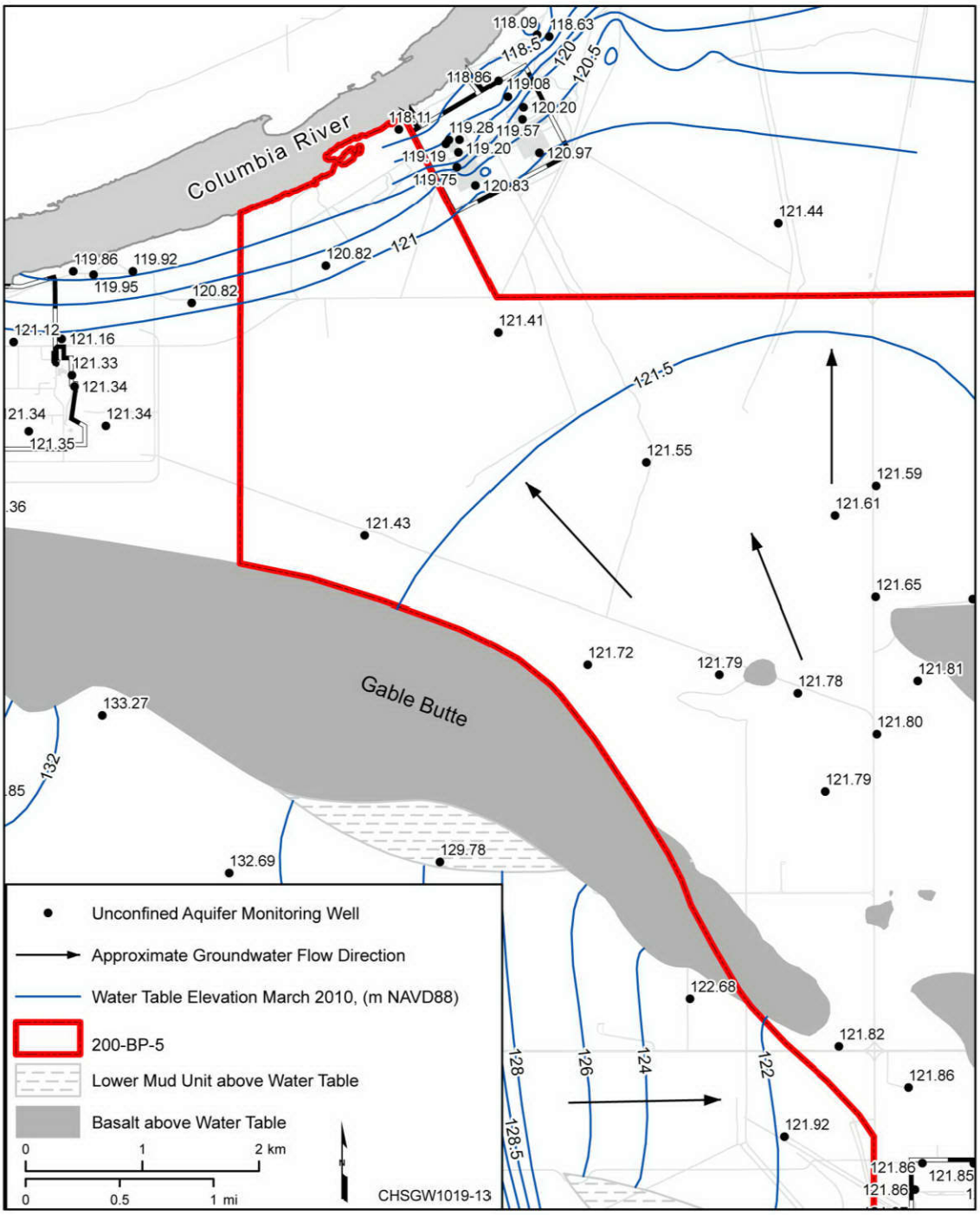
Groundwater velocity is dependent upon the hydraulic conductivity and effective porosity of the aquifer sediments, as well as the gradient of the water table (or piezometric surface in the case of a confined aquifer). For example, the large water table mound and steep water table gradient created during historical large-volume effluent disposal (which ending in the early 1990s) significantly influenced the velocity, unconfined aquifer thickness, flow paths, and travel time of 200-BP-5 OU contaminant plumes during that time.

Groundwater flow paths and contaminant plumes originating or traveling through 200-BP-5 OU migrated toward the Columbia River in two general directions:

- Plumes in the northwestern portion of the 200 East Area generally moved to the northwest toward Gable Gap and to the north toward the Columbia River until 2011, when flow direction in the 200 East Area reversed by 180 degrees (Section 3.6.2.3).
- Plumes further south in the 200 East Area moved southeast toward the Columbia River.

Both of these general flow paths were influenced by an artificially elevated water table created by past liquid waste disposal at ponds and cribs within both the 200 East Area (mainly B Pond and Gable Mountain Pond) and the 200 West Area (primarily U Pond and other cribs). A constantly changing groundwater divide beneath the 200 East Area was dependent on the location, volume, and timing of effluent disposal (RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*; PNNL-15837, *Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas*). Before 2011, the groundwater divide that existed in the 200 East Area controlled contaminant plume movement northwest through Gable Gap northward toward the river, and contaminant plume movement southeast toward the Columbia River. After cessation of liquid disposal to cribs, ponds, and ditches in the mid-1990s, the artificially elevated water table in the near-field area quickly declined. This water table declined approximately three times faster in the 200 East Area than in the 200 West Area because the sediments containing the water table in the 200 East Area are much more permeable

(i.e., Hanford/CCU gravel) than those in 200 West Area. The water table throughout most of the 200-BP-5 OU continues to decline but appears to be stabilizing and reaching equilibrium. The current groundwater gradient across the near-field area is now so small that detecting differences in groundwater elevation across the area is difficult.



Reference: NAVD88, *North American Vertical Datum of 1988*.

Figure 3-32. Water Table Contour Map of the Gable Gap Area, 200-BP-5 OU, March 2010

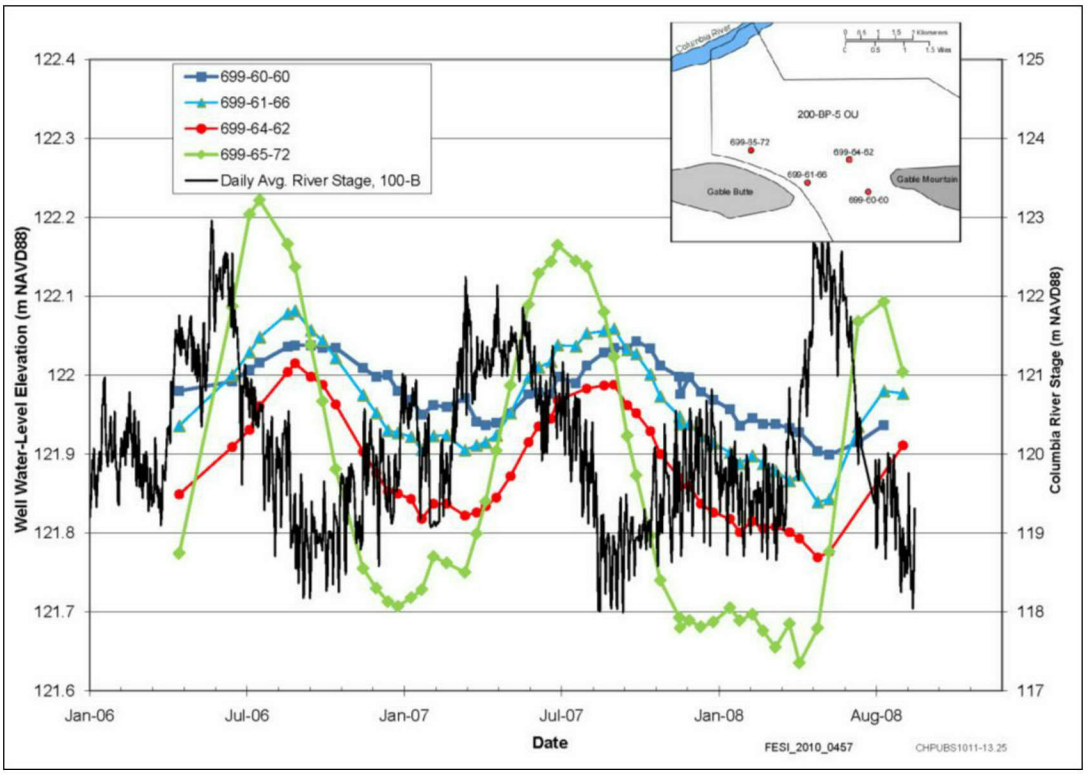


Figure 3-33. Correlation between Columbia River Stage and Water Level Elevations at Gable Gap

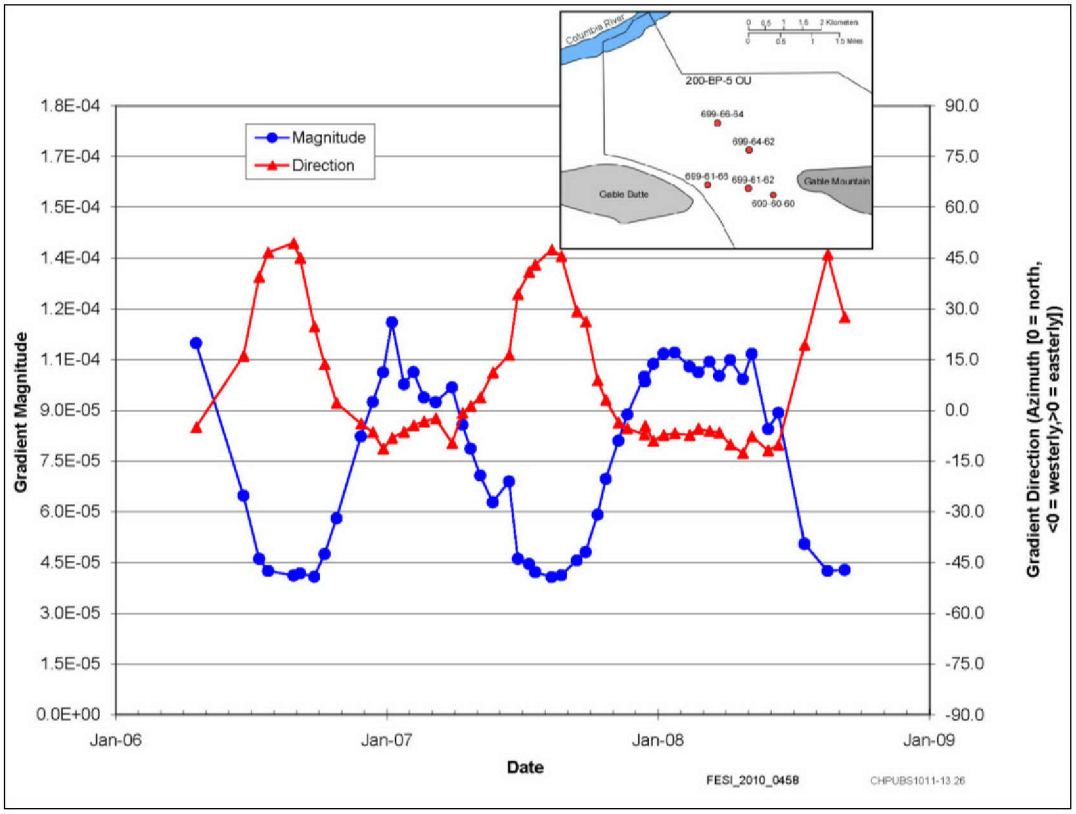


Figure 3-34. Seasonal Changes in Hydraulic Gradient and Flow Direction at Gable Gap

Groundwater velocity is affected directly by hydraulic gradient. The decline in gradient in the near-field area has indicated substantially lower groundwater velocities and longer travel times for contaminants within the groundwater during recent years. Since July 2011, the flow direction across most of the near-field area and the 200 East Area has been south-southeast (SGW-54165, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site*). Current groundwater flow velocities in the 200-BP-5 OU (within the 200 East Area) range from 0.02 to 0.6 m/d (0.07 to 1.97 ft/d) (Appendix B, DOE/RL-2014-32).

The large volumes of process water discharged to the vadose zone during Hanford Site operations substantially raised groundwater levels, which increased the hydraulic gradient and the annual volume of northward groundwater flow through Gable Gap. Since the advective transport of groundwater plumes is proportional to groundwater velocity, the lower groundwater velocities currently experienced in the 200-BP-5 OU are contribute to the decreasing size of some of the widespread groundwater plumes (e.g., nitrate). The decreased groundwater velocity also has the effect of slowing down advective transport and causing some emerging groundwater plumes to become more concentrated in the source areas than when the groundwater gradient was higher. This slowing phenomenon appears to be associated with recent reversals where a low gradient, water level study has been conducted for the past several years (SGW-54165).

A similar estimate can be made for southeastern flow from the OU. The regional gradient to the southeast from the 200 East Area (across the 200-BP-5 and 200-PO-1 OUs) has been estimated to be 1.8×10^{-5} (DOE/RL-2008-66). Southeastern flow from the 200-BP-5 OU now is likely dominant than northern flow through Gable Gap. Iodine-129 and tritium groundwater plumes occur in the southern portion of the near-field area. The extent of these plumes demonstrates mainly a southeast flow direction into the 200-PO-1 OU.

Groundwater velocity in the upper basalt-confined aquifer (HSU 10) is much lower than the unconfined aquifer and has been estimated at 0.7 to 2.9 m/yr (2.3 to 9.5 ft/yr) (0.002 to 0.008 m/d [0.0066 to 0.0262 ft/d]) based on hydraulic properties of the Rattlesnake Ridge interbed, and 2.2 m/yr (7.2 ft/yr) (0.006 m/d [0.0197 ft/d]) estimated using groundwater ages from carbon isotopic information (PNL-10817, *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System*).

3.6.7 Conceptual Site Model

The 200-BP-5 OU CSM is discussed separately for the near-field and far-field areas. The focus of the CSM is to describe the occurrence and migration of groundwater contaminants across the OU by describing the general sources and subsurface pathways through the hydrogeologic framework within the OU. Contaminant receptor scenarios are discussed in Chapter 6.

3.6.7.1 200-BP-5 Operable Unit Near-Field Area

The 200-BP-5 OU near-field area is divided into the following three general areas:

- Northern 200 East Area
- B Pond/Gable Mountain
- Gable Gap/West Lake/Gable Mountain Pond

Past-practice disposal of large volumes of liquid effluent infiltrated beneath the many waste disposal ponds, cribs, and ditches within and surrounding the 200 East Area and migrated vertically through the thick vadose zone, which consists mostly of permeable sand and gravel deposits (Hanford formation). The contaminants that have migrated to groundwater moved laterally within the relatively thin, but

highly permeable, sediments of the uppermost unconfined aquifer. As effluent disposal increased, the elevation of the water table rose and locally mounded beneath the various waste sites. This created an increase in horizontal and vertical groundwater gradients, which increased the lateral and downward spread of contamination.

Groundwater contamination within the uppermost unconfined aquifer initially moved laterally through very high-permeability sediment (HSU 1 and HSU 3). Over time, however, the increased volumes and water table elevation caused some of the contaminated groundwater to move deeper into lower permeability Ringold Formation sediments(i.e., HSU 5), including areas locally connected to the confined aquifer (i.e., HSU 9). In addition to disposal ponds, cribs, and ditches, other mechanisms such as reverse wells (no longer active) disposed contaminated effluent to deeper parts of the unconfined aquifer (PNNL-14111, *Fiscal Year 2003 Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project*).

The current CSM for the vicinity of the 200 East Area includes a thick sequence of relatively permeable suprabasalt sediments with a considerable number of known and potential source areas for groundwater contamination, a relatively thin unconfined aquifer, and a declining water table. The known sources for groundwater contamination within the 200-BP-5 OU (described in greater detail in Chapter 4) include cribs (e.g., BY Cribs), tank farms (e.g., WMA C and WMA B-BX-BY single-shell tanks [SSTs]), trenches, ditches, ponds (e.g., B Pond), and reverse wells. During operations, groundwater moved out of the 200 East area either north through Gable Gap or east-southeast toward the Columbia River. Since cessation of most direct liquid waste disposal to ground, the water table has declined and groundwater flow directions are returning to pre-Hanford conditions, primarily to the east-southeast across the 200 East Area. Chapter 4 discusses the source areas that have been directly associated with mapped groundwater plumes. The most extensive contaminant plumes are attributed primarily to liquid discharges to cribs, with some contribution from ponds, ditches, and other sources. Contamination from SST leaks and UPRs are difficult to separate from surrounding crib waste contaminants.

In the 200 East Area, a perched aquifer zone occurs a few meters above the water table beneath the B Complex. The perched condition observed in some recent boreholes occurs within low-permeability saturated sand and silt of the CCU_z facies. Liquid effluent migrating through the vadose zone from past disposal operations and/or leaking SSTs is being held up by lower permeability silt within the CCU_z. This saturated perched interval seeps contaminated perched water slowly into the aquifer and has slowed contaminant migration to the water table. Under current conditions, the saturated CCU_z may allow seepage of highly contaminated perched water to the unconfined aquifer over a long period. Perched contamination (e.g., uranium and technetium-99) is contributing to substantial plume concentrations beneath the B Complex within the slowly moving groundwater. Ongoing 200-DV-1 OU characterization and perched water extraction are occurring within the CCU perched zone. The 200-DV-1 OU is evaluating the nature and extent of the perched contamination, accelerating the removal of contaminated perched water (DOE/RL-2014-34, *Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*), and assessing future impacts to the unconfined aquifer (SGW-53604).

Most groundwater contaminant concentrations and plumes are declining throughout much of the 200 East Area. Notable exceptions to this trend are the nitrate, uranium, and technetium-99 plumes associated with the B Complex (including the perched vadose zone), which have enlarged in the past decade. Many short-lived radionuclides detected in the past (e.g., cobalt-60 and ruthenium-106) are no longer detected or are detected at much lower concentrations. Tritium concentrations near the source areas are declining because waste discharges have ended and the radionuclide is dispersing and decaying. Tritium formerly exceeded the DWS in portions of the far-field area of the 200-BP-5 OU north of Gable Gap, but concentrations have declined. Nitrate concentrations have generally declined in the far-field area

in recent years, and concentrations never exceeded the DWS north of Gable Gap. Data indicate that residual contamination in the vadose zone at many of the source locations continue to reach the water table. In addition, any uncontrolled discharge (e.g., leaks from water lines) may enhance transport of contaminants to the groundwater from the vadose zone (PNNL-14111).

Groundwater in the suprabasalt aquifer system generally flows from west to east beneath the Hanford Site (Figure 3-19). Prior to 2010, a groundwater divide occurred somewhere in the northern portion of the 200 East Area (i.e., the southern portion of the near-field area). Groundwater north of the groundwater divide generally migrated north toward Gable Gap (to the northwest). Groundwater south of the groundwater divide generally flowed south and then east into the 200-PO-1 OU. A combination of the location north of the 200 East Area, the elevated groundwater near Gable Mountain Pond during operations north of the 200 East Area, and the mound generated by cooling water discharges at 100-K Area reactor operations prevented contaminated groundwater beneath the 200 East Area from migrating rapidly north toward the Columbia River until the early 1970s. Geologic structures including basalt subcrops (HSU 10) and the RLM (HSU 8) partially diverted groundwater flow. After the cessation of decades of high-volume liquid effluent disposal to the ground, the water table declined rapidly. In 2011, a reversal of flow from the northwest to the southeast was documented in the northwestern portion of the 200 East Area.

This shift in the divide is significant because it has changed the direction in which contaminants migrate within the southern portion of the 200-BP-5 OU. Due to the flow direction reversal in 2011, contaminants in the 200 East Area are migrating to the southeast and are no longer interpreted to be migrating northward through Gable Gap. Movement of contaminants north of the 200 East Area toward the Gable Gap is stationary or very slow. The exact location of the current groundwater divide is uncertain because of the extremely flat surface of the water table in the near-field area. As artificial recharge has been substantially reduced in recent years, groundwater levels have responded with continuing declines; the rate of decline has slowed in recent years. Declining water levels and changes in recharge patterns are continuing to affect contaminant concentrations and contaminant migration patterns (DOE/RL-2014-32).

Possible seasonal effects from changes in the level of the Columbia River also influence water levels in the 200 East Area unconfined aquifer. Figures 3-33 and 3-34 provide hydrographs showing the magnitude of changes in gradient and changes in flow direction through Gable Gap and the far-field area, as well as changes in Columbia River stage below Priest Rapids Dam, which is upriver from the OU. In response to 4 m (13.1 ft) changes in Columbia River stage, the water level change at Gable Gap is approximately 0.25 m (0.82 ft), and the delay is approximately 1 to 3 months (DOE/RL-2008-66). East-west conceptual cross-section CC-CC' (Figure 3-35) shows the generalized geology in the Gable Gap area.

The northwest-southeast conceptual cross-section AA-AA' (Figure 3-36) focuses on the contribution of contaminants from the vadose zone to the unconfined aquifer near the BY Cribs and WMA B-BX-BY. Waste from the BY Cribs contributed greatly to past and present groundwater contaminants, and the tank farms contributed leaked contaminants to the unconfined aquifer. The relatively thin aquifer that occurs beneath the northern portion of the 200 East Area (and in areas immediately north) contrasts sharply with the thick, unconfined, channel-fill aquifer near Wells 699-55-60A and 699-55-60B.

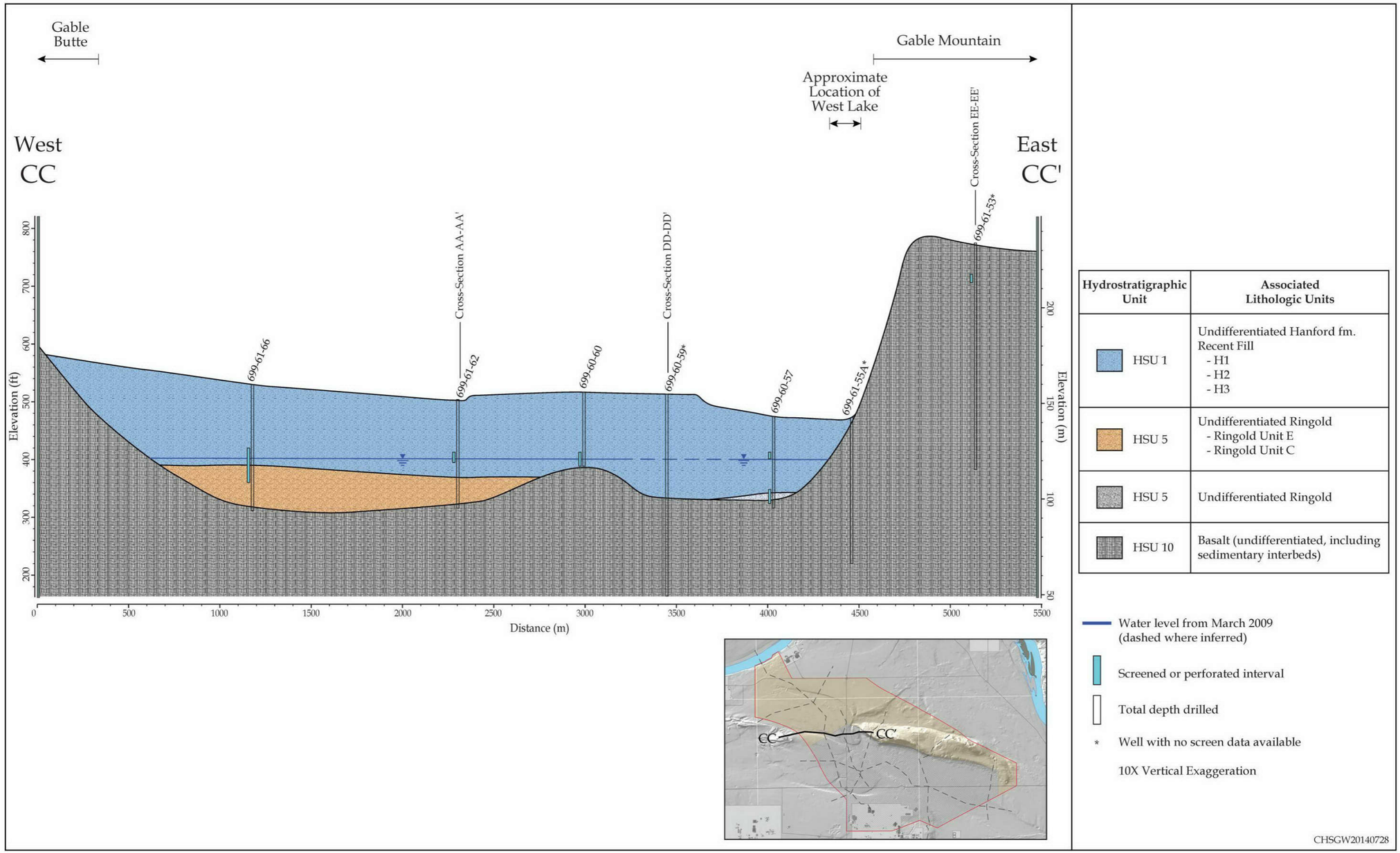


Figure 3-35. 200-BP-5 OU Hydrogeologic Cross-Section CC-CC'

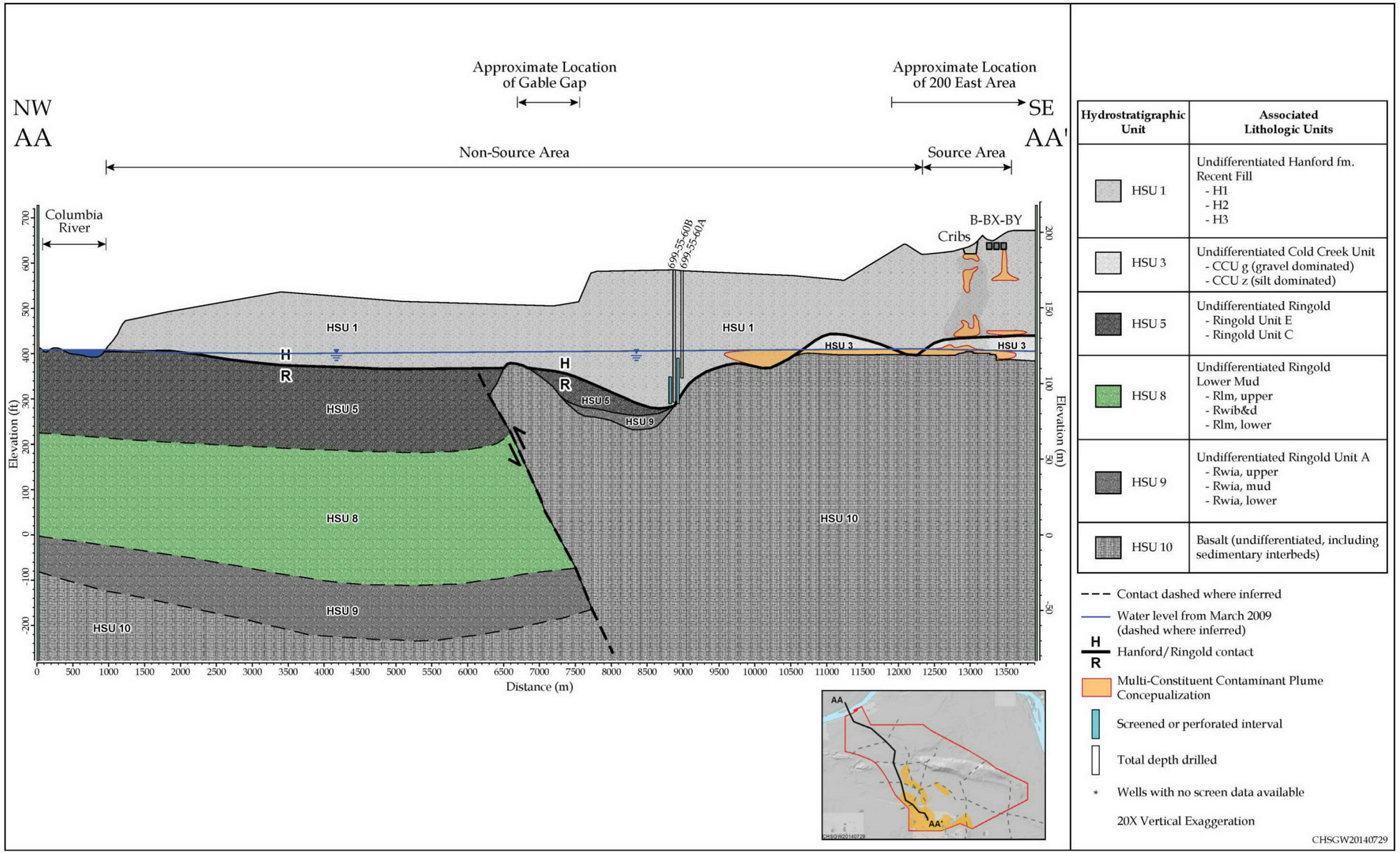


Figure 3-36. 200-BP-5 OU Conceptual Cross-Section AA-AA' Showing Contaminant Flow from B Complex Area Waste Sites to Gable Gap

The north-south conceptual cross-section FF-FF' (Figure 3-37) illustrates how past liquid effluent disposal and the associated groundwater mounding influenced the water level and contaminant distribution, driving some groundwater contamination into the semiconfined Rwia (HSU 9) aquifer. South-dipping Ringold Formation deposits near B Pond are exposed to Hanford formation deposits, which provided pathway for B Pond effluent to migrate into the HSU 9 semiconfined aquifer at the same time that the unconfined aquifer was being impacted. Since cessation of effluent disposal to B Pond, groundwater levels have declined more rapidly in the unconfined aquifer than in the confined Ringold (HSU 9), and higher head in HSU 9 persists.

3.6.7.2 200-BP-5 Operable Unit Far-Field Area

The 200-BP-5 OU far-field area is primarily located north of Gable Gap. Cross sections for the far-field area are presented in conceptual northwest-southeast cross-section AA-AA' (Figure 3-36), Gable Gap east-west cross-section CC-CC' (Figure 3-38), and southwest-northeast cross-section BB-BB' (Figure 3-39). Historically, groundwater contaminants (primarily tritium) have migrated northwest through Gable Gap into the northern portion of the 200-BP-5 OU. Since approximately 2005, the extent of contamination has decreased to below DWSs as the result of reduced groundwater flow through Gable Gap, which resulted from water table declines after cessation of large-volume wastewater discharges to the ground.

Conceptual cross-section AA-AA' (Figure 3-36) shows the change in the far-field area aquifer thickness (including both the confined and unconfined aquifers), ranging from approximately 15 m (50 ft) in the Gable Gap area to as much as 183 m (600 ft) in the area between the Gable Mountain reverse fault and the Columbia River. In the past, based on higher groundwater gradients northwest toward Gable Gap, groundwater contaminants (primarily nitrate and tritium) above DWSs migrating preferentially through the upper unconfined aquifer within saturated Hanford formation sediments as far northwest as Gable Gap.

Cross-sections CC-CC' (Figure 3-38) and BB-BB' (Figure 3-39) show the relationship between the geology and the water table north of Gable Gap. Only the very uppermost saturated Hanford formation sediments were historically contaminated within the thick unconfined aquifer. As recently as 2005, this area had tritium concentrations above the DWS, but sampling in 2013 indicated that contaminant concentrations had declined below the DWS north of Gable Gap. This tritium concentration decline and the plume extent are attributed to the decreased groundwater flow rate through Gable Gap, the reduced contaminant contribution from the past-practice source areas in the 200 East Area, and radioactive decay.

3.7 Water Use

Groundwater is not currently withdrawn for industrial, sanitary, or potable uses in the 200-BP-5 OU. Surface water and groundwater are removed for use extensively in the communities and agricultural lands surrounding the Hanford Site for drinking water, process applications, and irrigation. Routine groundwater pumping does not occur in the OU. Minor amounts of treated effluent are discharged to the ground within the 200-BP-5 OU, where it eventually reaches the groundwater.

3.7.1 Surface Water Use near the 200-BP-5 Operable Unit

The Columbia River is used as a source of both drinking water and industrial water for several Hanford Site facilities (DOE/RL-2013-18). Potable water is managed at facilities overlying the 200-BP-5 OU according to the Hanford area water system plan (HNF-35051, *Small Water Systems Management Program for Group A Water Systems Managed by Mission Support Alliance, LLC*) and a master water plan (HNF-5828, *Hanford Site Water System Master Plan*). Source water comes from a withdrawal location on the Columbia River near the 100-BC Area, upstream from the 200-BP-5 OU.

The water is treated at a water treatment plant in the 200 West Area and then delivered by pipeline to the 200 East Area. This water plant produces an average of approximately 17 million L/d (4.5 million gal/d) of treated water. The water is metered where it enters the 200 East Area, but no metering currently occurs downstream from the main 200 East Area meter. Water delivery to the 200 East Area is approximately one-half of the total (roughly 8.4 million L/d [2.25 million gal/d]).

3.7.2 Sewage Disposal near the 200-BP-5 Operable Unit

Sewage in the 200-BP-5 OU is handled two ways. Some buildings have holding tanks and drain fields, while others have holding tanks that are pumped periodically, and the pumped sewage is delivered to the 100-N Area sewage lagoon. In 2012, an evaporative sewage treatment plant was completed in the 200 West Area. Approximately seven active septic disposal systems operate in the 200 East Area. Updates to HNF-6612, *Hanford Site Sewer System Master Plan*, were completed in 2012.

3.8 Ecology

Terrestrial ecosystems on the Hanford Site and overlying the 200-BP-5 OU include upland and riparian/wetland habitat. Upland habitat at the Hanford Site is influenced by the arid climate and is characterized by vegetation and wildlife adapted to hot summers, cold winters, and low precipitation. Riparian habitat occurs along bodies of water and is inhabited by plants with greater requirements for water than upland plants. Wetlands are areas where some open water is present, and soils and associated vegetation reflect the presence of water. The distribution of plants within the upland habitat on the Hanford Site is greatly influenced by soil type, altitude, and precipitation. Range fires, industrial human activities, and the introduction of non-native species have also affected ecosystems.

The upland habitat within the Hanford Site, located within the Columbia Basin (Plateau) ecoregion, is predominantly shrub-steppe (Stoms et al., 1997, *Preserve Selection Modeling in the Columbia Plateau*). Shrub-steppe ecosystems are typified by a shrub overstory and a grass and forb understory (Daubenmire, 1970, *Steppe Vegetation of Washington*). Lichens and mosses, often referred to as microbiotic or cryptogamic crust, provide a soil stabilizing growth on undisturbed soils in the shrub-steppe ecosystem.

Riparian areas are vegetated wetlands that are especially associated with rivers and streams, which include shoreline areas along sloughs and backwaters. Riparian habitat that occurs in association with the Columbia River includes riffles, gravel bars, backwater sloughs, and cobble shorelines. These habitats occur infrequently along the Hanford Reach and have acquired greater significance because of the net loss of wetland habitat elsewhere within the region.

Riparian areas provide nesting, foraging habitat, and escape cover for many species of birds and mammals. Shoreline riparian communities are seasonally important for a variety of species. The Hanford Site is located in the Pacific Flyway, and the Hanford Reach serves as a resting area for neotropical migrant birds, migratory waterfowl, and shorebirds (Soll et al., 1999). The area between the old Hanford town site and the Vernita Bridge is closed to recreational hunting, and large numbers of migratory waterfowl find refuge in this portion of the Columbia River.

West Lake is an important habitat within the 200-BP-5 OU, primarily due to its uniqueness and rarity as a high-alkaline/saline lake. Saline lakes represent the terminus of inland basin flows and support unique communities of plants and microorganisms found in no other habitat. Although hypersaline lakes (e.g., West Lake) support limited species of hypersaline-tolerant plants and brine flies, these lakes play an important ecological role by providing food to migrating birds and mineral deposits to animals and people.

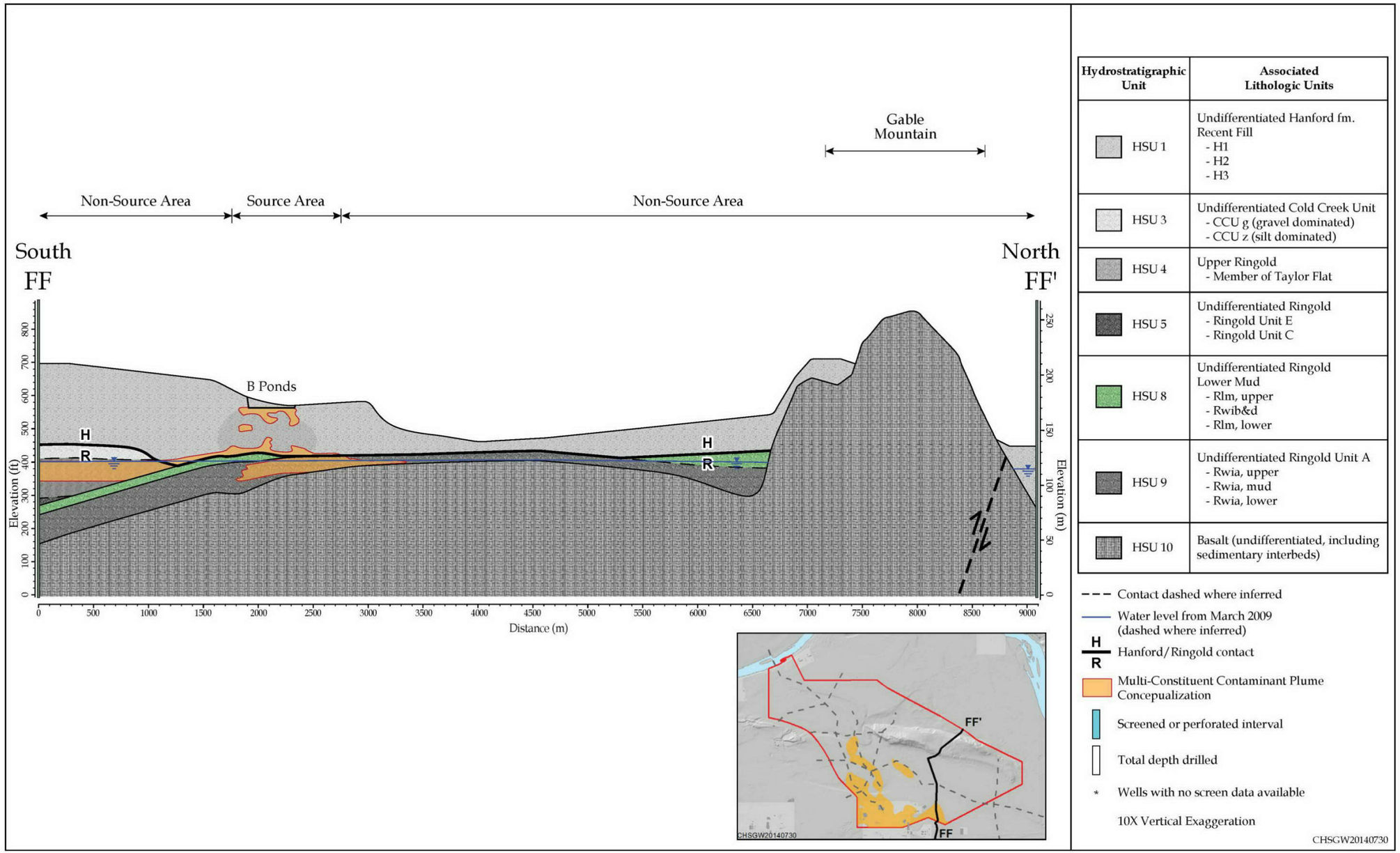


Figure 3-37. 200-BP-5 OU Conceptual Cross-Section FF-FF' Showing Effluent Infiltration near B Pond

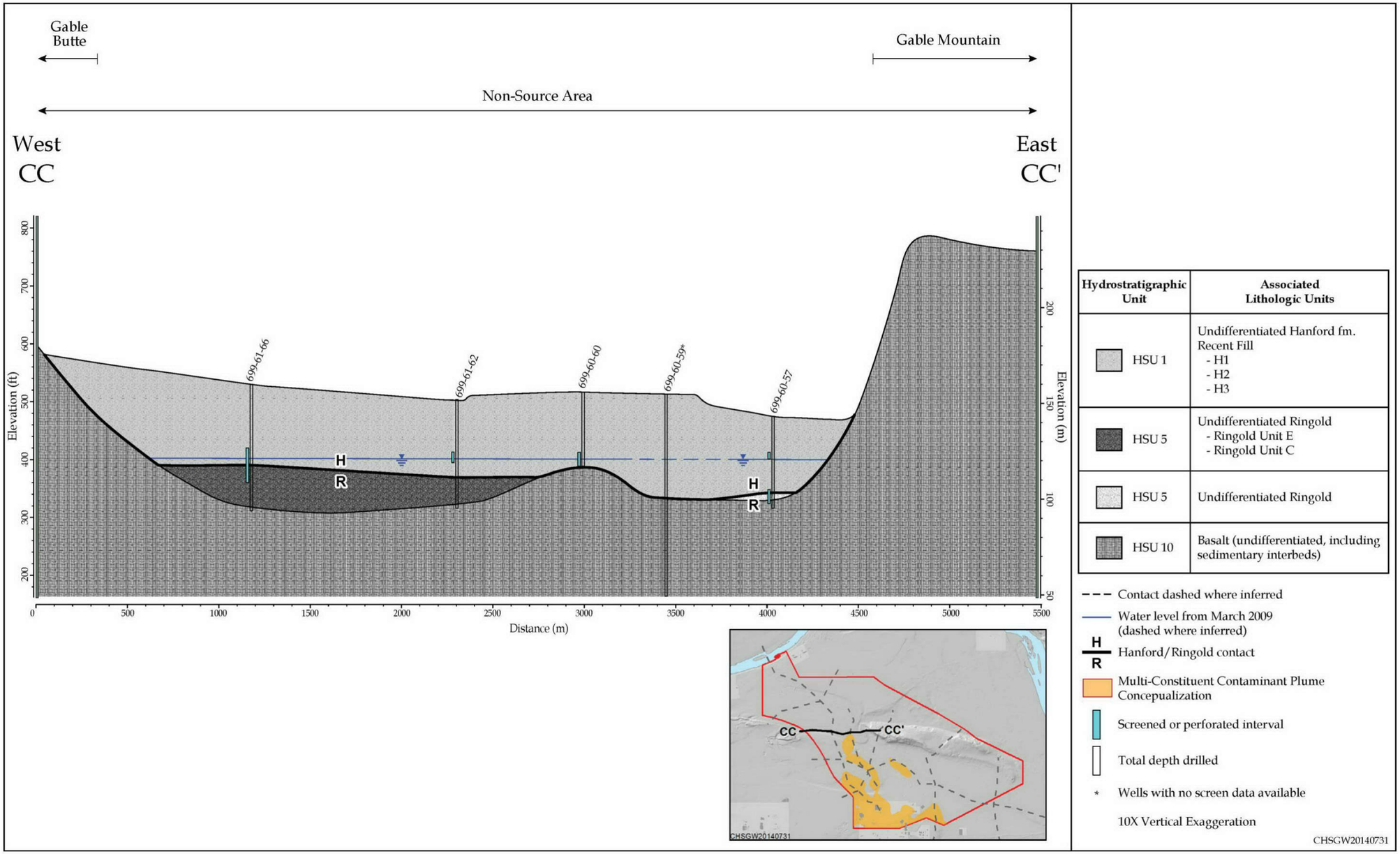


Figure 3-38. 200-BP-5 OU Conceptual Cross-Section CC-CC' Showing the Permeable Hanford Formation Sediments at Gable Gap

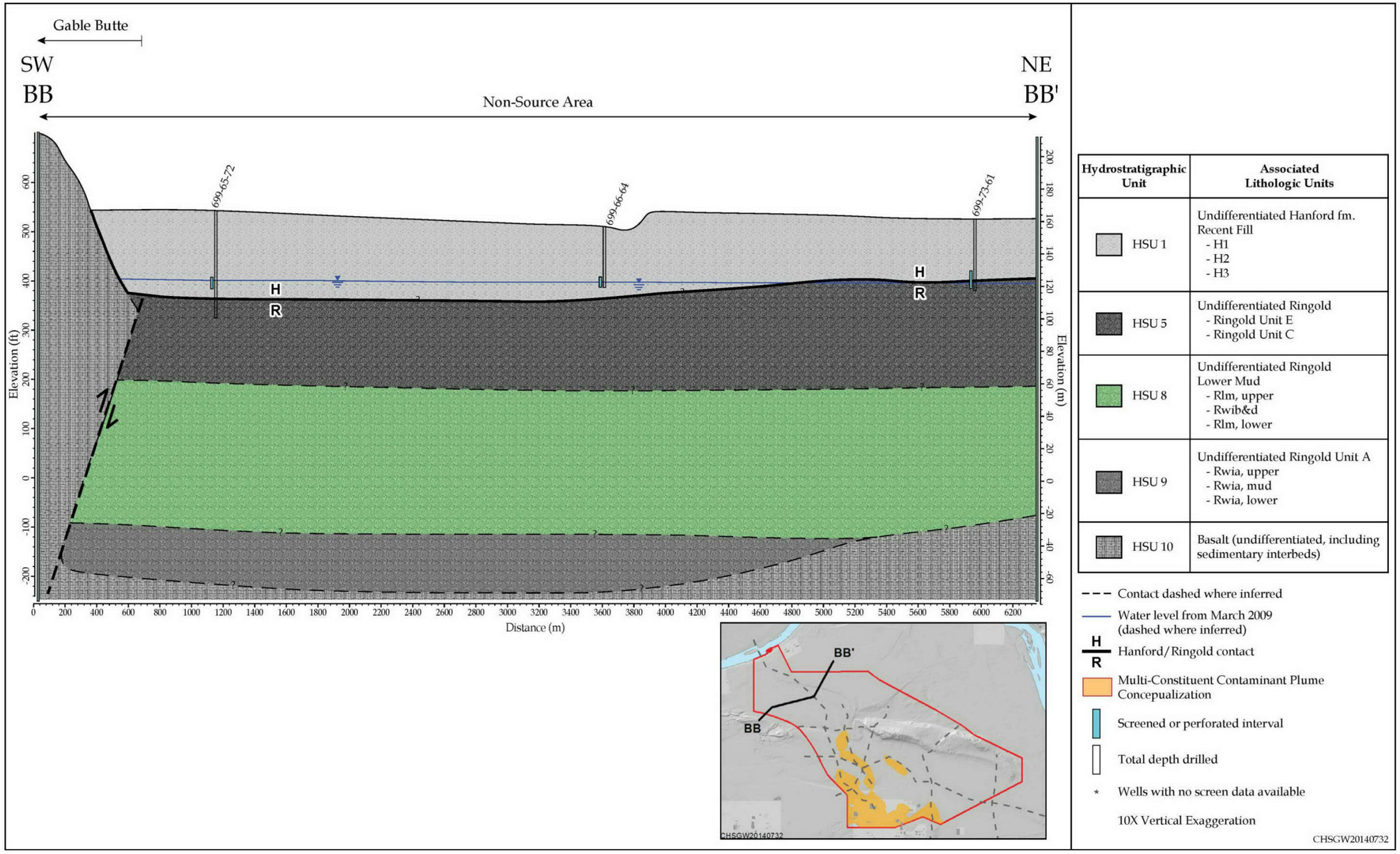


Figure 3-39. 200-BP-5 OU Conceptual Cross-Section BB-BB' Showing No Contaminant Migration in More Permeable Hanford Formation Sediments through the Far-Field Area

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West Lake and associated wetlands appeared to be substantially degraded during a 1997 survey by The Nature Conservancy of Washington (DOE/RL-2001-54, *Central Plateau Ecological Evaluation*). Alkali paintbrush (*Castilleja exilis*) and many other native species that were historically documented at the lake were not observed, and the lake basin was infested with weedy species, primarily smother weed (*Bassia hyssopifolia*).

In June, July, and November 2006, plant communities were characterized, and observed plant assemblages were identified and delineated (DOE/RL-2007-50, *Central Plateau Ecological Risk Assessment Data Package Report*, Appendix D). Plant community alliances (plant assemblages) that occur at West Lake occupy sites determined by hydrology and soil chemistry (alkalinity/salinity). Except for the presence and diversity contributed by non-native species, the structure of the alliance is relatively simple, with the dominant native species forming dense swards with few other native species. Ecological condition of the alliance varies across the site, with exotic taxa dominant in some alliances/site.

Mammals occurring primarily in riparian areas include rodents, bats, furbearers (e.g., mink [*Mustela vison*] and weasel [*Mustela* spp.]), porcupine (*Erithizon dorsatum*), raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*), and mule deer (*Odocoileus hemionus*). River otters (*Lutra canadensis*) have been observed infrequently at the Hanford Reach. During the summer, mule deer rely on riparian vegetation for foraging and use Columbia River islands for fawning and nursery areas. Beaver (*Castor canadensis*) and muskrat (*Ondatra zibethica*) rely on shoreline habitat for dens and foraging. The Columbia River and Rattlesnake Springs provide foraging habitat for bats, including Yuma myotis (*Myotis yumanensis*), small-footed myotis (*Myotis subulatus*), silver-haired bats (*Lasionycteris octivagans*), and pallid bats (*Antrozous pallidus*), all of which feed on emergent aquatic insects (PNL-8916, *A Preliminary Survey of Selected Structures on the Hanford Site for Townsend's Big-Eared Bat (Plecotus townsendii)*).

Along with the reptiles and insects identified in the grasslands discussion, five amphibians have been identified on the Hanford Site. The Great Basin spadefoot toad (*Scaphiopus intermontanus*), western toad (*Bufo boreas*), Woodhouse's toad (*Bufo woodhousei*), tiger salamander (*Ambystoma tigrinum*), and bullfrog (*Rana catesbeiana*) are the only amphibians found in proximity to water on the Hanford Site (Soll et al., 1999; WHC-SD-EN-TI-121, *Biological Resources of the 300-FF-5 Operable Unit*).

3.8.1 West Lake Receptors

As discussed previously, the unique properties of West Lake warrant discussion beyond the general discussion of the Central Plateau or the Outer Area. The ecology of West Lake is described in the following subsections.

3.8.1.1 Mammal Species of West Lake

Wildlife surveys were conducted to evaluate the use of West Lake by resident and migratory animals (DOE/RL-2007-50, Appendix D). Visual and echolocation surveys for bats were conducted at the lake between March 2006 and May 2007. Small mammal trapping was not performed; however, indirect evidence of small mammal activity, particularly the Great Basin pocket mouse (*Perognathus parvus*), was abundant in the vegetation communities surrounding West Lake throughout much of the year. Other small animal residents of the West Lake area most likely include the deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Riethrodontomys megalotis*), northern pocket gopher (*Thomomys talpoides*), and northern grasshopper mouse (*Onychomys leucogaster*), as well as a number of shrew and vole species. Direct and indirect evidence of mid- and large-size mammals was found around the perimeter of the lake and documented during the surveys. The standing water at the lake was minimally used as a water source by animals. However, ungulate appeared to be foraging on the succulent vegetation near the southeastern region of the lake, and the water seeps were used as a water source by all

observed mammals. The mammal species observed directly or indirectly at or near West Lake during the 2006 to 2007 surveys are presented in Table 3-2.

Table 3-2. Mammals Representative of West Lake

Feeding Guilds	Scientific Name
Herbivores	
Elk	*Cervus elaphus*
Great Basin pocket mouse	*Perognathus parvus*
Mule deer	*Odocoileus hemionus*
Northern pocket gopher	*Thomomys talpoides*
Voles	
Omnivores	
Deer mouse	*Peromyscus maniculatus*
Raccoon	*Procyon lotor*
Western harvest mouse	*Riethrodontonomys megalotis*
Insectivores	
Bats	
Northern grasshopper mouse	*Onychomys leucogaster*
Shrews	
Carnivores	
Badger	*Taxidea taxus*
Coyote	*Canis latrans*

Source: Appendix D of DOE/RL-2007-50, *Central Plateau Ecological Risk Assessment Data Package Report*.

3.8.1.2 Bird Species at West Lake

Bird surveys of West Lake were conducted monthly from March 2006 through March 2007 (DOE/RL-2007-50, Appendix D). Twenty-two species of birds were observed (indirect or direct evidence), including shorebirds during the spring when water and aquatic invertebrates were available. No birds were observed in October and November 2006. A historical comprehensive bird study conducted in the early 1970s (BNWL-1885, *Avifauna of Waste Ponds ERDA Hanford Reservation Benton County, Washington*) was compared to bird uses during 2006 and 2007. The species list of perching birds recorded in the late 1970s is remarkably similar to the list of perching birds observed during 2006 and 2007; however, species richness and relative abundance estimates of waterfowl and shorebirds have dropped dramatically since the 1970s. This decrease in use may be largely attributed to the elimination of the Central Plateau as a water source, making West Lake more like an ephemeral wetland. It is unclear whether the avian species richness and relative abundance trends at West Lake will

continue to decrease or whether current conditions observed at the lake are relatively stable. Some of the more common and representative species found near or at West Lake are presented in Table 3-3.

Table 3-3. Birds Representative of West Lake

Feeding Guilds	Scientific Name
Herbivores	
Mourning dove	*Zenaida macroura*
Omnivores	
Black-billed magpie	*Pica hudsonia*
Mallard	*Anas platyrhynchos*
Western meadowlark	*Sturnella neglecta*
Insectivores	
Common nighthawk	*Chordeiles minor*
Dunlin	*Calidris alpina*
Killdeer	*Charadrius vociferus*
Carnivores	
Common raven	*Corvus corax*
Northern harrier	*Circus cyaneus*

Source: Appendix D of DOE/RL-2007-50, *Central Plateau Ecological Risk Assessment Data Package Report*.

3.8.1.3 Amphibian and Insect Species at West Lake

Amphibian surveys were conducted at West Lake, and no evidence of amphibians was observed, likely due to the high alkaline conditions of the water (DOE/RL-2007-50, Appendix D). A limited characterization of aquatic invertebrates was performed during the 2006–2007 surveys. Brine flies (*Ephydridae* sp.) appear to be the only aquatic invertebrate capable of living in the highly alkaline waters of West Lake and are the primary food source for the observed shorebirds. A limited number of other aquatic invertebrates were found dwelling in the springs (seeps) that emerge along the southeastern portion of the lake (e.g., waterboatman [*Corixidae* sp.]).

3.8.1.4 Special Status Species at West Lake

During the bird survey conducted in March 2006, Sandhill cranes (*Grus canadensis*) were observed at West Lake (DOE/RL-2007-50, Appendix D). Sandhill cranes are currently listed as an endangered species in Washington State and are not a common resident of the Hanford Site. With the exception of the Sandhill crane, there are no additional special status species observed at West Lake that are not also found on the Central Plateau.

3.8.2 Threatened and Endangered Species

A variety of species are recognized by state or federal agencies as having special status based on the species' 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 (Table 5-1 of DOE/RL-2004-37, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA*). 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 regularly in PNNL-6415. No plants, invertebrates, reptiles, amphibians, or mammals on the federal list of threatened and endangered wildlife and plants are known to occur on the Hanford Site (PNNL-SA-41467, *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment*).

Two species of federally 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. Steelhead spawning has been observed in the Hanford Reach. The bull trout is listed as threatened by the National Marine Fisheries Service but 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 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 through 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 has decided to continue protection of nest and roost sites on the Hanford Site under DOE/RL-94-150, *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington*. This plan was revised in 2013 to account for the delisting of the bald eagle and to provide new management guidelines. 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").

Tables 3-4 and 3-5 list the flora and fauna species that are listed by Washington State as being threatened or endangered, including candidate, sensitive, and monitored species thought or known to occur on the Hanford Site. Ecological assessments of the surface area and river within the 200-BP-5 OU were conducted as part of the ecological risk assessment and DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*.

Table 3-4. Flora Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Upland			
Oenothera caespitosa ssp. *Caespitosa**	Caespitose evening-primrose	SS	
Orobanche californica	California broomrape	SX	
Astragalus columbianus	Columbia milk-vetch	SS	FCo
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	FCo
Aliciella leptomeria	Great Basin gilia	ST	
Lomatium tuberosum	Hoover's desert parsley	SS	FCo
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	SE	
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	
Eriogonum codium	Umtanum desert buckwheat	SE	FC
Eatonella nivea	White etonella	ST	
Riparian			
*Lipocarpha aristulata**	Awned halfchaff sedge	ST	
Eleocharis rostellata	Beaked spike-rush	SS	
*Hypericum majus**	Canadian St. John's-wort	SS	
Anagallis minima	Chaffweed	ST	
*Ammannia robusta**	Grand redstem	ST	

Table 3-4. Flora Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
*Rotala ramosior**	Lowland toothcup	ST	
*Rorippa columbiae**	Persistantsepal yellowcress	SE	FCo

Source: WNHP, 2014, *List of Vascular Plants Tracked by the Washington Natural Heritage Program*.

* Species possibly affected by discharges to the Columbia River in the 200-BP-5 Operable Unit area were deemed directly affected based on habitats associated with each species outlined in Section D.2.5.2, Table D.4, of DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*. Associated habitats selected were bluffs, Columbia River, islands, riparian, and White Bluffs.

FC = federal candidate
FCo = federal species of concern
SE = exotic established in state
SS = state sensitive
ST = state threatened
SX = apparently extirpated from the state

1

Table 3-5. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Birds			
*Pelecanus erythrorhynchos**	American white pelican	SE	
*Haliaeetus leucocephalus**	Bald eagle	SS	FCo
Athene cunicularia	Burrowing owl	SC	FCo
*Gavia immer**	Common loon	SS	
*Buteo regalis**	Ferruginous hawk	ST	FCo
Otus flammeolus	Flammulated owl	SC	
Aquila chrysaetos	Golden eagle	SC	
Centrocercus urophasianus	Greater sage grouse	ST	FC
Melanerpes lewis	Lewis' woodpecker	SC	
Lanius ludovicianus	Loggerhead shrike	SC	FCo
Accipiter gentilis	Northern goshawk	SC	FCo
*Falco peregrines**	Peregrine falcon	SS	FCo
Amphispiza belli	Sage sparrow	SC	
Oreoscoptes montanus	Sage thrasher	SC	
Grus canadensis	Sandhill crane	SE	
*Aechmophorus occidenalis**	Western grebe	SC	

Table 3-5. Fauna Threatened and Endangered Species List

Scientific Name	Common Name	State Status	Federal Status
Mammals			
Lepus californicus	Black-tailed jackrabbit	SC	
Sorex merriami	Merriam's shrew	SC	
Urocitellus townsendii (formerly *Spermophilus townsendii*)	Townsend's ground squirrel	SC	FCo
Urocitellus washingtoni (formerly *Spermophilus washingtoni*)	Washington ground squirrel	SC	FC
Lepus townsendii	White-tailed jackrabbit	SC	
Reptiles/Amphibians			
Sceloporus graciosus	Northern sagebrush lizard	SC	FCo
Masticophis taeniatus	Striped whipsnake	SC	
Aquatics			
*Salvelinus confluentus**	Bull trout	SC	FT
*Anodonta californiensis**	California floater (mussel)	SC	FCo
*Fluminicola Columbiana**	Columbia pebblesnail	SC	
*Oncorhynchus tshawytscha**	Chinook salmon	SC	FE
*Rhinichthys falcatus**	Leopard dace	SC	
*Catostormus platyrhynchus**	Mountain sucker	SC	
Lampetra tridentata	Pacific lamprey	SM	FCo
*Oncorhynchus mykiss**	Rainbow trout (steelhead)	SC	FT
*Lampetra ayresii**	River lamprey	SC	FCo
Fisherola nuttalli	Shortface lanx (snail)	SC	

Source: Washington State Department of Fish and Wildlife website, "Species of Concern" (WDFW, 2014).

* Animal species possibly affected by discharges to the Columbia River in the 200-BP-5 Operable Unit were deemed directly affected based on preferred habitat outlined in Section D.2.5.6, Table D.10, of DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*. Birds preferential to freshwater were selected.

FC = federal candidate
FCo = federal species of concern
FE = federal endangered
FT = federal threatened
SE = exotic established in state
SM = state monitored
SS = state sensitive
ST = state threatened
SX = apparently extirpated from the state

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4 Nature and Extent of Contamination

This chapter describes the current distribution of contaminants in the 200-BP-5 OU using information from the physical setting described in Chapter 3, as well as previous surveillance data, RI data, and routine groundwater sampling data. A discussion of groundwater contaminant sources is also included.

A discussion of the nature and extent of 15 contaminants exceeding the primary and secondary DWS or above the groundwater cleanup levels (MTCA Method B [WAC 173-340-720, "Groundwater Cleanup Standards"]) is provided. The contaminants include arsenic, cesium-137, cobalt-60, cyanide, fluoride, gross alpha, Cr(VI), iodine-129, nitrate, plutonium-239/240, strontium-90, sulfate, technetium-99, tritium, and uranium. Nitrate, iodine-129, technetium-99, and uranium are the most widespread groundwater contaminants observed in the OU. Cyanide, tritium, strontium-90, and sulfate are localized contaminants, where concentrations exceeding DWSs are limited to wells beneath and adjacent the overlying waste site sources. The other contaminants are only found beneath the source, and detections are limited to only a few wells. Gross alpha is an indicator parameter of plutonium-239/240 and uranium, and it is only elevated at wells associated with these plumes. Figure 4-1 provides the 2013 extent of the widespread and localized plumes within the 200-BP-5 OU, except for sulfate.

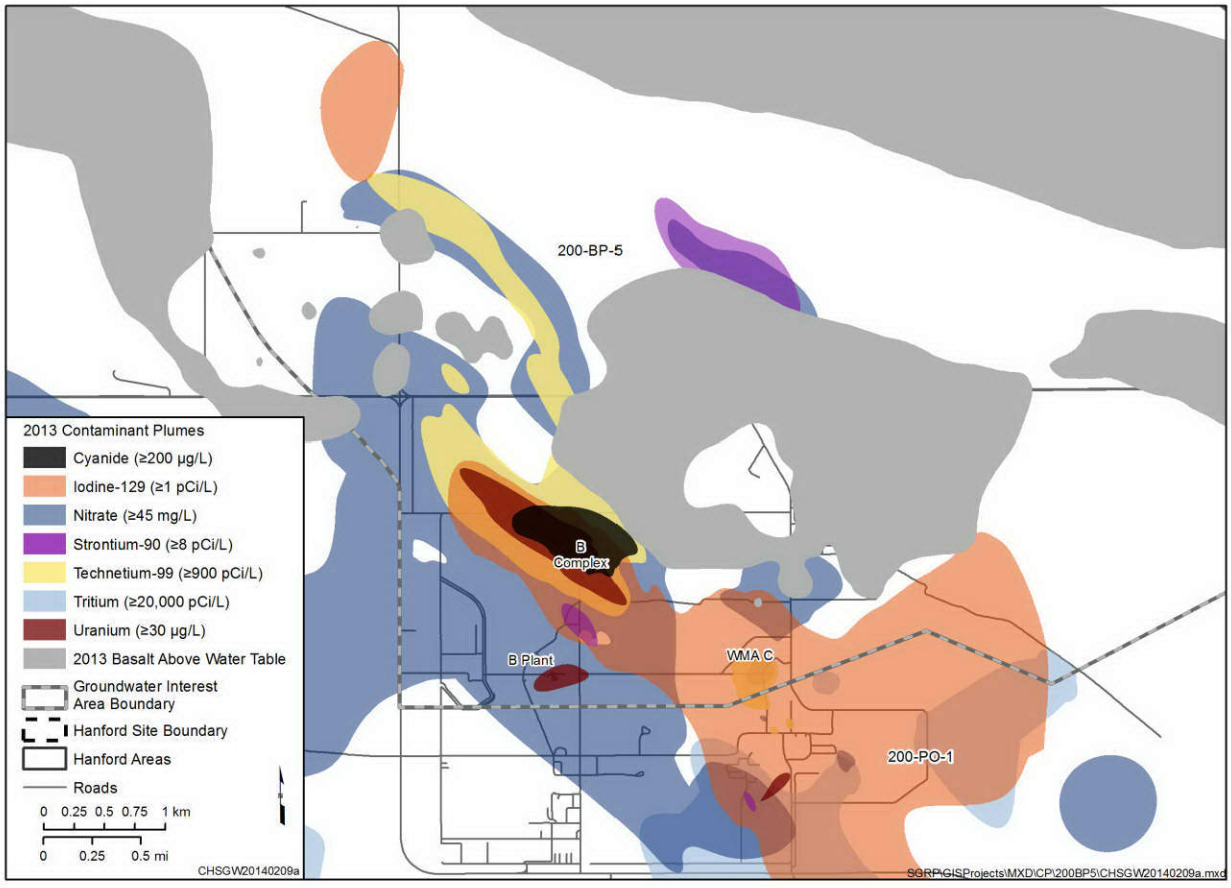

Figure 4-1. 2013 200-BP-5 OU Consolidated Plume Map

Groundwater monitoring in the OU, as presented in the 200-BP-5 OU SAP (DOE/RL-2001-49), has been designed to detect and track local and regional groundwater contaminant plumes in accordance with CERCLA and the AEA. The sampling program is supplemented with additional groundwater data from sites monitored in accordance with RCRA and the 200-BP-5 RI/FS work plan (DOE/RL-2007-18). Figure 2-3 provides the locations of groundwater monitoring wells in the 200-BP-5 OU.

The primary sites where groundwater contamination has persisted over time within the OU are located in the northwest corner of the 200 East Area, or the area referred to as the B Complex (Figure 4-2). At this location, moderate-activity liquid waste stored in underground storage tanks was intentionally discharged to the ground due to limited tank capacity. The majority of the discharges were from 1946 through 1955 and were associated with early plutonium and uranium recovery process wastes that were generated at B Plant and U Plant, respectively (WHC-MR-0227, *Tank Waste Discharged Directly to the Soil Column at the Hanford Site*). Outside of this area, only a few sites had sufficient radiological and chemical inventories to affect groundwater within the upper unconfined aquifer. These sites include B Plant (including the 216-B-5 Reverse Well and the 216-B-12 Crib), Gable Mountain Pond, and B Pond (Figure 4-2). Additional liquid waste sites overlying the OU that have in the past and continue to affect groundwater are UPRs at two high-activity underground storage areas, WMA B-BX-BY (within the B Complex) and WMA C. These two areas (Figure 4-2) have affected groundwater quality over the past couple of decades and have shown varying degrees of groundwater contamination.

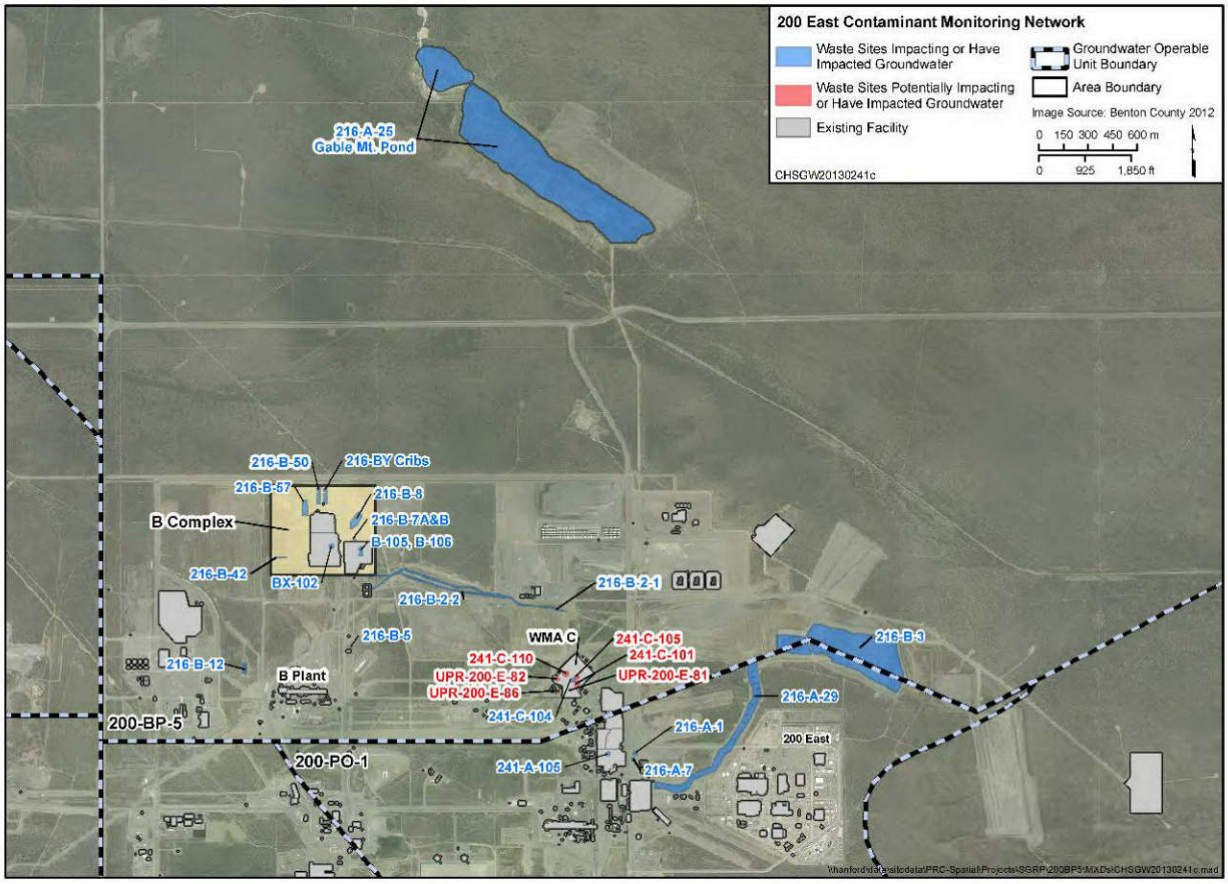

Figure 4-2. Waste Sites Potentially Associated with and Associated with Affected Groundwater Quality

4.1 Background Concentrations

Background substances are usually naturally occurring (i.e., present in the environment in forms not influenced by human activity) or anthropogenic (i.e., natural or artificial forms present in the environment due to human activities not related to the CERCLA sites under consideration). Some chemicals may be present in background due to both natural and artificial conditions, such as naturally occurring arsenic and arsenic from historical agricultural pesticide applications (EPA 540-R-01-003, *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*).

Knowledge of the background composition of groundwater from the unconfined aquifer beneath the Hanford Site serves as a potential basis for distinguishing the presence and significance of groundwater contamination. Background composition of groundwater in the unconfined aquifer at the Hanford Site has been determined for a wide range of major and trace constituents, including the contaminants found in the 200-BP-5 OU. The evaluation of background composition was performed on a Hanford Sitewide basis to provide a consistent, technically defensible definition of background, as opposed to determining local background compositions at each waste management unit, and is presented in DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

Table 4-1 presents Hanford Site background values for 15 contaminants in the 200-BP-5 OU that exceed the primary and secondary DWSs or that are above the groundwater cleanup levels (MTCA Method B). Filtered and unfiltered samples were used to develop the values listed in Table 4-1, as described in Chapter 6 of DOE/RL-96-61. The use of filtered or unfiltered samples was evaluated based on sample size and distribution. All of the samples were evaluated on a statistical basis; where the values were similar, the filtered status was not specified. For comparison, the federal DWS for each contaminant has been included in the table. Table 4-1 shows that, for the 15 contaminants listed, the measured background concentrations at the Hanford Site do not exceed DWSs.

Table 4-1. Summary Statistics for Hanford Site Background Groundwater Composition for 200-BP-5 OU Contaminants

Analyte	Units	90th Percentile	DWS[a]
Arsenic[b]	µg/L	7.85	10
Cesium-137	pCi/L	8.576	200
Chromium[b]	µg/L	2.4	100
Cobalt-60	pCi/L	22.5	100
Cyanide	µg/L	8.41	200
Fluoride[b]	µg/L	1,047	4,000
Gross Alpha[b]	pCi/L	0	15
Iodine-129	pCi/L	0.0000009	1
Nitrate	µg/L	26,871	45,000[c]
Plutonium-239/240	pCi/L	0	15
Strontium-90	pCi/L	0.00103	8
Sulfate	µg/L	47,014	250,000[d]

Table 4-1. Summary Statistics for Hanford Site Background Groundwater Composition for 200-BP-5 OU Contaminants

Analyte	Units	90th Percentile	DWS[a]
Technetium-99	pCi/L	0.83	900
Tritium	pCi/L	119	20,000
Uranium (Total)	µg/L	9.85	30

Note: Background values from DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.

a. EPA primary DWSs. For individual radioisotopes, the DWSs shown are maximum contaminant levels in accordance with EPA's OSWER Directive No. 9283.1-14, *Use of Uranium Drinking Water Standards under 40 CFR 141 and 40 CFR 192 as Remediation Goals for Groundwater at CERCLA Sites*. Note that cumulative annual dose results of 4 mrem/yr for beta/photon-emitting radioisotopes are evaluated in Chapter 6.

b. COPC is identified in Chapter 6 of this report but was not included in DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*. Note that gross-alpha results are used as an indicator parameter for other alpha-emitting isotopes and based on process knowledge indicate either uranium or plutonium-239/240. The 15 pCi/L gross-alpha maximum contaminant level derived from 40 CFR 141, "National Primary Drinking Water Regulations," does not apply to uranium (metal).

c. Expressed as the NO_3^- ion. The federal and state DWS for nitrate is 10 mg/L, expressed as NO_3-N, which is equivalent to approximately 45 mg/L as NO_3^- ion.

d. EPA secondary DWS.

DWS = drinking water standard

EPA = U.S. Environmental Protection Agency

4.2 Sources

The sources of groundwater contamination observed in the 200-BP-5 OU are chemical and radiological constituents from multiple process wastes and wastewater streams generated by the nuclear fuel reprocessing facilities, as well as associated waste and material handling and storage activities, within and around the 200 East Area. Releases of wastes and contaminated wastewater to the environment resulted from both intentional and unintentional events. Nonradiologically contaminated wastewater (e.g., steam condensate and process cooling water) was released to engineered infiltration ponds and allowed to percolate into the soil column. The two primary infiltration ponds overlying the 200-BP-5 OU during Hanford Site operations were Gable Mountain Pond and the B Pond system, which were located outside of the 200 East Area (Figure 4-2). Although the ponds were originally designed to receive nonradiologically contaminated wastewater, they routinely received chemical contaminants and periodically received varying volumes of radiologically contaminated water, typically during plant upset events. Contaminated liquid process wastes were intentionally released to engineered structures (e.g., cribs, trenches, French drains, and reverse wells) or source release points designed to allow the wastes to percolate through the soil column and to prevent exposure to contaminants at the ground surface. Most of the intentional release points were located within the 200 East Area, which overlies the southern portion of the 200-BP-5 OU (Figure 4-3). All of these sites have been deactivated. The most highly radiologically contaminated wastes were stored in underground storage tanks (e.g. B-BX-BY Tank Farms and C Tank Farm) to limit release to the environment and to protect workers from exposure. Some of these tanks were associated with UPRs prior to their interim closure in the 1970s or 1980s.

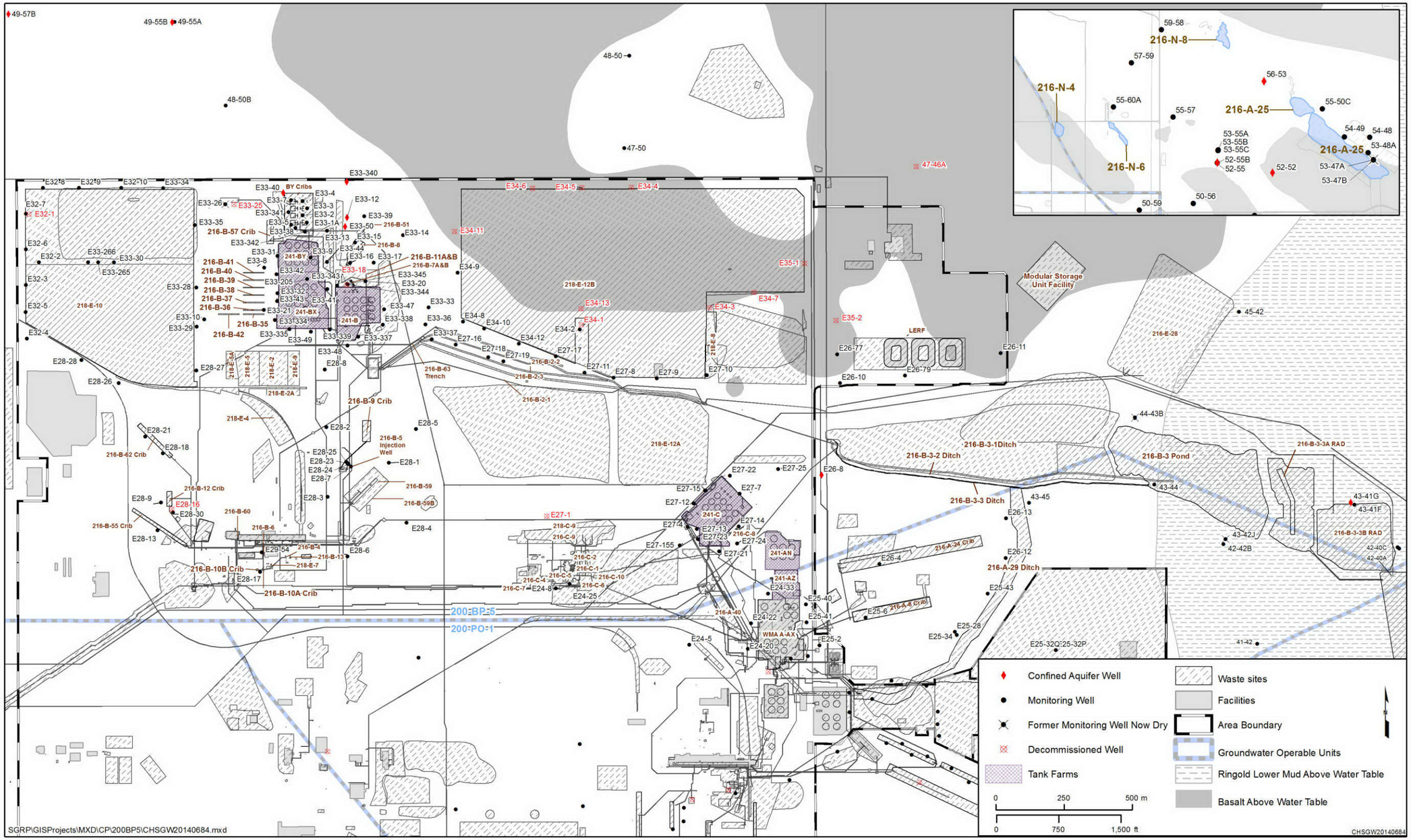

Figure 4-3. Waste Sites and Associated Groundwater Monitoring Wells for the 200-BP-5 OU in the 200 East Area and Vicinity

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Much of the observed groundwater contamination in the 200-BP-5 OU resulted from intentional discharge of contaminated wastes to cribs. The waste disposal practices applied to the intermediate-level waste streams changed during the years of Hanford Site operations. Initially and until the mid-1950s, these wastes were discharged to ground using a "breakthrough" protocol. Groundwater monitoring wells were placed around the cribs and groundwater samples were collected. When indications of longer half-life radioisotopes were detected, the crib was considered to be at capacity, and discharges were stopped and releases moved to a replacement crib (HW-28121, *Release of Radioactive Wastes to Ground*). While this practice limited discharges of low-mobility contaminants to groundwater, highly mobile constituents (e.g., nitrate, ruthenium-106, technetium-99, and tritium) moved readily through the vadose zone and into groundwater.

Later (starting in the mid-1950s), reprocessing activity outpaced the construction of high-level waste storage tanks, and higher level contaminated wastes that had previously been held in the tank farms were discharged directly to the ground in excavated cribs and trenches. Supplemental processing to precipitate cesium and strontium isotopes was generally completed prior to discharging to the soil column in order to reduce the long-lived radionuclide inventory. After lessons learned from disposal to the BY Cribs, a new "specific retention" discharge practice was employed for the higher-level contaminated wastes. Under the specific retention basis, studies were conducted for land disposal sites and for the estimated water-holding capacity of individual waste sites. Disposal volumes were then limited to a fraction of that capacity, with the intent to prevent migration of liquid wastes and their dissolved constituents to the groundwater. Preliminary discussion of the application of specific retention disposal is presented in HW-28121.

An extensive review of potential groundwater contamination sources was conducted during the 200-BP-5 OU DQO process (WMP-28945) and during preparation of the CSM for the B Complex (PNNL-19277). The sources of liquid waste that have affected or currently affect groundwater in the 200-BP-5 OU were mainly determined based upon comparison of the discharged activity/concentration to the soil column, volume discharged, vadose zone thickness, mobility of the contaminant, and contaminant concentrations in the groundwater. The main source of information for determining the discharged activity/concentration to the soil column and volume discharged was RPP-26744, *Hanford Soil Inventory Model, Rev. 1*. Summaries of the mean discharge volumes and derived mass/activity associated with liquid waste discharges to soils overlying the OU are provided in Tables 4-2 and 4-3.

Based on evaluations of waste discharged to source sites overlying the OU, groundwater was affected by liquid waste generated from five different chemical separation processes:

- Bismuth phosphate/lanthanum fluoride reprocessing of irradiated nuclear fuel (early plutonium separation process used in the mid-1940s to mid-1950s)
- Uranium recovery from high-level radioactive waste (tributyl phosphate separation process to recover useful uranium from bismuth phosphate process wastes in the 1950s)
- Fission product scavenging process to reduce concentration of selected fission products in high-level wastes generated by the uranium recovery process (e.g., application of metal ferrocyanides to precipitate cesium-137 and strontium-90 from liquid fraction of high-level waste in the 1950s)
- Waste fractionation process to separate cesium and strontium isotopes from high-level waste (in the 1960s to mid-1970s)
- Plutonium-uranium extraction process at the PUREX Plant for reprocessing irradiated nuclear fuel (tributyl phosphate, plutonium, and uranium separation process in the mid-1950s to 1980s)

Table 4-4 provides a list of the waste sites that have impacted, or are continuing to impact, groundwater quality above DWSs. Most sources of groundwater contamination are located in the B Complex (Figure 4-4), where moderate-activity liquid waste stored in underground storage tanks was intentionally discharged to the ground due to limited tank capacity. In other areas of the OU, some sites with small release volumes and high-radioactivity UPRs (e.g., equipment failures) may have affected groundwater due to nearby anthropogenic or natural water discharges (e.g., leaking water lines, water abatement discharges to reduce surface exposure, large precipitation events, etc.). In some instances, these nearby discharges may have provided sufficient liquid to mobilize the released contaminants to groundwater.

The following subsections discuss specific groups of waste sites that are known or suspected to have impacted groundwater quality, including cribs and trenches, reverse wells, ditches and ponds, SSTs, ancillary equipment (e.g., pipelines and valves), and other miscellaneous waste sites.

4.2.1 Cribs and Trenches

The cribs and trenches overlying the 200-BP-5 OU received varying volumes of low- to moderate-activity liquid waste. Liquid disposal to ground began in 1945 for select low-level waste (PNL-MA-588, *Resource Book – Decommissioning of Contaminated Facilities at Hanford*). As more information was learned about the selective retention of radionuclides, and underground storage tank capacity became limited, disposal to the ground became more prominent. Cribbing criteria were developed for liquid waste disposal to ground, as summarized in Appendix A of WMP-28945 (also see HW-19140, *Uranium Recovery Technical Manual*). The cribbing criteria were based on assumptions of the adsorption of a large fraction of the radionuclides to the soil column, decay of the short-lived radionuclides before they reached the Columbia River, and dilution of other mobile contaminants by the groundwater. Another criterion was that if longer lived radionuclides (cesium-137, strontium-90, and plutonium isotopes) were detected above the maximum permissible concentration (and later above one-tenth of the maximum permissible concentration) in samples collected at groundwater monitoring wells beneath the boundary of the liquid waste site, then the facility was removed from further use (ARH-231, *Hanford Low Level Waste Management Reevaluation Study*; ERDA-1538, *Final Environmental Statement Waste Management Operations: Hanford Reservation*).

The majority of the low- to moderate-activity liquid waste disposed above the 200-BP-5 OU was in the B Complex, within the 200 East Area. Waste streams generated by five processes were discharged to the cribs and trenches in this area: bismuth phosphate/plutonium recovery process, tributyl phosphate uranium recovery, fission product scavenging, waste fractionation, and PUREX plutonium and uranium recovery waste after treated by fission fractionation. Initially, only low-activity waste from the 224 Building was released to the 216-B-7A&B and 216-B-8 Cribs (Appendix A of WMP-28945). As underground tank storage space became limited, moderate second-cycle decontamination waste was included. By the mid-1950s, scavenged waste (i.e., a metal waste/uranium recovery/ferrocyanide derivative) and first-cycle decontamination waste were also discharged to the ground at the BY Cribs and BX Trenches, respectively (WMP-28945). The locations of the cribs and trenches in the B Complex are shown in Figure 4-4. Outside of this area, only a few sites (e.g., 216-B-9, 216-B-12, and 216-C-1 Cribs) had sufficient inventories and liquid volumes to affect groundwater within the upper unconfined aquifer (Figure 4-2). These sites are discussed below.

Table 4-2. Mean Average Liquid Volume Discharged and Contaminant Mass Released for Liquid Waste Release Sites Overlying the 200-BP-5 OU

#	Site ID	Operable_Unit_Name	Na Mean_kg	Al Mean_kg	Fe Mean_kg	Cr Mean_kg	Bi Mean_kg	La Mean_kg	Hg Mean_kg	Zr Mean_kg	Pb Mean_kg	Ni Mean_kg	Ag Mean_kg	Mn Mean_kg	Ca Mean_kg	K Mean_kg	NO3 Mean_kg	NO2 Mean_kg	CO3 Mean_kg	PO4 Mean_kg	SO4 Mean_kg	Si Mean_kg	F Mean_kg	Cl Mean_kg	CCl4 Mean_kg	Butanol Mean_kg	TBP Mean_kg	NPH Mean_kg	NH3 Mean_kg	Fe(CN)6 Mean_kg	U-Total Mean_kg	Volume Discharge (ML)
1	216-A-25	200-E Ponds Zone	5.81E+05	7.35E+00	1.32E+04	4.58E+00	7.08E-05	0.00E+00	8.80E-01	9.37E-06	9.37E+01	1.35E+00	4.84E-03	1.74E+03	2.81E+06	2.01E+05	1.64E+05	2.85E+02	1.98E+07	3.14E+04	3.56E+06	6.79E+05	4.88E+04	3.57E+05	2.20E+03	1.05E+04	0.00E+00	0.00E+00	5.28E+00	0.00E+00	1.22E+04	2.94E+05
2	216-B-2-2E	200-E Ponds Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
3	216-B-2-2W	200-E Ponds Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
4	216-B-3	200-E Ponds Zone	5.23E+05	1.04E+04	2.18E+04	1.41E+03	1.81E+01	7.42E-03	2.79E+02	1.19E+00	5.88E+03	2.50E+02	2.56E+02	2.27E+03	4.13E+06	3.64E+05	2.94E+05	2.07E+02	1.37E+07	9.84E+04	3.31E+06	6.04E+05	4.61E+04	3.30E+05	4.68E+03	4.26E+04	0.00E+00	3.75E+04	7.46E+01	0.00E+00	2.79E+03	2.64E+05
5	216-B-4	B Plant Zone	8.17E-02	0.00E+00	1.90E-04	5.57E-04	1.59E-04	6.53E-08	1.68E-07	1.05E-05	0.00E+00	1.80E-04	2.95E-08	1.43E-05	2.73E-04	4.56E-03	1.24E-01	1.50E-03	1.93E-02	1.05E-02	1.11E-02	3.11E-04	5.83E-03	1.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.52E-04	0.00E+00	4.98E-04	1.00E-02
6	216-B-5	B Plant Zone	4.34E+05	0.00E+00	6.34E+03	3.79E+03	8.65E+03	3.46E+03	0.00E+00	0.00E+00	0.00E+00	1.04E+03	2.93E+00	1.93E+03	5.43E+03	8.97E+04	9.50E+05	4.99E+00	8.17E+03	4.22E+04	9.13E+03	3.83E+02	5.63E+04	1.15E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.07E-06	0.00E+00	1.05E+01	3.21E+01
7	216-B-6	B Plant Zone	2.70E+04	0.00E+00	6.28E+02	2.50E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.42E+02	0.00E+00	0.00E+00	2.16E+03	1.62E+02	5.84E+04	6.63E+03	7.09E+02	0.00E+00	2.31E+03	0.00E+00	0.00E+00	6.76E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-01	6.00E+00
8	216-B-7A%B	B Farm Zone	1.18E+06	0.00E+00	3.46E+03	1.16E+04	2.98E+03	4.22E+00	1.23E-02	0.00E+00	7.69E+00	3.08E+03	8.35E+00	9.35E+02	5.12E+03	2.81E+05	2.71E+06	1.48E+03	7.31E+03	9.77E+04	1.16E+04	1.44E+02	1.62E+05	3.24E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E+00	0.00E+00	1.97E+02	4.46E+01
9	216-B-8	B Farm Zone	1.06E+06	0.00E+00	2.54E+03	6.23E+03	2.33E+03	4.68E-02	0.00E+00	0.00E+00	0.00E+00	2.36E+03	6.47E+00	1.03E+01	3.65E+03	9.44E+03	1.94E+06	9.12E+01	5.46E+03	1.62E+05	1.18E+05	7.08E+03	1.05E+05	2.69E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.10E-04	0.00E+00	1.91E+02	3.53E+01
10	216-B-9	Solid Waste Zone	8.81E+04	0.00E+00	2.19E+02	6.40E+02	2.01E+02	7.70E-02	0.00E+00	0.00E+00	0.00E+00	2.02E+02	5.58E-01	1.69E+01	3.15E+02	5.45E+03	1.71E+05	6.36E+00	4.71E+02	1.20E+04	7.76E+03	4.56E+02	9.53E+03	2.29E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.34E-06	0.00E+00	1.23E+01	3.60E+01
11	216-B-10A	B Plant Zone	5.30E+02	0.00E+00	1.06E+01	4.22E+01	1.57E-01	6.45E-05	1.85E-04	1.04E-02	0.00E+00	1.09E+01	2.91E-05	1.42E-02	3.64E+01	6.84E+01	1.17E+03	1.12E+02	3.09E+01	1.17E+01	4.94E+01	3.07E-01	5.88E+00	1.29E+01	0.00E+00	2.51E-05	0.00E+00	0.00E+00	6.44E-01	0.00E+00	4.83E+00	9.98E+00
12	216-B-10B	B Plant Zone	1.26E+02	0.00E+00	2.93E+00	1.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E+00	0.00E+00	0.00E+00	1.01E+01	7.56E-01	2.72E+02	3.10E+01	3.31E+00	0.00E+00	1.08E+01	0.00E+00	0.00E+00	3.15E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.63E-08	2.80E-02
13	216-B-11A&B	B Farm Zone	1.25E+02	5.68E-01	1.53E+00	4.72E-01	9.64E-02	0.00E+00	2.52E-01	2.50E-02	4.34E-01	1.07E-01	0.00E+00	2.09E-01	1.87E+02	3.74E+00	2.45E+02	8.54E+00	9.17E+00	6.73E+00	3.72E+01	2.97E-01	3.60E+00	4.34E+00	0.00E+00	6.08E-04	0.00E+00	2.72E+00	1.59E+00	0.00E+00	4.21E-02	2.96E+01
14	216-B-12	B Plant Zone	1.41E+04	1.91E+01	1.71E+02	5.61E+02	3.24E+00	0.00E+00	2.14E+00	8.39E-01	3.54E+00	1.59E+02	0.00E+00	3.75E+00	8.15E+03	2.29E+06	2.86E+06	1.68E+03	1.17E+04	5.01E+04	2.58E+03	3.77E+02	4.74E+03	4.18E+02	0.00E+00	9.58E-01	0.00E+00	1.71E+01	5.43E+01	0.00E+00	1.51E+04	1.43E+02
15	216-B-13	B Plant Zone	4.93E-02	0.00E+00	8.55E-04	2.92E-04	8.35E-05	3.43E-08	1.34E-04	5.51E-06	2.31E-04	9.43E-05	1.55E-08	1.19E-04	9.97E-02	3.92E-03	7.94E-02	7.89E-04	1.01E-02	5.50E-03	1.93E-02	1.63E-04	3.06E-03	8.90E-04	0.00E+00	0.00E+00	0.00E+00	1.42E-03	3.42E-04	0.00E+00	0.000267	2.10E-02
16	216-B-35	B Farm Zone	6.00E+04	2.90E+01	1.58E+02	3.80E+02	1.43E+02	0.00E+00	3.79E-01	2.85E+01	0.00E+00	1.06E+02	2.90E-01	0.00E+00	1.69E+02	4.17E+02	1.14E+05	2.46E+03	2.54E+02	7.47E+03	7.51E+03	3.34E+02	3.97E+03	1.74E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.53E+03	0.00E+00	3.63E+01	1.06E+00
17	216-B-36	B Farm Zone	1.10E+05	5.30E+01	2.88E+02	6.95E+02	2.61E+02	0.00E+00	6.93E-01	5.22E+01	0.00E+00	1.93E+02	5.30E-01	0.00E+00	3.10E+02	7.64E+02	2.08E+05	4.50E+03	4.64E+02	1.37E+04	1.37E+04	6.12E+02	7.27E+03	3.18E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.80E+03	0.00E+00	6.64E+01	1.94E+00
18	216-B-37	B Farm Zone	2.44E+05	1.18E+02	6.42E+02	1.55E+03	5.82E+02	0.00E+00	1.54E+00	1.16E+02	0.00E+00	4.30E+02	1.18E+00	0.00E+00	6.91E+02	1.70E+03	4.63E+05	1.00E+04	1.03E+03	3.04E+04	3.06E+04	1.36E+03	1.62E+04	7.09E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.23E+03	0.00E+00	1.48E+02	4.32E+00
19	216-B-38	B Farm Zone	8.09E+04	3.91E+01	2.13E+02	5.12E+02	1.92E+02	0.00E+00	5.11E-01	3.85E+01	0.00E+00	1.42E+02	3.91E-01	0.00E+00	2.29E+02	5.63E+02	1.53E+05	3.31E+03	3.42E+02	1.01E+04	1.01E+04	4.51E+02	5.36E+03	2.35E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.06E+03	0.00E+00	4.90E+01	1.43E+00
20	216-B-39	B Farm Zone	8.71E+04	4.20E+01	2.29E+02	5.52E+02	2.07E+02	0.00E+00	5.50E-01	4.14E+01	0.00E+00	1.53E+02	4.21E-01	0.00E+00	2.46E+02	6.06E+02	1.65E+05	3.57E+03	3.69E+02	1.09E+04	1.09E+04	4.86E+02	5.77E+03	2.53E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.22E+03	0.00E+00	5.27E+01	1.54E+00
21	216-B-40	B Farm Zone	9.28E+04	4.48E+01	2.44E+02	5.87E+02	2.21E+02	0.00E+00	5.86E-01	4.41E+01	0.00E+00	1.63E+02	4.48E-01	0.00E+00	2.62E+02	6.45E+02	1.76E+05	3.80E+03	3.93E+02	1.16E+04	1.16E+04	5.17E+02	6.14E+03	2.69E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.36E+03	0.00E+00	5.62E+01	1.64E+00
22	216-B-41	B Farm Zone	8.15E+04	3.92E+01	2.14E+02	5.16E+02	1.94E+02	0.00E+00	5.15E-01	3.87E+01	0.00E+00	1.43E+02	3.93E-01	0.00E+00	2.30E+02	5.67E+02	1.54E+05	3.34E+03	3.45E+02	1.01E+04	1.02E+04	4.54E+02	5.39E+03	2.36E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.07E+03	0.00E+00	4.93E+01	1.44E+00
23	216-B-42	B Farm Zone	1.34E+05	0.00E+00	1.57E+02	2.58E+02	5.79E+01	0.00E+00	4.78E-01	0.00E+00	0.00E+00	1.58E+02	4.50E-03	0.00E+00	2.21E+02	9.85E+02	2.98E+05	1.42E+02	3.31E+02	1.00E+04	1.76E+04	4.36E+02	6.08E+03	4.11E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E-03	0.00E+00	4.65E+01	1.50E+00
24	216-B-43	B Farm Zone	1.89E+05	0.00E+00	2.22E+02	3.65E+02	8.18E+01	0.00E+00	6.75E-01	0.00E+00	0.00E+00	2.23E+02	6.35E-03	0.00E+00	3.13E+02	1.39E+03	4.21E+05	2.01E+02	4.68E+02	1.42E+04	2.49E+04	6.16E+02	8.59E+03	5.80E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.41E-03	0.00E+00	6.58E+01	2.12E+00
25	216-B-44	B Farm Zone	4.99E+05	0.00E+00	5.86E+02	9.63E+02	2.16E+02	0.00E+00	1.78E+00	0.00E+00	0.00E+00	5.89E+02	1.68E-02	0.00E+00	8.27E+02	3.68E+03	1.11E+06	5.30E+02	1.24E+03	3.75E+04	6.59E+04	1.63E+03	2.27E+04	1.53E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.36E-03	0.00E+00	1.74E+02	5.60E+00
26	216-B-45	B Farm Zone	4.39E+05	0.00E+00	5.85E+02	8.46E+02	1.90E+02	0.00E+00	1.69E+00	0.00E+00	0.00E+00	5.31E+02	2.29E-02	0.00E+00	7.48E+02	3.23E+03	9.77E+05	5.13E+02	1.12E+03	3.32E+04	5.81E+04	1.46E+03	1.99E+04	1.35E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.14E-01	5.15E+01	1.65E+02	4.92E+00
27	216-B-46	B Farm Zone	5.97E+05	0.00E+00	7.02E+02	1.15E+03	2.59E+02	0.00E+00	2.13E+00	0.00E+00	0.00E+00	7.04E+02	2.01E-02	0.00E+00	9.89E+02	4.40E+03	1.33E+06	6.34E+02	1.48E+03	4.49E+04	7.88E+04	1.95E+03	2.71E+04	1.84E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.61E-03	0.00E+00	2.08E+02	6.70E+00
28	216-B-47	B Farm Zone	3.30E+05	0.00E+00	3.85E+02	6.33E+02	1.42E+02	0.00E+00	1.17E+00	0.00E+00	0.00E+00	3.87E+02	1.47E+00	0.00E+00	5.43E+02	2.42E+03	7.32E+05	2.53E+02	8.13E+02	2.47E+04	4.33E+04	1.07E+03	1.49E+04	1.01E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.64E-03	0.00E+00	1.14E+02	3.68E+00
29	216-B-48	B Farm Zone	3.65E+05	0.00E+00	4.28E+02	7.03E+02	1.58E+02	0.00E+00	1.30E+00	0.00E+00	0.00E+00	4.30E+02	1.23E-02	0.00E+00	6.03E+02	2.69E+03	8.12E+05	3.87E+02	9.04E+02	2.74E+04	4.81E+04	1.19E+03	1.66E+04	1.12E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.65E-03	0.00E+00	1.27E+02	4.09E+00
30	216-B-49	B Farm Zone	5.98E+05	0.00E+00	7.02E+02	1.15E+03	2.59E+02	0.00E+00	2.13E+00	0.00E+00	0.00E+00	7.04E+02	2.01E-02	0.00E+00	9.89E+02	4.40E+03	1.33E+06	6.35E+02	1.48E+03	4.49E+04	7.88E+04	1.95E+03	2.71E+04	1.83E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.61E-03	0.00E+00	2.08E+02	6.70E+00
31	216-B-50	B Farm Zone	1.57E+02	1.57E+01	2.55E+00	1.48E+01	1.13E-02	8.15E-08	7.85E-01	1.14E-03	5.94E-01	3.55E-02	2.65E+00	2.01E-01	7.22E+02	2.39E+01	1.11E+02	3.90E+01	1.05E+01	1.97E+00	4.20E+02	5.98E+01	7.59E+00	1.06E+02	0.00E+00	5.64E-01	0.00E+00	3.90E+02	3.03E-01	0.00E+00	2.88E-02	5.47E+01
32	216-B-51	B Farm Zone	9.05E+01	0.00E+00	1.05E-01	1.72E-01	3.86E-02	0.00E+00	3.19E-04	0.00E+00	0.00E+00	1.05E-01	9.59E-04	0.00E+00	1.48E-01	6.57E-01	1.99E+02	3.20E-02	2.21E-01	6.70E+00	1.18E+01	2.91E-01	4.05E+00	2.74E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-07	0.00E+00	3.10E-02	1.00E-03
33	216-B-55	B Plant Zone	2.49E+03	9.32E-02	4.23E+01	1.47E-02	9.51E-06	0.00E+00	2.94E-06	1.26E-06	6.65E+00	9.90E-04	0.00E+00	6.04E+00	2.27E+04	8.96E+02	6.04E+02	3.58E-01	9.07E+04	5.57E-03	1.25E+04	2.97E+03	1.60E+02	1.06E+03	0.00E+00	1.75E-08	0.00E+00	0.00E+00	3.77E-03	0.00E+00	2.81E-04	1.20E+03
34	216-B-57	B Farm Zone	3.66E+02	4.70E+01	3.98E+00	2.42E+01	3.39E-02	2.44E-07	1.21E+00	3.41E-03	9.86E-01	1.07E-01	4.09E+00	3.21E-01	1.11E+03	3.78E+01	2.76E+02	1.17E+02	3.16E+01	5.91E+00	6.53E+02	9.23E+01	1.27E+01	1.67E+02	0.00E+00	1.69E+00	0.00E+00	6.00E+02	9.09E-01	0.00E+00	5.94E-02	8.43E+01
35	216-B-59	B Plant Zone	9.92E-01	3.71E-05	1.69E-02	5.88E-06	3.79E-09	0.00E+00	1.17E-09	5.02E-10	2.65E-03	3.95E-07	0.00E+00	2.41E-03	9.06E+00	3.57E-01	2.41E-01	1.43E-04	3.61E+01	2.22E-06	4.96E+00	1.19E+00	6.36E-02	4.22E-01	0.00E+00	6.99E-12	0.00E+00	0.00E+00	1.50E-06	0.00E+00	1.12E-07	4.77E-01
36	216-B-60	B Plant Zone	8.49E+01	0.00E+00	1.98E+00	7.87E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E+00	0.00E+00	0.00E+00	7.04E+00	5.11E-01	1.84E+02	2.09E+01	2.58E+00	0.00E+00	7.29E+00	0.00E+00	0.00E+00	2.13E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.33E-01	1.89E-02
37	216-B-62	B Plant Zone	1.62E+03	1.97E+01	1.34E+01	2.96E+01	1.43E-02	0.00E+00	1.08E-02	1.25E-04	3.11E+00	3.56E+00	0.00E+00	1.74E+00	5.32E+03	2.20E+02	7.62E+02	7.31E+02	2.15E+04	7.08E+01	3.15E+03	7.05E+02	3.77E+01	2.70E+02	0.00E+00	4.10E-09	0.00E+00	0.00E+00	1.00E+01	0.00E+00	1.04E+00	2.80E+02
38	216-B-63	Solid Waste Zone	1.70E+04	7.19E-03	4.27E+02	1.38E+01	7.34E-07	0.00E+00	7.81E-01	9.71E-08	1.06E+00	1.11E-02	2.64E+00	4.62E+01	1.48E+05	8.88E+03	3.14E+03	2.76E-02	5.73E+05	5.34E+01	8.92E+04	1.87E+04	1.12E+03	1.21E+04	0.00E+00	1.00E-03	0.00E+00	3.87E+02	1.29E-03	0.00E+00	1.78E+02	7.98E+03
39	216-C-1	Semi-Works Zone	2.56E+06	4.46E+05	2.53E+03	5.77E+04	0.00E+00	0.00E+00	7.70E+00	0.00E+00	9.15E+01	2.51E+03	9.85E-01	5.94E+02	3.54E+03	2.09E+04	2.76E+06	7.39E+05	5.29E+03	0.00E+00	5.27E+04	6.95E+03	0.00E+00	6.81E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.73E+03	0.00E+00	9.08E+02	2.34E+01
40	216-C-2	Semi-Works Zone	1.29E+00	0.00E+00	1.51E-01	0.00E+00	0.00E+00	0.00E+00	2.68E-02	0.00E+00	4.62E-02	0.00E+00	0.00E+00	2.23E-02	1.99E+01	3.04E-01	2.86E+00	0.00E+00	0.00E+00	0.00E+00	2.68E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.85E-01	0.00E+00	0.00E+00	1.18E-03	3.15E+00
41	216-C-3	Semi-Works Zone	1.18E+02	0.00E+00	8.50E-01	5.85E-01	0.00E+00	0.00E+00	1.46E-02	0.00E+00	4.54E-02	3.01E-01	0.00E+00	4.54E-02	9.95E+01	6.16E+04	7.65E+04	1.34E+00	2.94E-02	1.34E+03	6.48E-01	0.00E+00	1.24E+02	1.74E-01	0.00E+00	2.52E-02	0.00E+00	0.00E+00	3.14E-02	0.00E+00	4.54E+00	5.00E+00
42	216-C-4	Semi-Works Zone	8.51E+00	7.05E-01	1.03E-01	1.04E-06	0.00E+00	0.00E+00	1.47E-03	0.00E+00	2.49E-03	5.89E-02	0.00E+00	1.20E-03	1.12E+00	7.53E-02	4.94E+00	5.37E-01	1.63E+00	9.52E-02	5.68E-01	8.44E-03	0.00E+00	2.46E-01	0.00E+00	0.00E+00	0.00E+00	1.54E-02	1.11E-03	0.00E+00	3.17E-03	1.70E-01
43	216-C-5	Semi-Works Zone	6.49E+02	0.00E+00	1.23E+01	1.63E+01	0.00E+00	0.00E+00	2.50E-02	0.00E+00	9.03E-01	4.49E+00	0.00E+00	0.00E+00	7.30E+00	4.80E+00	4.22E+02	4.95E+02	1.09E+01	0.00E+00	1.64E+02	1.41E+01	0.00E+00	2.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.71E+00	0.00E+00	2.07E+01	3.89E-02
44	216-C-6	Semi-Works Zone	2.75E+01	3.16E+00	2.57E-01	2.82E-06	0.00E+00	0.00E+00	8.75E-05	0.00E+00	0.00E+00	1.59E-01	0.00E+00	0.00E+00	1.12E-01	1.59E-01	2.81E+02	1.45E+00	4.39E+00	2.57E-01	1.14E+00	2.28E-02	0.00E+00	6.63E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.01E-03	0.00E+00	1.78E+00	5.31E-01
45	216-C-7	Semi-Works Zone	1.29E-01	0.00E+00	6.72E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.45E-04	0.00E+00	0.00E+00	1.86E-03	1.19E+00	4.33E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.75E-03	6.42E-02	0.00E+00	0.00E+00	0.00E+00	7.87E-02	0.00E+00	0.00E+00	3.65E-05	5.99E-02
46	216-C-8	WTP-ETF-A-C Farm Zone	4.09E-03	0.00E+00	4.80E-04	0.00E+00	0.00E+00	0.00E+00	8.48E-05	0.00E+00	1.46E-04	0.00E+00	0.00E+00	7.07E-05	6.32E-02	9.65E-04	9.08E-03	0.00E+00	0.00E+00	0.00E+00	8.51E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.04E-04	0.00E+00	0.00E+00	3.72E-06	1.00E-02
47	216-C-9	Semi-Works Zone	2.08E+03	7.28E-02	3.86E+01	1.15E-02	7.44E-06	0.00E+00	4.39E-01	9.84E-07	5.98E+00	7.74E-04	0.00E+00	5.47E+00	1.91E+04	7.48E+02	5.19E+02	2.80E-01	7.45E+04	4.36E-03	1.03E+04	2.44E+03	1.32E+02	9.07E+02	0.00E+00	1.37E-08	0.00E+00	8.09E+00	2.95E-03	0.00E+00	4.52E-02	1.04E+03
48	216-C-10	Semi-Works Zone	1.06E+01	0.00E+00	5.82E-01	7.96E-02	0.00E+00	0.00E+00	7.67E-03	0.00E+00	1.04E-01	4.70E-02	0.00E+00	6.34E-03	5.71E+00	7.81E-01	1.07E+01	2.68E+00	5.88E-02	0.00E+00	2.06E+00	0.00E+00	0.00E+00	3.49E-01	0.00E+00	0.00E+00	0.00E+00	8.11E-02	1.23E-02	0.00E+00	6.52E-03	8.97E-01
49	216-N-1	200-E Ponds Zone	2.04E+03	0.00E+00	1.06E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.61E+00	0.00E+00	0.00E+00	2.94E+01	1.88E+04	6.85E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E+02	1.01E+03	0.00E+00	0.00E+00	0.00E+00	1.24E+03	0.00E+00	0.00E+00	5.77E-01	9.47E+02
50	216-N-2	200-E Ponds Zone	1.85E+01	0.00E+00	8.15E-01	2.00E-02	5.72E-03	2.35E-06	6.04E-06	3.77E-04	6.55E-02	6.46E-03	1.06E-06	2.24E-01	1.43E+02	5.38E+00	4.46E+00	5.40E-02	6.94E-01	3.77E-01	4.01E-01	1.12E-02	1.14E+00	7.78E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+00	2.35E-02	0.00E+00	2.23E-02	7.57E+00
51	216-N-3	200-E Ponds Zone	1.84E+01	0.00E+00	8.15E-01	2.00E-02	5.72E-03	2.35E-06	6.04E-06	3.77E-04	6.55E-02	6.46E-03	1.06E-06	2.24E-01	1.43E+02	5.38E+00	4.46E+00	5.40E-02	6.94E-01	3.77E-01	4.01E-01	1.12E-02	1.14E+00	7.78E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+00	2.34E-02	0.00E+00	2.23E-02	7.57E+00
52	216-N-4	200-E Ponds Zone	2.04E+03	0.00E+00	1.06E+02	2.01E-02	5.73E-03	2.35E-06	6.05E-06	3.77E-04	8.61E+00	6.47E-03	1.06E-06	2.94E+01	1.88E+04	6.85E+02	4.46E+00	5.41E-02	6.95E-01	3.77E-01	4.01E-01	1.12E-02	1.23E+02	1.01E+03	0.00E+00	0.00E+00	0.00E+00	1.24E+03	2.35E-02	0.00E+00	5.95E-01	9.47E+02
53	216-N-5	200-E Ponds Zone	1.85E+01	0.00E+00	8.15E-01	2.00E-02	5.72E-03	2.35E-06	6.04E-06	3.77E-04	6.55E-02	6.45E-03	1.06E-06	2.24E-01	1.43E+02	5.38E+00	4.46E+00	5.40E-02	6.94E-01	3.76E-01	4.01E-01	1.12E-02	1.14E+00	7.78E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+00	2.34E-02	0.00E+00	2.23E-02	7.57E+00
54	216-N-6	200-E Ponds Zone	2.04E+03	0.00E+00	1.06E+02	2.01E-02	5.73E-03	2.35E-06	6.05E-06	3.78E-04	8.61E+00	6.46E-03	1.06E-06	2.94E+01	1.88E+04	6.85E+02	4.46E+00	5.41E-02	6.95E-01	3.77E-01	4.01E-01	1.12E-02	1.23E+02	1.01E+03	0.00E+00	0.00E+00	0.00E+00	1.24E+03	2.35E-02	0.00E+00	5.95E-01	9.47E+02
55	216-N-7	200-E Ponds Zone	1.85E+01	0.00E+00	8.15E-01	2.00E-02	5.72E-03	2.35E-06	6.04E-06	3.77E-04	6.55E-02	6.46E-03	1.06E-06	2.24E-01	1.43E+02	5.38E+00	4.46E+00	5.40E-02	6.94E-01	3.77E-01	4.01E-01	1.12E-02	1.14E+00	7.78E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+00	2.34E-02	0.00E+00	2.23E-02	7.57E+00
56	241-B-101	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
57	241-B-103	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
58	241-B-105	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
59	241-B-107	B Farm Zone	2.04E+03	7.52E+02	4.98E+00	9.29E+00	2.36E-01	0.00E+00	1.82E-03	5.91E-02	6.26E+00	4.38E+00	1.80E-03	3.41E-05	7.20E+00	6.36E+00	2.35E+03	8.07E+02	4.25E+01	1.73E+01	7.53E+01	4.17E+00	8.56E+00	2.83E+01	0.00E+00	1.42E+00	0.00E+00	0.00E+00	4.37E+00	0.00E+00	1.47E+00	5.30E-02
60	241-B-110	B Farm Zone	4.16E+02	6.26E+01	3.73E-01	5.56E+00	3.70E-02	2.44E-07	1.11E-03	3.76E-03	4.48E-01	3.80E-01	9.22E-05	4.88E-02	8.82E-01	3.47E+00	3.40E+02	1.92E+02	5.01E+01	6.90E+00	3.36E+01	1.11E+00	2.15E+00	1.20E+01	0.00E+00	1.69E+00	0.00E+00	0.00E+00	1.85E+00	0.00E+00	1.10E-01	3.79E-02
61	241-B-111	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
62	241-B-112	B Farm Zone	6.29E+02	7.61E+01	7.48E-01	9.89E+00	2.47E-02	1.14E-07	2.19E-03	2.63E-03	8.09E-01	7.61E-01	2.86E-04	9.57E-02	1.11E+00	5.25E+00	5.00E+02	2.90E+02	6.81E+01	5.97E+00	6.56E+01	2.06E+00	1.28E+00	1.70E+01	0.00E+00	7.99E-01	0.00E+00	0.00E+00	3.16E+00	0.00E+00	2.17E-01	7.57E-03
63	241-B-201	B Farm Zone	1.26E+02	0.00E+00	3.57E-01	1.21E+00	3.23E-01	4.65E-04	0.00E+00	0.00E+00	0.00E+00	3.15E-01	9.04E-04	1.03E-01	5.13E-01	3.09E+01	2.93E+02	1.36E-04	8.52E-01	1.04E+01	9.63E-01	2.87E-03	1.75E+01	3.48E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E-12	0.00E+00	1.24E-04	4.54E-03
64	241-B-203	B Farm Zone	3.85E+01	0.00E+00	1.12E-01	3.81E-01	9.78E-02	1.41E-04	0.00E+00	0.00E+00	0.00E+00	9.91E-02	2.74E-04	3.12E-02	1.65E-01	9.38E+00	8.92E+01	3.79E-02	2.42E-01	3.15E+00	3.02E-01	1.74E-04	5.32E+00	1.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.68E-13	0.00E+00	2.43E-05	1.14E-03
65	241-B-204	B Farm Zone	4.34E+00	0.00E+00	9.52E-02	3.78E-01	7.30E-04	1.05E-06	0.00E+00	0.00E+00	0.00E+00	9.72E-02	2.05E-06	2.37E-04	3.32E-01	9.48E-02	9.43E+00	9.96E-01	1.54E-01	2.35E-02	3.55E-01	1.52E-03	3.98E-02	1.10E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.24E-15	0.00E+00	2.93E-05	1.51E-03
66	241-BX-101	B Farm Zone	1.23E+03	1.06E+02	1.30E+01	1.50E+00	1.04E-03	5.42E-11	4.73E-03	1.48E-04	1.16E-01	8.10E+00	4.33E-05	1.68E-02	5.82E+00	8.75E+00	7.24E+02	1.09E+02	2.31E+02	1.35E+01	6.58E+01	1.45E+00	3.66E-02	3.57E+01	0.00E+00	2.51E-02	0.00E+00	0.00E+00	5.28E-01	0.00E+00	4.54E-01	1.51E-02
67	241-BX-102	B Farm Zone	1.68E+04	0.00E+00	1.73E+02	6.05E+01	2.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E+01	8.72E-02	5.97E-07	1.51E+02	1.00E+01	3.80E+03	2.70E+02	1.27E+04	4.13E+03	5.59E+03	4.08E+01	1.31E-05	4.18E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.28E-01	0.00E+00	1.01E+04	3.47E-01
68	241-BX-108	B Farm Zone	8.37E+02	1.04E+02	9.68E-01	1.37E+01	1.38E-02	1.07E-08	2.67E-03	1.62E-03	9.82E-01	9.71E-01	4.31E-04	1.46E-01	1.39E+00	6.92E+00	6.98E+02	3.45E+02	9.23E+01	5.76E+00	7.58E+01	2.44E+00	4.45E-01	2.15E+01	0.00E+00	7.42E-02	0.00E+00	0.00E+00	3.49E+00	0.00E+00	2.87E-01	9.46E-03
69	241-BX-110	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
70	241-BX-111	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
71	241-BY-103	B Farm Zone	3.87E+02	7.12E+01	1.57E-01	4.36E+00	5.13E-02	3.70E-07	4.56E-04	5.17E-03	2.19E-01	1.62E-01	0.00E+00	3.54E-02	2.27E-01	3.15E+00	3.27E+02	1.77E+02	4.78E+01	8.96E+00	1.80E+01	4.33E-01	3.07E+00	1.15E+01	0.00E+00	2.56E+00	0.00E+00	0.00E+00	1.38E+00	0.00E+00	4.70E-02	1.51E-03
72	241-BY-105	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
73	241-BY-106	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
74	241-BY-107	B Farm Zone	1.16E+03	2.14E+02	4.70E-01	1.31E+01	1.54E-01	1.11E-06	1.37E-03	1.55E-02	6.56E-01	4.85E-01	0.00E+00	1.06E-01	6.81E-01	9.45E+00	9.80E+02	5.32E+02	1.43E+02	2.69E+01	5.41E+01	1.30E+00	9.22E+00	3.44E+01	0.00E+00	7.69E+00	0.00E+00	0.00E+00	4.13E+00	0.00E+00	1.41E-01	4.54E-03
75	241-BY-108	B Farm Zone	3.87E+02	7.12E+01	1.57E-01	4.36E+00	5.13E-02	3.70E-07	4.56E-04	5.17E-03	2.19E-01	1.62E-01	0.00E+00	3.54E-02	2.27E-01	3.15E+00	3.27E+02	1.77E+02	4.78E+01	8.96E+00	1.80E+01	4.33E-01	3.07E+00	1.15E+01	0.00E+00	2.56E+00	0.00E+00	0.00E+00	1.38E+00	0.00E+00	4.70E-02	1.51E-03
76	216-BY-201	B Farm Zone	3.71E+03	0.00E+00	4.36E+00	7.16E+00	1.61E+00	0.00E+00	1.33E-02	0.00E+00	0.00E+00	4.38E+00	1.25E-04	0.00E+00	6.14E+00	2.74E+01	8.27E+03	3.94E+00	9.19E+00	2.79E+02	4.90E+02	1.21E+01	1.69E+02	1.14E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.73E-05	0.00E+00	1.29E+00	3.57E-02
77	241-C-101	WTP-ETF-A-C Farm Zone	6.65E+01	2.95E+00	3.91E-01	1.51E+00	6.05E-04	0.00E+00	9.67E-04	1.09E-04	9.69E-02	3.96E-01	1.40E-04	2.61E-03	5.62E-01	4.56E-01	5.03E+01	4.07E+01	8.88E+00	5.68E-02	1.31E+01	8.82E-01	1.82E-02	1.74E+00	0.00E+00	1.11E+00	0.00E+00	0.00E+00	4.39E-01	0.00E+00	1.16E-01	3.79E-03
78	241-C-105	WTP-ETF-A-C Farm Zone	1.05E+02	6.52E+00	3.75E-01	1.42E+00	2.21E-03	9.23E-10	7.25E-04	2.70E-04	2.35E-01	3.65E-01	9.63E-05	1.99E-02	5.14E-01	9.24E-01	1.14E+02	3.77E+01	1.63E+01	2.01E+00	1.45E+01	6.56E-01	8.33E-02	2.86E+00	0.00E+00	6.47E-01	0.00E+00	0.00E+00	5.03E-01	0.00E+00	9.86E-02	3.79E-03

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Table 4-2. Mean Average Liquid Volume Discharged and Contaminant Mass Released for Liquid Waste Release Sites Overlying the 200-BP-5 OU

#	Site ID	Operable_Unit_Name	Na Mean_kg	Al Mean_kg	Fe Mean_kg	Cr Mean_kg	Bi Mean_kg	La Mean_kg	Hg Mean_kg	Zr Mean_kg	Pb Mean_kg	Ni Mean_kg	Ag Mean_kg	Mn Mean_kg	Ca Mean_kg	K Mean_kg	NO3 Mean_kg	NO2 Mean_kg	CO3 Mean_kg	PO4 Mean_kg	SO4 Mean_kg	Si Mean_kg	F Mean_kg	Cl Mean_kg	CCl4 Mean_kg	Butanol Mean_kg	TBP Mean_kg	NPH Mean_kg	NH3 Mean_kg	Fe(CN)6 Mean_kg	U-Total Mean_kg	Volume Discharge (ML)
79	241-C-110	WTP-ETF-A-C Farm Zone	6.53E+02	0.00E+00	7.81E-01	1.47E+00	3.48E-01	0.00E+00	2.06E-03	2.96E-02	0.00E+00	7.16E-01	2.21E-03	0.00E+00	1.12E+00	4.41E+00	1.30E+03	5.08E+01	7.20E+01	5.00E+01	8.35E+01	3.26E-01	4.13E+00	2.36E+01	0.00E+00	4.40E-03	0.00E+00	0.00E+00	2.23E+00	0.00E+00	2.35E-01	7.57E-03
80	241-C-111	WTP-ETF-A-C Farm Zone	1.07E+03	2.16E+02	2.42E+01	5.27E+00	7.87E-02	0.00E+00	3.16E-03	1.01E-02	5.29E+00	3.02E+00	3.74E-04	8.66E-06	3.33E+00	3.11E+01	1.07E+03	4.65E+02	1.34E+01	8.81E+00	7.99E+01	2.99E+00	2.68E+00	2.16E+01	0.00E+00	8.03E-03	0.00E+00	0.00E+00	1.19E+00	0.00E+00	6.02E-01	2.08E-02
81	241-C-201	WTP-ETF-A-C Farm Zone	9.99E+01	0.00E+00	5.28E+00	7.80E-01	0.00E+00	0.00E+00	6.35E-04	0.00E+00	8.90E-01	4.60E-01	0.00E+00	7.63E-07	3.86E-01	6.80E+00	9.69E+01	2.63E+01	5.86E-01	0.00E+00	1.27E+01	3.08E-04	1.67E-05	3.42E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-01	0.00E+00	6.08E-02	2.08E-03
82	241-C-202	WTP-ETF-A-C Farm Zone	8.16E+01	0.00E+00	4.31E+00	6.37E-01	0.00E+00	0.00E+00	5.19E-04	0.00E+00	7.28E-01	3.76E-01	0.00E+00	6.35E-07	3.16E-01	5.56E+00	7.92E+01	2.15E+01	4.79E-01	0.00E+00	1.04E+01	2.56E-04	1.39E-05	2.79E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.83E-02	0.00E+00	4.97E-02	1.70E-03
83	241-C-203	WTP-ETF-A-C Farm Zone	7.72E+01	0.00E+00	4.08E+00	6.03E-01	0.00E+00	0.00E+00	4.91E-04	0.00E+00	6.88E-01	3.56E-01	0.00E+00	0.00E+00	2.98E-01	5.25E+00	7.49E+01	2.03E+01	4.46E-01	0.00E+00	9.81E+00	0.00E+00	0.00E+00	2.64E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.30E-02	0.00E+00	4.70E-02	1.51E-03
84	241-C-204	WTP-ETF-A-C Farm Zone	6.55E+01	0.00E+00	3.46E+00	5.12E-01	0.00E+00	0.00E+00	4.17E-04	0.00E+00	5.84E-01	3.02E-01	0.00E+00	2.43E-07	2.53E-01	4.46E+00	6.36E+01	1.72E+01	3.81E-01	0.00E+00	8.33E+00	9.80E-05	5.31E-06	2.24E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.90E-02	0.00E+00	3.99E-02	1.32E-03
85	200-E-4	Unassigned 200 Area	3.77E-02	0.00E+00	1.96E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E-04	0.00E+00	0.00E+00	5.43E-04	3.49E-01	1.27E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E-03	1.88E-02	0.00E+00	0.00E+00	0.00E+00	2.30E-02	0.00E+00	0.00E+00	1.07E-05	1.75E-02
86	200-E-25	Unassigned 200 Area	3.02E-02	0.00E+00	3.55E-03	0.00E+00	0.00E+00	0.00E+00	6.27E-04	0.00E+00	1.08E-03	0.00E+00	0.00E+00	5.23E-04	4.67E-01	7.14E-03	6.71E-02	0.00E+00	0.00E+00	0.00E+00	6.29E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.68E-03	0.00E+00	0.00E+00	2.75E-05	7.39E-02
87	200-E-28	Unassigned 200 Area	2.40E-01	0.00E+00	2.81E-02	0.00E+00	0.00E+00	0.00E+00	4.97E-03	0.00E+00	8.58E-03	0.00E+00	0.00E+00	4.14E-03	3.70E+00	5.67E-02	5.33E-01	0.00E+00	0.00E+00	0.00E+00	4.99E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.30E-02	0.00E+00	0.00E+00	2.18E-04	5.86E-01
88	200-E-41	Unassigned 200 Area	4.31E-02	1.60E-06	7.26E-04	3.15E-06	8.28E-07	3.40E-10	9.25E-10	5.46E-08	1.14E-04	9.52E-07	1.54E-10	1.04E-04	3.89E-01	1.54E-02	1.10E-02	1.39E-05	1.55E+00	5.46E-05	2.13E-01	5.09E-02	2.76E-03	1.81E-02	0.00E+00	3.00E-13	0.00E+00	0.00E+00	3.46E-06	0.00E+00	2.60E-06	2.20E-02
89	200-E-55	Unassigned 200 Area	3.61E-01	0.00E+00	1.01E-02	1.91E-03	5.46E-04	2.24E-07	1.67E-03	3.60E-05	2.88E-03	6.16E-04	1.01E-07	1.44E-03	1.24E+00	3.46E-02	6.04E-01	5.15E-03	6.63E-02	3.59E-02	2.06E-01	1.07E-03	2.00E-02	5.82E-03	0.00E+00	0.00E+00	0.00E+00	1.78E-02	2.24E-03	0.00E+00	1.78E-03	2.31E-01
90	200-E-56	Unassigned 200 Area	3.85E+03	0.00E+00	2.03E+02	3.01E+01	0.00E+00	0.00E+00	2.45E-02	0.00E+00	3.43E+01	1.77E+01	0.00E+00	0.00E+00	1.48E+01	2.62E+02	3.73E+03	1.01E+03	2.22E+01	0.00E+00	4.89E+02	0.00E+00	0.00E+00	1.32E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.64E+00	0.00E+00	2.35E+00	7.55E-02
91	200-E-57	Unassigned 200 Area	5.77E+03	0.00E+00	3.05E+02	4.51E+01	0.00E+00	0.00E+00	3.67E-02	0.00E+00	5.15E+01	2.66E+01	0.00E+00	0.00E+00	2.23E+01	3.93E+02	5.60E+03	1.52E+03	3.33E+01	0.00E+00	7.34E+02	0.00E+00	0.00E+00	1.98E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.96E+00	0.00E+00	3.51E+00	1.13E-01
92	200-E-60	Unassigned 200 Area	2.34E+01	0.00E+00	5.44E-01	2.17E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.57E-01	0.00E+00	0.00E+00	1.87E+00	1.40E-01	5.06E+01	5.75E+00	6.14E-01	0.00E+00	2.00E+00	0.00E+00	0.00E+00	5.86E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.88E-09	5.20E-03
93	200-E-89	Unassigned 200 Area 1	4.20E-01	1.53E-05	6.99E-03	7.02E-05	1.94E-05	7.94E-09	2.09E-08	1.28E-06	1.09E-03	2.20E-05	3.59E-09	9.97E-04	3.74E+00	1.48E-01	1.15E-01	2.42E-04	1.49E+01	1.28E-03	2.05E+00	4.90E-01	2.70E-02	1.74E-01	0.00E+00	2.89E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.06E-05	2.32E-01
94	200-E-90	Unassigned 200 Area 1	4.20E-01	1.53E-05	6.99E-03	7.02E-05	1.94E-05	7.94E-09	2.09E-08	1.28E-06	1.09E-03	2.20E-05	3.59E-09	9.97E-04	3.74E+00	1.48E-01	1.15E-01	2.42E-04	1.49E+01	1.28E-03	2.05E+00	4.90E-01	2.70E-02	1.74E-01	0.00E+00	2.89E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.06E-05	2.32E-01
95	200-E-91	Unassigned 200 Area 1	4.20E-01	1.53E-05	6.99E-03	7.02E-05	1.93E-05	7.94E-09	2.09E-08	1.28E-06	1.09E-03	2.20E-05	3.59E-09	9.97E-04	3.74E+00	1.48E-01	1.15E-01	2.42E-04	1.49E+01	1.27E-03	2.05E+00	4.90E-01	2.70E-02	1.74E-01	0.00E+00	2.89E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.05E-05	2.32E-01
96	200-E-92	Unassigned 200 Area 1	4.20E-01	1.53E-05	6.99E-03	7.02E-05	1.93E-05	7.94E-09	2.09E-08	1.28E-06	1.09E-03	2.20E-05	3.59E-09	9.97E-04	3.74E+00	1.48E-01	1.15E-01	2.42E-04	1.49E+01	1.27E-03	2.05E+00	4.90E-01	2.70E-02	1.74E-01	0.00E+00	2.89E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.05E-05	2.32E-01
97	200-E-93	Unassigned 200 Area 2	4.20E-01	1.53E-05	6.99E-03	7.02E-05	1.94E-05	7.94E-09	2.09E-08	1.28E-06	1.09E-03	2.20E-05	3.59E-09	9.97E-04	3.74E+00	1.48E-01	1.15E-01	2.42E-04	1.49E+01	1.28E-03	2.05E+00	4.90E-01	2.70E-02	1.74E-01	0.00E+00	2.89E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.06E-05	2.32E-01
98	200-E-94	Unassigned 200 Area 2	4.20E-01	1.53E-05	6.99E-03	7.02E-05	1.94E-05	7.94E-09	2.09E-08	1.28E-06	1.09E-03	2.20E-05	3.59E-09	9.97E-04	3.74E+00	1.48E-01	1.15E-01	2.42E-04	1.49E+01	1.28E-03	2.05E+00	4.90E-01	2.70E-02	1.74E-01	0.00E+00	2.89E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	1.81E-03	2.32E-01
99	200-E-95	Unassigned 200 Area 2	3.62E-01	0.00E+00	9.49E-03	1.95E-03	5.58E-04	2.29E-07	1.56E-03	3.68E-05	2.69E-03	6.29E-04	1.03E-07	1.35E-03	1.16E+00	3.37E-02	6.01E-01	5.26E-03	6.77E-02	3.67E-02	1.96E-01	1.09E-03	2.04E-02	5.94E-03	0.00E+00	0.00E+00	0.00E+00	1.66E-02	2.29E-03	0.00E+00	1.82E-03	2.19E-01
100	200-E-97	Unassigned 200 Area 2	3.67E-01	0.00E+00	1.01E-02	1.95E-03	5.58E-04	2.29E-07	1.67E-03	3.67E-05	2.89E-03	6.29E-04	1.03E-07	1.44E-03	1.25E+00	3.50E-02	6.13E-01	5.26E-03	6.76E-02	3.67E-02	2.07E-01	1.09E-03	2.04E-02	5.94E-03	0.00E+00	0.00E+00	0.00E+00	1.78E-02	2.28E-03	0.00E+00	1.51E-03	2.32E-01
101	200-E-98	Unassigned 200 Area 2	3.05E-01	0.00E+00	8.36E-03	1.63E-03	4.65E-04	1.91E-07	1.38E-03	3.06E-05	2.38E-03	5.24E-04	8.61E-08	1.19E-03	1.03E+00	2.90E-02	5.10E-01	4.39E-03	5.64E-02	3.06E-02	1.71E-01	9.09E-04	1.70E-02	4.95E-03	0.00E+00	0.00E+00	0.00E+00	1.47E-02	1.90E-03	0.00E+00	6.06E-05	1.92E-01
102	200-E-99	Unassigned 200 Area 2	4.29E-01	1.57E-05	7.15E-03	7.02E-05	1.94E-05	7.94E-09	2.09E-08	1.28E-06	1.12E-03	2.20E-05	3.59E-09	1.02E-03	3.83E+00	1.51E-01	1.17E-01	2.43E-04	1.53E+01	1.28E-03	2.10E+00	5.01E-01	2.76E-02	1.78E-01	0.00E+00	2.95E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.06E-05	2.37E-01
103	200-E-100	Unassigned 200 Area	4.29E-01	1.57E-05	7.15E-03	7.02E-05	1.94E-05	7.94E-09	2.09E-08	1.28E-06	1.12E-03	2.20E-05	3.59E-09	1.02E-03	3.83E+00	1.51E-01	1.17E-01	2.43E-04	1.53E+01	1.28E-03	2.10E+00	5.01E-01	2.76E-02	1.78E-01	0.00E+00	2.95E-12	0.00E+00	0.00E+00	7.99E-05	0.00E+00	6.05E-05	2.37E-01
104	UPR-200-E-1	B Plant Zone	1.17E+03	0.00E+00	2.13E+00	7.30E+00	1.95E+00	0.00E+00	0.00E+00	5.48E-01	0.00E+00	2.03E+00	5.59E-03	0.00E+00	3.06E+00	8.05E+00	2.20E+03	6.27E+01	4.60E+00	1.37E+02	1.45E+02	6.04E+00	7.64E+01	3.35E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.05E+01	0.00E+00	6.33E-01	2.04E-02
105	UPR-200-E-3	B Plant Zone	1.86E+01	0.00E+00	3.45E-02	1.18E-01	3.14E-02	0.00E+00	1.07E-04	8.86E-03	0.00E+00	3.29E-02	9.03E-05	0.00E+00	4.97E-02	1.30E-01	3.54E+01	7.64E-01	7.43E-02	2.22E+00	2.34E+00	9.76E-02	1.24E+00	5.42E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.76E-01	0.00E+00	5.87E-03	3.30E-04
106	UPR-200-E-6	B Farm Zone	2.17E+02	0.00E+00	4.03E-01	1.38E+00	3.66E-01	0.00E+00	1.25E-03	1.04E-01	0.00E+00	3.83E-01	1.05E-03	0.00E+00	5.79E-01	1.52E+00	4.13E+02	8.92E+00	8.67E-01	2.58E+01	2.73E+01	1.14E+00	1.44E+01	6.32E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.55E+00	0.00E+00	1.02E-02	3.85E-03
107	UPR-200-E-7	B Plant Zone	4.50E+01	0.00E+00	1.15E-01	4.15E-01	1.06E-01	7.67E-05	0.00E+00	0.00E+00	0.00E+00	1.06E-01	2.93E-04	1.68E-02	1.65E-01	5.17E+00	9.13E+01	2.84E-03	2.48E-01	5.39E+00	2.87E+00	1.62E-01	5.22E+00	1.19E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E-09	0.00E+00	1.20E-01	1.89E-02
108	UPR-200-E-9	B Farm Zone	3.80E+03	0.00E+00	4.28E+00	6.91E+00	1.56E+00	0.00E+00	1.33E-02	0.00E+00	0.00E+00	3.90E+00	1.23E-02	0.00E+00	6.15E+00	2.56E+01	7.58E+03	3.05E+02	4.62E+02	2.74E+02	4.87E+02	0.00E+00	0.00E+00	1.40E+02	0.00E+00	2.83E-02	0.00E+00	0.00E+00	2.83E-01	0.00E+00	4.40E-03	4.16E-02
109	UPR-200-E-16	WTP-ETF-A-C Farm Zone	1.04E+01	4.35E+00	1.98E-02	3.04E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E-02	1.71E-02	7.53E-06	0.00E+00	2.84E-02	1.12E-02	8.10E+00	6.92E+00	4.26E-02	0.00E+00	1.61E-01	5.60E-02	0.00E+00	4.67E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.93E-04	0.00E+00	1.29E+00	1.89E-04
110	UPR-200-E-38	Unassigned 200 Area 2	1.96E+03	2.12E+02	2.14E+00	3.36E+01	2.17E-02	0.00E+00	6.62E-03	2.87E-03	2.07E+00	2.18E+00	9.36E-04	3.63E-01	3.06E+00	1.68E+01	1.59E+03	8.16E+02	2.26E+02	1.25E+01	1.85E+02	6.03E+00	7.48E-01	5.14E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.60E+00	0.00E+00	6.32E-01	7.00E-02
111	UPR-200-E-41	Unassigned 200 Area 2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0	0.00E+00
112	UPR-200-E-68	WTP-ETF-A-C Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
113	UPR-200-E-73	B Farm Zone	1.53E+01	0.00E+00	3.63E-02	6.43E-02	2.31E-02	0.00E+00	1.13E-04	0.00E+00	0.00E+00	3.63E-02	9.30E-05	0.00E+00	5.22E-02	1.07E-02	3.93E+00	3.67E-01	1.31E+01	2.33E+00	4.13E+00	4.34E-02	0.00E+00	4.45E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.09E-04	0.00E+00	3.31E-01	1.73E-04
114	UPR-200-E-74	B Farm Zone	1.73E-01	0.00E+00	4.03E-03	1.61E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.12E-03	0.00E+00	0.00E+00	1.39E-02	1.04E-03	3.74E-01	4.25E-02	4.55E-03	0.00E+00	1.48E-02	0.00E+00	0.00E+00	4.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.91E-06	3.85E-05
115	UPR-200-E-75	B Farm Zone	2.17E+02	0.00E+00	4.03E-01	1.38E+00	3.67E-01	0.00E+00	1.25E-03	1.03E-01	0.00E+00	3.84E-01	1.05E-03	0.00E+00	5.80E-01	1.52E+00	4.13E+02	8.93E+00	8.68E-01	2.58E+01	2.73E+01	1.14E+00	1.44E+01	6.32E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.56E+00	0.00E+00	1.19E-01	1.93E-03
116	UPR-200-E-77	B Plant Zone	1.52E+00	0.00E+00	3.61E-03	6.33E-03	2.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.57E-03	9.30E-06	0.00E+00	5.22E-03	1.05E-03	4.00E-01	2.66E-02	1.30E+00	2.33E-01	4.14E-01	4.27E-03	0.00E+00	4.38E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.23E-05	0.00E+00	3.30E-02	3.47E-05
117	UPR-200-E-78	Solid Waste Zone	7.85E+00	0.00E+00	4.14E-01	6.13E-02	0.00E+00	0.00E+00	5.00E-05	0.00E+00	7.00E-02	3.62E-02	0.00E+00	0.00E+00	3.03E-02	5.35E-01	7.62E+00	2.07E+00	4.53E-02	0.00E+00	9.98E-01	0.00E+00	0.00E+00	2.68E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.45E-03	0.00E+00	4.74E-03	1.54E-04
118	UPR-200-E-79	B Farm Zone	4.36E+02	2.19E+00	4.04E-01	1.82E+00	3.71E-01	0.00E+00	1.25E-03	9.60E-02	0.00E+00	4.14E-01	0.00E+00	0.00E+00	5.80E-01	3.39E+00	8.39E+02	3.29E+01	3.53E+01	2.59E+01	4.61E+01	1.14E+00	1.38E+01	1.67E+01	0.00E+00	2.34E-03	0.00E+00	0.00E+00	6.11E+00	0.00E+00	1.20E-01	3.85E-03
119	UPR-200-E-80	B Plant Zone	1.69E+00	0.00E+00	4.03E-03	7.05E-03	2.52E-03	8.63E-10	2.22E-09	1.39E-07	0.00E+00	3.97E-03	1.03E-05	1.90E-07	5.79E-03	1.22E-03	4.46E-01	2.95E-02	1.44E+00	2.59E-01	4.58E-01	4.75E-03	7.71E-05	4.88E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.56E-05	0.00E+00	3.66E-02	3.85E-03
120	UPR-200-E-81	Unassigned 200 Area 2	5.08E+03	2.31E+03	1.43E+01	2.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.03E+01	1.22E+01	5.27E-03	0.00E+00	2.05E+01	1.34E+01	5.81E+03	1.78E+03	3.07E+01	0.00E+00	8.82E+01	0.00E+00	0.00E+00	5.58E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.29E-02	0.00E+00	4.23E+00	1.36E-01
121	UPR-200-E-82	Unassigned 200 Area 2	9.43E+02	1.02E+02	1.03E+00	1.62E+01	1.05E-02	0.00E+00	3.19E-03	1.38E-03	9.99E-01	1.05E+00	4.51E-04	1.75E-01	1.48E+00	8.09E+00	7.65E+02	3.93E+02	1.09E+02	6.03E+00	8.91E+01	2.90E+00	3.60E-01	2.48E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.14E+00	0.00E+00	3.04E-01	9.84E-03
122	UPR-200-E-84	B Plant Zone	6.56E-02	0.00E+00	7.28E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.22E+00	0.00E+00	0.00E+00	0.00E+00	3.63E-02	0.00E+00	0.00E+00	6.50E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.81E-04	6.43E-03
123	UPR-200-E-85	B Plant Zone	2.37E+02	2.57E+01	2.59E-01	4.08E+00	2.64E-03	0.00E+00	8.06E-04	3.47E-04	2.51E-01	2.65E-01	1.13E-04	4.40E-02	3.71E-01	2.04E+00	1.93E+02	9.90E+01	2.73E+01	1.52E+00	2.25E+01	7.34E-01	9.07E-02	6.21E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.04E+00	0.00E+00	7.76E-02	2.48E-03
124	UPR-200-E-86	WTP-ETF-A-C Farm Zone	2.11E+03	4.01E+01	7.11E+00	6.04E+01	2.90E-02	0.00E+00	2.20E-02	2.53E-04	3.17E+00	7.26E+00	0.00E+00	6.64E-01	1.02E+01	2.04E+01	1.27E+03	1.49E+03	5.75E+02	1.44E+02	4.85E+02	2.01E+01	8.43E-01	4.60E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.04E+01	0.00E+00	2.11E+00	6.58E-02
125	UPR-200-E-87	B Plant Zone	2.04E+03	0.00E+00	4.45E+02	9.41E+00	6.51E+02	2.95E+02	0.00E+00	0.00E+00	0.00E+00	2.48E+00	4.58E-03	1.40E+02	3.27E+02	2.41E+02	2.28E+03	1.42E-03	4.89E+02	3.76E+02	7.49E+00	0.00E+00	1.37E+02	2.72E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.33E-11	0.00E+00	5.39E-04	2.88E-02
126	UPR-200-E-105	Unassigned 200 Area 2	4.91E+03	0.00E+00	9.12E+00	3.12E+01	8.30E+00	0.00E+00	2.82E-02	2.34E+00	0.00E+00	8.67E+00	2.38E-02	0.00E+00	1.31E+01	3.43E+01	9.34E+03	2.02E+02	1.96E+01	5.84E+02	6.17E+02	2.58E+01	3.26E+02	1.43E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+02	0.00E+00	2.70E+00	8.71E-02

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Table 4-2. Mean Average Liquid Volume Discharged and Contaminant Mass Released for Liquid Waste Release Sites Overlying the 200-BP-5 OU

#	Site ID	Operable_Unit_Name	Na	Al	Fe	Cr	Bi	La	Hg	Zr	Pb	Ni	Ag	Mn	Ca	K	NO3	NO2	CO3	PO4	SO4	Si	F	Cl	CCl4	Butanol	TBP	NPH	NH3	Fe(CN)6	U-Total	Volume Discharge (ML)
			Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	Mean_kg	
127	UPR-200-E-107	Unassigned 200 Area 2	1.73E+00	0.00E+00	1.95E-03	3.14E-03	7.10E-04	0.00E+00	6.03E-06	0.00E+00	0.00E+00	1.77E-03	5.58E-06	0.00E+00	2.80E-03	1.16E-02	3.44E+00	1.39E-01	2.10E-01	1.25E-01	2.21E-01	0.00E+00	0.00E+00	6.39E-02	0.00E+00	1.29E-05	0.00E+00	0.00E+00	1.29E-04	0.00E+00	5.87E-04	1.89E-05
128	UPR-200-E-108	Unassigned 200 Area 2	3.27E+01	0.00E+00	7.79E-02	1.38E-01	4.94E-02	0.00E+00	2.41E-04	0.00E+00	0.00E+00	7.77E-02	1.99E-04	0.00E+00	1.12E-01	2.28E-02	8.42E+00	7.85E-01	2.79E+01	4.98E+00	8.83E+00	9.30E-02	0.00E+00	9.52E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.73E-03	0.00E+00	7.08E-01	7.42E-04
129	UPR-200-E-109	Unassigned 200 Area 2	5.18E+01	0.00E+00	5.84E-02	9.42E-02	2.13E-02	0.00E+00	1.81E-04	0.00E+00	0.00E+00	5.32E-02	1.67E-04	0.00E+00	8.38E-02	3.49E-01	1.03E+02	4.16E+00	6.30E+00	3.74E+00	6.64E+00	0.00E+00	0.00E+00	1.92E+00	0.00E+00	3.86E-04	0.00E+00	0.00E+00	3.86E-03	0.00E+00	1.76E-02	5.68E-04
130	UPR-200-E-110	Unassigned 200 Area 2	1.09E+03	0.00E+00	2.01E+00	6.89E+00	1.83E+00	0.00E+00	6.24E-03	5.17E-01	0.00E+00	1.92E+00	5.27E-03	0.00E+00	2.90E+00	7.59E+00	2.06E+03	4.47E+01	4.34E+00	1.29E+02	1.36E+02	5.70E+00	7.21E+01	3.15E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.77E+01	0.00E+00	5.97E-01	1.93E-02
131	UPR-200-E-116	Unassigned 200 Area 2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
132	UPR-200-E-133	Unassigned 200 Area 2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
133	UPR-200-E-141	Unassigned 200 Area 2	4.68E-03	0.00E+00	2.41E-05	2.26E-05	0.00E+00	0.00E+00	7.69E-07	0.00E+00	0.00E+00	1.15E-05	0.00E+00	1.88E-06	4.12E-03	2.55E+00	3.18E+00	0.00E+00	0.00E+00	5.56E-02	0.00E+00	0.00E+00	5.16E-03	0.00E+00	0.00E+00	1.04E-06	0.00E+00	0.00E+00	1.04E-06	0.00E+00	1.80E-01	2.08E-04
Total			1.05E+07	4.61E+05	5.87E+04	9.59E+04	1.80E+04	3.76E+03	3.09E+02	3.66E+02	6.25E+03	1.55E+04	2.90E+02	7.79E+03	7.24E+06	3.36E+06	2.05E+07	7.97E+05	3.43E+07	8.32E+05	7.72E+06	1.34E+06	6.28E+05	9.66E+05	6.88E+03	5.31E+04	0.00E+00	4.27E+04	2.34E+04	5.15E+01	4.33E+04	5.72E+05

Source: Derived from RPP-26744, *Hanford Soil Inventory Model*, *Rev. 1.*

Table 4-3. Mean Average Liquid Volume Discharged and Contaminant Activity Released for Liquid Waste Release Sites Overlying the 200-BP-5 OU

Num#	Site ID	Operable_Unit_Name	H-3 Mean_Ci	C-14 Mean_Ci	Ni-59 Mean_Ci	Ni-63 Mean_Ci	Co-60 Mean_Ci	Se-79 Mean_Ci	Sr-90 Mean_Ci	Y-90 Mean_Ci	Zr-93 Mean_Ci	Nb-93m Mean_Ci	Tc-99 Mean_Ci	Ru-106 Mean_Ci	Cd-113m Mean_Ci	Sb-125 Mean_Ci	Sn-126 Mean_Ci	I-129 Mean_Ci	Cs-134 Mean_Ci	Cs-137 Mean_Ci	Ba-137m Mean_Ci	Sm-151 Mean_Ci
1	216-A-25	200-E Ponds Zone	8.75E+02	3.49E+01	1.38E-02	1.33E+00	2.51E-01	5.46E-03	1.83E+02	1.84E+02	3.26E-01	2.56E-01	1.71E+00	5.63E-07	3.75E-01	8.94E-02	2.28E-02	1.40E-02	1.01E-02	7.26E+03	6.87E+03	4.93E+01
2	216-B-2-2E	200-E Ponds Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	216-B-2-2W	200-E Ponds Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	216-B-3	200-E Ponds Zone	2.01E+04	9.90E+01	3.22E-03	3.05E-01	5.18E-02	8.17E-04	1.34E+02	1.34E+02	4.42E-02	3.73E-02	3.20E-01	2.59E-05	3.86E-02	6.65E-03	3.24E-03	3.20E-03	2.57E-04	4.26E+02	4.02E+02	2.34E+01
5	216-B-4	B Plant Zone	1.19E-05	2.30E-07	6.79E-08	6.43E-06	2.66E-07	1.11E-08	1.32E-03	1.32E-03	5.39E-07	4.78E-07	4.90E-06	4.14E-16	3.56E-07	1.04E-08	4.19E-08	4.89E-09	9.66E-11	1.08E-02	1.02E-02	4.85E-04
6	216-B-5	B Plant Zone	1.07E-04	1.11E-02	2.91E-03	2.48E-01	5.28E-03	4.97E-04	7.55E+00	7.55E+00	1.99E-01	1.79E-01	4.25E-03	1.43E-11	1.17E-02	1.53E-04	1.79E-03	1.88E-06	1.17E-08	8.67E+00	8.19E+00	1.88E+02
7	216-B-6	B Plant Zone	7.12E-03	1.38E-04	4.07E-05	3.85E-03	1.59E-04	6.65E-06	7.91E-01	7.91E-01	3.23E-04	2.86E-04	2.94E-03	2.48E-13	2.13E-04	6.22E-06	2.51E-05	2.93E-06	5.79E-08	6.50E+00	6.14E+00	2.91E-01
8	216-B-7A%B	B Farm Zone	7.81E-03	2.15E-02	5.37E-02	5.04E+00	3.61E-01	1.15E-03	1.64E+03	1.63E+03	1.17E-01	1.02E-01	9.47E-02	7.64E-07	4.27E-02	7.65E-02	4.45E-03	6.67E-04	2.97E-04	3.73E+02	3.53E+02	8.42E+02
9	216-B-8	B Farm Zone	1.32E-02	1.50E-01	3.91E-02	3.36E+00	8.72E-02	6.71E-03	1.46E+02	1.46E+02	4.07E+00	3.64E+00	8.00E-02	1.38E-09	1.74E-01	3.48E-03	2.46E-02	2.67E-05	7.06E-07	1.68E+02	1.59E+02	1.40E+03
10	216-B-9	Solid Waste Zone	1.68E-03	1.10E-02	2.87E-03	2.49E-01	7.59E-03	4.94E-04	1.07E+01	1.07E+01	2.89E-01	2.57E-01	5.74E-03	2.09E-10	1.39E-02	3.59E-04	1.84E-03	1.32E-06	8.33E-08	1.24E+01	1.17E+01	1.10E+02
11	216-B-10A	B Plant Zone	6.37E-02	2.29E-04	6.78E-05	6.42E-03	2.65E-04	1.11E-05	1.32E+00	1.32E+00	5.38E-04	4.77E-04	5.35E-03	4.12E-13	3.55E-04	1.04E-05	4.18E-05	4.87E-06	9.63E-08	1.08E+01	1.02E+01	4.84E-01
12	216-B-10B	B Plant Zone	5.11E-08	1.17E-09	1.87E-09	1.79E-07	9.43E-09	9.92E-11	1.04E-06	1.04E-06	5.90E-09	4.70E-09	3.13E-08	1.06E-09	6.41E-09	8.75E-09	4.13E-10	1.64E-05	9.80E-09	1.30E-04	1.23E-04	1.93E-06
13	216-B-11A&B	B Farm Zone	1.59E+01	2.77E-04	4.34E-05	4.46E-03	3.12E-04	1.09E-05	3.04E+00	3.04E+00	9.97E-04	8.90E-04	3.25E-03	4.30E-13	3.66E-04	1.01E-05	4.09E-05	4.54E-06	8.40E-08	9.66E+00	9.14E+00	4.95E-01
14	216-B-12	B Plant Zone	2.34E+03	9.54E-03	1.47E-03	1.51E-01	1.06E-02	3.69E-04	1.20E+02	1.20E+02	3.37E-02	3.00E-02	1.65E+00	6.01E-11	1.24E-02	3.50E-04	1.39E-03	1.55E-04	2.87E-06	3.26E+02	3.07E+02	1.68E+01
15	216-B-13	B Plant Zone	6.24E-06	1.21E-07	3.57E-08	3.37E-06	1.40E-07	5.82E-09	0.001091	0.001092	2.83E-07	2.51E-07	2.57E-06	2.17E-16	1.87E-07	5.45E-09	2.20E-08	2.57E-09	5.07E-11	0.0057379	0.0054172	0.000255
16	216-B-35	B Farm Zone	6.46E+00	8.57E-02	2.82E-02	3.90E+00	3.37E-01	2.82E-03	7.62E+01	7.63E+01	1.31E+00	1.15E+00	2.14E-01	1.40E-09	1.71E-01	4.92E-03	1.10E-02	1.87E-03	5.74E-06	4.85E+02	4.58E+02	2.25E+02
17	216-B-36	B Farm Zone	1.18E+01	1.57E-01	5.16E-02	7.14E+00	6.16E-01	5.16E-03	1.40E+02	1.40E+02	2.40E+00	2.11E+00	3.92E-01	2.56E-09	3.13E-01	9.00E-03	2.01E-02	3.42E-03	1.05E-05	8.87E+02	8.38E+02	4.11E+02
18	216-B-37	B Farm Zone	2.63E+01	3.49E-01	1.15E-01	1.59E+01	1.37E+00	1.15E-02	3.11E+02	3.11E+02	5.34E+00	4.70E+00	8.73E-01	5.69E-09	6.96E-01	2.00E-02	4.48E-02	7.62E-03	2.34E-05	1.98E+03	1.87E+03	9.15E+02
19	216-B-38	B Farm Zone	8.72E+00	1.16E-01	3.80E-02	5.26E+00	4.54E-01	3.80E-03	1.03E+02	1.03E+02	1.77E+00	1.55E+00	2.89E-01	1.88E-09	2.31E-01	6.63E-03	1.48E-02	2.52E-03	7.74E-06	6.54E+02	6.18E+02	3.03E+02
20	216-B-39	B Farm Zone	9.39E+00	1.24E-01	4.09E-02	5.67E+00	4.89E-01	4.09E-03	1.11E+02	1.11E+02	1.90E+00	1.67E+00	3.11E-01	2.03E-09	2.48E-01	7.14E-03	1.60E-02	2.72E-03	8.33E-06	7.04E+02	6.65E+02	3.26E+02
21	216-B-40	B Farm Zone	1.00E+01	1.33E-01	4.36E-02	6.03E+00	5.21E-01	4.36E-03	1.18E+02	1.18E+02	2.03E+00	1.78E+00	3.32E-01	2.16E-09	2.64E-01	7.60E-03	1.70E-02	2.89E-03	8.87E-06	7.50E+02	7.08E+02	3.47E+02
22	216-B-41	B Farm Zone	8.78E+00	1.16E-01	3.83E-02	5.30E+00	4.57E-01	3.83E-03	1.04E+02	1.04E+02	1.78E+00	1.57E+00	2.91E-01	1.90E-09	2.32E-01	6.68E-03	1.49E-02	2.54E-03	7.79E-06	6.59E+02	6.22E+02	3.05E+02
23	216-B-42	B Farm Zone	9.35E+00	3.62E-01	6.13E-03	5.36E-01	2.82E-01	1.64E-02	2.01E+02	2.01E+02	4.40E-03	3.88E-03	5.70E+00	4.84E-12	4.91E-01	1.46E-02	6.17E-02	7.31E-03	4.68E-07	5.27E+01	4.97E+01	6.06E+02
24	216-B-43	B Farm Zone	1.32E+01	5.12E-01	8.67E-03	7.57E-01	3.98E-01	2.31E-02	2.84E+02	2.84E+02	6.21E-03	5.49E-03	8.05E+00	6.84E-12	6.94E-01	2.06E-02	8.72E-02	1.03E-02	6.61E-07	7.44E+01	7.03E+01	8.57E+02
25	216-B-44	B Farm Zone	3.49E+01	1.35E+00	2.29E-02	2.00E+00	1.05E+00	6.11E-02	7.50E+02	7.51E+02	1.64E-02	1.45E-02	2.13E+01	1.81E-11	1.83E+00	5.45E-02	2.30E-01	2.73E-02	1.75E-06	1.97E+02	1.86E+02	2.26E+03
26	216-B-45	B Farm Zone	3.07E+01	1.19E+00	2.23E-02	1.95E+00	9.24E-01	5.36E-02	1.03E+03	1.03E+03	1.44E-02	1.27E-02	1.87E+01	1.59E-11	1.61E+00	4.79E-02	2.02E-01	2.40E-02	5.39E-06	6.08E+02	5.72E+02	1.99E+03
27	216-B-46	B Farm Zone	4.18E+01	1.62E+00	2.74E-02	2.39E+00	1.26E+00	7.31E-02	8.97E+02	8.98E+02	1.96E-02	1.73E-02	2.55E+01	2.16E-11	2.19E+00	6.52E-02	2.76E-01	3.26E-02	2.09E-06	2.35E+02	2.22E+02	2.71E+03
28	216-B-47	B Farm Zone	2.29E+01	8.89E-01	2.48E-02	2.17E+00	6.92E-01	4.01E-02	3.29E+02	3.29E+02	1.08E-02	9.53E-03	1.40E+01	1.19E-11	1.20E+00	3.58E-02	1.51E-01	1.79E-02	1.15E-06	1.29E+02	1.22E+02	1.49E+03
29	216-B-48	B Farm Zone	2.55E+01	9.88E-01	1.67E-02	1.46E+00	7.69E-01	4.46E-02	5.48E+02	5.48E+02	1.20E-02	1.06E-02	1.55E+01	1.32E-11	1.34E+00	3.98E-02	1.68E-01	1.99E-02	1.27E-06	1.44E+02	1.36E+02	1.65E+03
30	216-B-49	B Farm Zone	4.18E+01	1.62E+00	2.74E-02	2.39E+00	1.26E+00	7.31E-02	8.98E+02	8.98E+02	1.96E-02	1.74E-02	2.55E+01	2.16E-11	2.19E+00	6.52E-02	2.76E-01	3.27E-02	2.09E-06	2.35E+02	2.22E+02	2.71E+03
31	216-B-50	B Farm Zone	1.26E+02	3.04E-03	1.32E-03	1.27E-01	8.01E-03	2.08E-04	1.52E+00	1.52E+00	1.23E-02	9.91E-03	6.60E-02	1.12E-11	1.54E-02	9.39E-05	8.63E-04	9.34E-05	6.33E-05	5.49E+01	5.17E+01	2.42E-01
32	216-B-51	B Farm Zone	6.24E-03	2.42E-04	1.05E-05	9.15E-04	1.88E-04	1.09E-05	2.66E-02	2.66E-02	2.93E-06	2.59E-06	3.80E-03	3.23E-15	3.28E-04	9.73E-06	4.12E-05	4.87E-06	3.12E-10	3.51E-02	3.31E-02	4.04E-01
33	216-B-55	B Plant Zone	1.77E-04	3.40E-05	6.42E-06	6.10E-04	3.93E-04	4.05E-06	2.20E-04	2.20E-04	2.41E-04	1.95E-04	1.29E-03	3.69E-10	2.52E-04	6.00E-05	1.68E-05	7.63E-07	1.35E-07	1.43E-01	1.35E-01	5.32E-02
34	216-B-57	B Farm Zone	1.95E+02	9.10E-03	3.96E-03	3.80E-01	2.40E-02	6.24E-04	3.55E+00	3.55E+00	3.69E-02	2.97E-02	1.97E-01	3.38E-11	4.61E-02	2.83E-04	2.59E-03	2.80E-04	1.89E-04	1.64E+02	1.55E+02	7.28E-01
35	216-B-59	B Plant Zone	7.06E-08	1.35E-08	2.56E-09	2.43E-07	1.57E-07	1.61E-09	8.76E-08	8.76E-08	9.61E-08	7.76E-08	5.15E-07	1.47E-13	1.01E-07	2.39E-08	6.71E-09	3.04E-10	5.39E-11	5.71E-05	5.40E-05	2.12E-05
36	216-B-60	B Plant Zone	4.60E-06	4.51E-08	4.18E-07	4.01E-05	3.05E-07	1.92E-09	2.28E-03	2.28E-03	1.14E-07	8.65E-08	8.14E-07	7.27E-10	1.66E-07	1.50E-07	8.28E-09	1.11E-05	2.71E-08	2.79E-03	2.60E-03	7.41E-05
37	216-B-62	B Plant Zone	3.57E-01	6.47E-02	1.85E-02	1.73E+00	6.23E-01	7.68E-03	8.25E+01	8.21E+01	4.59E-01	3.71E-01	2.39E+00	1.69E-06	4.72E-01	1.41E-01	3.21E-02	1.29E-03	8.06E-03	9.67E+03	9.15E+03	1.87E+02
38	216-B-63	Solid Waste Zone	1.30E+02	3.36E-02	4.95E-07	4.70E-05	5.29E-05	3.12E-07	6.91E-01	6.91E-01	1.86E-05	1.50E-05	1.66E-02	2.84E-11	1.95E-05	4.63E-06	1.30E-06	5.89E-08	1.04E-08	9.33E-02	8.83E-02	4.10E-03
39	216-C-1	Semi-Works Zone	1.95E-04	7.11E-05	1.46E-03	1.38E-01	1.03E-02	8.76E-06	4.88E+01	4.88E+01	5.22E-04	4.23E-04	2.74E-03	3.36E-08	5.25E-04	2.29E-03	3.63E-05	7.70E-06	8.82E-06	1.10E+01	1.04E+01	9.84E+00
40	216-C-2	Semi-Works Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.00E-02	7.99E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.43E-03	8.92E-03	0.00E+00
41	216-C-3	Semi-Works Zone	7.92E+01	1.42E-05	2.92E-04	2.75E-02	2.06E-03	1.75E-06	9.78E+00	9.77E+00	1.04E-04	8.46E-05	6.96E-04	4.06E-09	1.05E-04	4.57E-04	7.26E-06	3.27E-08	1.74E-06	2.20E+00	2.07E+00	1.97E+00
42	216-C-4	Semi-Works Zone	1.68E-04	1.22E-05	5.22E-05	4.94E-03	6.68E-04	2.63E-06	7.40E+00	7.39E+00	1.56E-04	1.18E-04	8.05E-04	4.06E-09	2.25E-04	2.49E-04	1.13E-05	4.95E-08	0.00E+00	5.08E-04	4.80E-04	3.65E-01
43	216-C-5	Semi-Works Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44	216-C-6	Semi-Works Zone	1.25E+01	3.29E-05	1.41E-04	1.34E-02	1.88E-03	1.86E-05	2.07E+01	2.07E+01	5.70E-04	3.17E-04	2.84E-03	1.09E-08	6.04E-04	6.71E-04	3.05E-05	1.33E-07	1.33E-07	3.88E-01	3.67E-01	1.01E+00
45	216-C-7	Semi-Works Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46	216-C-8	WTP-ETF-A-C Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.53E-04	2.53E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.99E-05	2.83E-05	0.00E+00
47	216-C-9	Semi-Works Zone	8.28E-03	2.44E-04	5.02E-06	4.77E-04	3.07E-04	3.16E-06	1.31E+00	1.31E+00	1.89E-04	1.52E-04	1.01E-03	2.88E-10	1.97E-04	4.69E-05	1.32E-05	5.97E-07	1.06E-07	2.67E-01	2.52E-01	4.16E-02
48	216-C-10	Semi-Works Zone	6.54E-05	2.83E-05	5.83E-04	5.50E-02	4.13E-03	3.50E-06	1.96E+01	1.96E+01	2.08E-04	1.69E-04	1.09E-03	8.11E-09	2.09E-04	9.14E-04	1.45E-05	6.55E-08	3.47E-06	4.40E+00	4.15E+00	3.94E+00
49	216-N-1	200-E Ponds Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50	216-N-2	200-E Ponds Zone	4.27E-04	8.26E-06	2.44E-06	2.31E-04	9.56E-06	3.99E-07	4.74E-02	4.74E-02	1.94E-05	1.72E-05	1.76E-04	1.49E-14	1.28E-05	3.73E-07	1.51E-06	1.76E-07	3.47E-09	3.89E-01	3.68E-01	1.74E-02
51	216-N-3	200-E Ponds Zone	4.27E-04	8.26E-06	2.44E-06	2.31E-04	9.57E-06	3.99E-07	4.74E-02	4.74E-02	1.94E-05	1.72E-05	1.76E-04	1.49E-14	1.28E-05	3.73E-07	1.51E-06	1.76E-07	3.47E-09	3.89E-01	3.68E-01	1.74E-02
52	216-N-4	200-E Ponds Zone	4.28E-04	8.27E-06	2.44E-06	2.31E-04	9.58E-06	3.99E-07	4.75E-02	4.75E-02	1.94E-05	1.72E-05	1.76E-04	1.49E-14	1.28E-05	3.74E-07	1.51E-06	1.76E-07	3.48E-09	3.90E-01	3.68E-01	1.75E-02
53	216-N-5	200-E Ponds Zone	4.27E-04	8.25E-06	2.44E-06	2.31E-04	9.56E-06	3.99E-07	4.74E-02	4.74E-02	1.94E-05	1.72E-05	1.76E-04	1.49E-14	1.28E-05	3.73E-07	1.50E-06	1.76E-07	3.47E-09	3.90E-01	3.68E-01	1.75E-02
54	216-N-6	200-E Ponds Zone	4.28E-04	8.27E-06	2.44E-06	2.31E-04	9.58E-06	3.99E-07	4.75E-02	4.75E-02	1.94E-05	1.72E-05	1.76E-04	1.49E-14	1.28E-05	3.74E-07	1.51E-06	1.76E-07	3.48E-09	3.90E-01	3.68E-01	1.75E-02
55	216-N-7	200-E Ponds Zone	4.27E-04	8.25E-06	2.44E-06	2.31E-04	9.56E-06	3.99E-07	4.74E-02	4.74E-02	1.94E-05	1.72E-05	1.76E-04	1.49E-14	1.28E-05	3.73E-07	1.51E-06	1.76E-07	3.47E-09	3.90E-01	3.68E-01	1.74E-02
56	241-B-101	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
57	241-B-103	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
58	241-B-105	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
59	241-B-107	B Farm Zone	6.94E+00	5.71E-02	3.12E-01	2.99E+01	8.25E-01	8.96E-04	3.68E+01	3.68E+01	5.41E-02	4.45E-02	2.83E-01	5.26E-08	1.33E-01	9.06E-03	3.70E-03	8.23E-03	6.16E-04	1.09E+03	1.03E+03	2.35E+01
60	241-B-110	B Farm Zone	1.20E-01	1.68E-02	6.28E-03	6.02E-01	8.38E-02	1.71E-03	8.67E+00	8.67E+00	1.02E-01	8.14E-02	5.42E-01	1.12E-07	1.19E-01	1.91E-02	7.14E-03	4.09E-04	9.17E-04	6.59E+02	6.22E+02	1.27E+01
61	241-B-111	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
62	241-B-112	B Farm Zone	1.81E-01	2.68E-02	8.40E-03	8.01E-01	1.65E-01	3.22E-03	1.70E+01	1.70E+01	1.92E-01	1.54E-01	1.02E+00	2.72E-07	2.10E-01	4.52E-02	1.34E-02	6.05E-04	1.52E-03	1.13E+03	1.07E+03	3.48E+01
63	241-B-201	B Farm Zone	5.90E-10	1.32E-06	3.45E-07	2.94E-05	6.25E-07	5.89E-08	2.12E-04	2.12E-04	0.00E+00	0.00E+00	1.19E-07	2.80E-15	1.38E-06	1.81E-08	2.12E-07	1.16E-10	3.27E-13	2.43E-04	2.29E-04	4.12E-02
64	241-B-203	B Farm Zone	2.42E-10	4.00E-07	1.05E-07	8.92E-06	1.90E-07	1.79E-08	6.42E-05	6.42E-05	7.23E-12	5.75E-12	3.62E-08	1.30E-12	4.20E-07	5.51E-09	6.44E-08	2.01E-08	1.21E-11	7.39E-05	6.97E-05	1.25E-02
65	241-B-204	B Farm Zone	1.64E-09	5.38E-09	8.41E-10	7.23E-08	1.72E-09	1.36E-10	5.13E-07	5.13E-07	1.90E-10	1.51E-10	1.28E-09	3.41E-11	3.34E-09	3.22E-10	4.94E-10	5.29E-07	3.15E-10	4.73E-06	4.46E-06	9.34E-05
66	241-BX-101	B Farm Zone	4.81E-02	5.21E-03	8.10E-03	7.68E-01	1.16E-01	7.91E-04	1.00E+03	1.00E+03	4.71E-02	3.68E-02	2.48E-01	5.94E-07	5.84E-02	4.09E-02	3.34E-03	9.06E-05	3.26E-05	1.64E+01	1.54E+01	5.49E+01
67	241-BX-102	B Farm Zone	3.85E+00	1.04E-01	2.75E-02	2.35E+00	4.99E-02	4.70E-03	2.36E+03	2.36E+03	1.27E-03	1.15E-03	2.27E+00	4.99E-14	1.11E-01	1.45E-03	1.70E-02	1.01E-03	6.23E-06	4.64E+03	4.38E+03	1.78E+02
68	241-BX-108	B Farm Zone	3.32E-01	3.24E-02	1.36E-02	1.30E+00	2.17E-01	3.70E-03	2.10E+01	2.10E+01	2.20E-01	1.78E-01	1.18E+00	3.31E-07	2.33E-01	5.40E-02	1.54E-02	8.88E-04	1.09E-04	1.31E+02	1.23E+02	4.81E+01
69	241-BX-110	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
70	241-BX-111	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
71	241-BY-103	B Farm Zone	1.17E-01	1.38E-02	6.00E-03	5.75E-01	3.63E-02	9.44E-04	3.76E+00	3.76E+00	5.59E-02	4.50E-02	2.99E-01	5.10E-11	6.99E-02	4.27E-04	3.92E-03	4.24E-04	2.87E-04	2.49E+02	2.35E+02	1.10E+00
72	241-BY-105	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
73	241-BY-106	B Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
74	241-BY-107	B Farm Zone	3.51E-01	4.14E-02	1.80E-02	1.73E+00	1.09E-01	2.83E-03	1.13E+01	1.13E+01	1.68E-01	1.35E-01	8.98E-01	1.53E-10	2.10E-01	1.28E-03	1.18E-02	1.27E-03	8.61E-04	7.47E+02	7.05E+02	3.31E+00
75	241-BY-108	B Farm Zone	1.17E-01	1.38E-02	6.00E-03	5.75E-01	3.63E-02	9.44E-04	3.76E+00	3.76E+00	5.59E-02	4.50E-02	2.99E-01	5.10E-11	6.99E-02	4.27E-04	3.92E-03	4.24E-04	2.87E-04	2.49E+02	2.35E+02	1.10E+00
76	216-BY-201	B Farm Zone	2.59E-01	1.01E-02	1.70E-04	1.49E-02	7.83E-03	4.54E-04	5.58E+00	5.58E+00	1.22E-04	1.08E-04	1.58E-01	1.35E-13	1.36E-02	4.05E-04	1.71E-03	2.03E-04	1.30E-08	1.46E+00	1.38E+00	1.68E+01
77	241-C-101	WTP-ETF-A-C Farm Zone	4.09E-02	7.68E-03	3.18E-03	3.01E-01	4.04E-02	7.16E-04	7.75E+00	7.75E+00	4.27E-02	3.55E-02	2.25E-01	1.21E-08	3.82E-02	5.65E-03	2.96E-03	1.21E-04	2.26E-04	8.52E+02	8.05E+02	2.18E+01
78	241-C-105	WTP-ETF-A-C Farm Zone	4.19E-02	5.00E-03	2.70E-03	2.58E-01	4.57E-02	7.24E-04	8.99E+00	9.00E+00	4.31E-02	3.41E-02	2.26E-01	7.98E-08	5.00E-02	1.38E-02	3.04E-03	8.85E-05	7.25E-04	6.21E+02	5.86E+02	1.01E+01
79	241-C-110	WTP-ETF-A-C Farm Zone	4.28E-02	1.64E-03	4.22E-04	3.82E-02	1.32E-03	7.16E-05	1.63E+01	1.63E+01	1.07E-03	9.65E-04	2.43E-02	6.81E-14	2.18E-03	6.34E-05	2.70E-04	3.11E-05	6.60E-07	7.46E+01	7.04E+01	2.76E+00
80	241-C-111	WTP-ETF-A-C Farm Zone	1.58E+00	1.63E-02	8.30E-02	7.78E+00	2.92E-01	1.69E-04	8.42E+02	8.42E+02	9.71E-03	7.93E-03	5.38E-02	3.48E-07	2.90E-02	3.92E-02	6.95E-04	2.64E-03	1.50E-04	1.95E+02	1.84E+02	1.69E+02
81	241-C-201	WTP-ETF-A-C Farm Zone	6.41E-04	2.78E-04	5.72E-03	5.39E-01	4.05E-02	3.43E-05	1.91E+02	1.92E+02	2.04E-03	1.66E-03	1.07E-02	7.96E-08	2.05E-03	8.96E-03	1.42E-04	6.42E-07	3.40E-05	4.30E+01	4.06E+01	3.86E+01
82	241-C-202	WTP-ETF-A-C Farm Zone	5.24E-04	2.27E-04	4.67E-03	4.41E-01	3.31E-02	2.80E-05	1.56E+02	1.57E+02	1.67E-03	1.35E-03	8.77E-03	6.51E-08	1.68E-03	7.32E-03	1.16E-04	5.24E-07	2.78E-05	3.52E+01	3.32E+01	3.15E+01
83	241-C-203	WTP-ETF-A-C Farm Zone	4.96E-04	2.14E-04	4.42E-03	4.17E-01	3.13E-02	2.65E-05	1.48E+02	1.48E+02	1.58E-03	1.28E-03	8.29E-03	6.15E-08	1.59E-03	6.93E-03	1.10E-04	4.96E-07	2.63E-05	3.32E+01	3.14E+01	2.98E+01
84	241-C-204	WTP-ETF-A-C Farm Zone	4.21E-04	1.82E-04	3.75E-03	3.54E-01	2.66E-02	2.25E-05	1.26E+02	1.26E+02	1.34E-03	1.09E-03	7.04E-03	5.22E-08	1.35E-03	5.88E-03	9.33E-05	4.21E-07	2.23E-05	2.82E+01	2.67E+01	2.53E+01

Num#	Site ID	Eu-152 Mean_Ci	Eu-154 Mean_Ci	Eu-155 Mean_Ci	Ra-226 Mean_Ci	Ra-228 Mean_Ci	Ac-227 Mean_Ci	Pa-231 Mean_Ci	Th-229 Mean_Ci	Th-232 Mean_Ci	U-232 Mean_Ci	U-233 Mean_Ci	U-234 Mean_Ci	U-235 Mean_Ci	U-236 Mean_Ci	U-238 Mean_Ci	Np-237 Mean_Ci	Pu-238 Mean_Ci	Pu-239 Mean_Ci	Pu-240 Mean_Ci	Pu-241 Mean_Ci	Pu-242 Mean_Ci	Am-241 Mean_Ci	Am-243 Mean_Ci	Cm-242 Mean_Ci	Cm-243 Mean_Ci	Cm-244 Mean_Ci	Volume Discharge (ML)
1	216-A-25	1.14E-02	9.09E-01	5.03E-01	2.15E-04	6.87E-08	1.03E-03	1.71E-03	1.17E-06	4.91E-09	1.10E-03	5.85E-04	4.96E+00	2.07E-01	2.50E-01	4.06E+00	1.17E-01	2.49E+00	2.91E+01	8.53E+00	1.55E+02	1.09E-03	2.84E+00	8.27E-04	1.59E-03	2.23E-04	5.67E-03	2.94E+05
2	216-B-2-2E	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
3	216-B-2-2W	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
4	216-B-3	1.70E-03	1.28E-01	6.47E-02	3.60E-05	1.01E-06	1.76E-04	3.61E-04	3.14E-07	1.63E-08	3.51E-04	1.93E-04	1.24E+00	4.89E-02	1.01E-01	9.28E-01	8.66E-02	1.82E+00	1.91E+01	5.20E+00	1.40E+02	6.15E-04	1.19E+01	3.30E-03	6.09E-03	9.13E-04	2.34E-02	2.64E+05
5	216-B-4	1.80E-08	1.36E-06	7.78E-07	3.66E-11	1.76E-16	2.04E-10	4.74E-10	3.44E-14	2.90E-16	2.04E-12	1.66E-13	1.63E-07	7.27E-09	1.86E-09	1.66E-07	3.02E-08	3.66E-08	5.60E-06	5.67E-07	1.05E-06	7.20E-12	1.72E-06	2.38E-10	4.10E-10	4.87E-12	1.14E-10	1.00E-02
6	216-B-5	2.33E-03	2.26E-01	1.83E-01	3.65E-06	1.23E-11	7.36E-05	1.55E-03	5.75E-08	4.81E-10	3.02E-08	2.68E-09	3.46E-03	1.56E-04	2.95E-05	3.52E-03	5.71E-03	1.29E-01	3.72E+01	2.51E+00	2.42E+00	1.13E-05	1.24E-01	5.34E-06	9.38E-06	5.55E-08	1.30E-06	3.21E+01
7	216-B-6	1.08E-05	8.14E-04	4.66E-04	2.19E-08	1.05E-13	1.22E-07	2.84E-07	2.06E-11	1.74E-13	1.22E-09	9.95E-11	9.77E-05	4.36E-06	1.12E-06	9.95E-05	1.81E-05	2.20E-05	3.35E-03	3.40E-04	6.27E-04	4.31E-09	1.03E-03	1.43E-07	2.46E-07	2.91E-09	6.84E-08	6.00E+00
8	216-B-7A%B	8.32E-02	6.52E+00	3.57E+00	4.38E-06	4.88E-08	1.60E-04	3.46E-03	1.94E-07	3.96E-08	2.17E-02	1.29E+00	9.57E-02	3.68E-03	4.11E-03	6.57E-02	1.83E-02	2.15E+00	2.17E+01	6.84E+00	1.25E+02	1.14E-03	5.62E+00	2.50E-03	5.40E-04	1.99E-05	4.70E-04	4.46E+01
9	216-B-8	2.96E-02	2.48E+00	1.70E+00	4.31E-05	1.60E-10	3.69E-04	7.83E-03	3.18E-07	2.67E-09	6.17E-07	5.30E-08	6.28E-02	2.82E-03	5.89E-04	6.39E-02	3.29E-02	5.49E-01	1.26E+02	9.74E+00	1.27E+01	7.42E-05	1.12E+00	1.14E-04	1.98E-04	2.14E-06	5.03E-05	3.53E+01
10	216-B-9	3.38E-03	2.64E-01	1.61E-01	2.72E-06	1.13E-11	2.53E-05	5.45E-04	2.51E-08	2.12E-10	4.47E-08	3.73E-09	4.04E-03	1.81E-04	4.18E-05	4.11E-03	2.73E-03	4.35E-02	8.08E+00	7.16E-01	1.14E+00	7.40E-06	1.33E-01	1.76E-05	3.04E-05	3.53E-07	8.31E-06	3.60E+01
11	216-B-10A	1.80E-05	1.36E-03	7.76E-04	3.65E-08	1.75E-13	2.04E-07	4.73E-07	3.43E-11	2.89E-13	2.36E-08	1.86E-09	1.58E-03	6.99E-05	2.11E-05	1.61E-03	3.02E-05	3.65E-05	5.58E-03	5.66E-04	1.04E-03	7.18E-09	1.71E-03	2.37E-07	4.09E-07	4.85E-09	1.14E-07	9.98E+00
12	216-B-10B	3.57E-10	2.89E-08	1.55E-08	5.34E-15	5.32E-12	8.80E-14	1.28E-11	1.09E-14	4.09E-14	1.30E-12	7.99E-11	1.04E-11	4.05E-13	4.24E-13	8.77E-12	1.27E-10	2.13E-10	4.27E-09	1.05E-09	1.32E-08	8.43E-14	3.69E-09	1.04E-12	9.19E-12	2.68E-13	6.82E-12	2.80E-02
13	216-B-11A&B	1.68E-05	1.29E-03	7.49E-04	5.38E-08	2.45E-13	2.40E-07	7.27E-07	4.21E-11	3.54E-13	2.13E-10	1.66E-11	1.38E-05	6.11E-07	1.83E-07	1.41E-05	3.04E-05	5.39E-05	6.61E-03	7.87E-04	1.65E-03	1.20E-08	1.58E-03	2.12E-07	3.67E-07	4.31E-09	1.02E-07	2.96E+01
14	216-B-12	5.73E-04	4.37E-02	2.54E-02	1.96E-06	1.09E-09	8.67E-06	2.52E-05	2.99E-09	2.93E-11	7.54E-05	6.68E-06	4.94E+00	2.19E-01	6.71E-02	5.05E+00	9.93E-04	1.60E-03	1.92E-01	2.29E-02	4.88E-02	3.56E-07	5.36E-02	7.24E-06	1.24E-05	1.48E-07	3.47E-06	1.43E+02
15	216-B-13	9.45E-09	7.13E-07	4.08E-07	1.93E-11	9.35E-17	1.08E-10	2.50E-10	1.92E-14	1.53E-16	1.44E-12	6.32E-13	8.77E-08	3.91E-09	1.05E-09	8.91E-08	1.97E-08	6.50E-08	3.67E-06	4.92E-07	2.96E-06	2.48E-11	9.01E-07	1.25E-10	2.15E-10	2.55E-12	6.00E-11	2.10E-02
16	216-B-35	1.23E-02	8.60E-01	3.91E-01	9.28E-06	6.03E-11	2.81E-05	6.14E-04	4.17E-08	3.52E-10	2.15E-07	1.62E-08	1.18E-02	5.22E-04	1.76E-04	1.21E-02	4.93E-03	4.37E-03	4.28E-01	6.10E-02	1.40E-01	1.06E-06	5.51E-01	6.34E-05	1.09E-04	1.33E-06	3.11E-05	1.06E+00
17	216-B-36	2.25E-02	1.57E+00	7.15E-01	1.70E-05	1.10E-10	5.14E-05	1.12E-03	7.64E-08	6.45E-10	3.93E-07	2.97E-08	2.17E-02	9.56E-04	3.22E-04	2.22E-02	9.02E-03	8.00E-03	7.85E-01	1.11E-01	2.56E-01	1.93E-06	1.01E+00	1.16E-04	2.00E-04	2.43E-06	5.70E-05	1.94E+00
18	216-B-37	5.02E-02	3.51E+00	1.59E+00	3.78E-05	2.46E-10	1.15E-04	2.50E-03	1.70E-07	1.44E-09	8.75E-07	6.61E-08	4.83E-02	2.13E-03	7.16E-04	4.93E-02	2.01E-02	1.78E-02	1.75E+00	2.47E-01	5.70E-01	4.32E-06	2.24E+00	2.58E-04	4.45E-04	5.40E-06	1.27E-04	4.32E+00
19	216-B-38	1.66E-02	1.16E+00	5.27E-01	1.25E-05	8.13E-11	3.79E-05	8.29E-04	5.63E-08	4.75E-10	2.90E-07	2.19E-08	1.60E-02	7.04E-04	2.37E-04	1.63E-02	6.65E-03	5.91E-03	5.79E-01	8.19E-02	1.89E-01	1.44E-06	7.43E-01	8.54E-05	1.47E-04	1.79E-06	4.20E-05	1.43E+00
20	216-B-39	1.79E-02	1.25E+00	5.68E-01	1.35E-05	8.75E-11	4.08E-05	8.92E-04	6.07E-08	5.12E-10	3.12E-07	2.36E-08	1.72E-02	7.58E-04	2.55E-04	1.76E-02	7.16E-03	6.32E-03	6.22E-01	8.82E-02	2.04E-01	1.54E-06	8.00E-01	9.21E-05	1.58E-04	1.93E-06	4.52E-05	1.54E+00
21	216-B-40	1.90E-02	1.33E+00	6.05E-01	1.44E-05	9.32E-11	4.35E-05	9.50E-04	6.46E-08	5.45E-10	3.32E-07	2.51E-08	1.83E-02	8.08E-04	2.72E-04	1.87E-02	7.62E-03	6.76E-03	6.63E-01	9.37E-02	2.18E-01	1.64E-06	8.52E-01	9.80E-05	1.69E-04	2.05E-06	4.81E-05	1.64E+00
22	216-B-41	1.67E-02	1.17E+00	5.31E-01	1.26E-05	8.19E-11	3.82E-05	8.34E-04	5.67E-08	4.78E-10	2.92E-07	2.20E-08	1.61E-02	7.09E-04	2.39E-04	1.64E-02	6.70E-03	5.91E-03	5.82E-01	8.23E-02	1.90E-01	1.45E-06	7.48E-01	8.61E-05	1.48E-04	1.80E-06	4.23E-05	1.44E+00
23	216-B-42	2.22E-02	1.68E+00	9.86E-01	7.81E-05	3.65E-10	3.78E-04	3.25E-06	1.74E-08	1.48E-10	1.90E-07	1.55E-08	1.52E-02	6.80E-04	1.74E-04	1.55E-02	4.52E-02	8.52E-03	1.19E+00	1.29E-01	2.51E-01	1.76E-06	2.50E+00	3.52E-04	6.07E-04	7.18E-06	1.69E-04	1.50E+00
24	216-B-43	3.13E-02	2.38E+00	1.39E+00	1.10E-04	5.16E-10	5.34E-04	4.60E-06	2.46E-08	2.08E-10	2.69E-07	2.19E-08	2.15E-02	9.61E-04	2.46E-04	2.19E-02	6.39E-02	1.20E-02	1.69E+00	1.82E-01	3.55E-01	2.49E-06	3.53E+00	5.00E-04	8.61E-04	1.02E-05	2.40E-04	2.12E+00
25	216-B-44	8.27E-02	6.28E+00	3.68E+00	2.91E-04	1.36E-09	1.41E-03	1.21E-05	6.51E-08	5.51E-10	7.09E-07	5.78E-08	5.69E-02	2.54E-03	6.50E-04	5.79E-02	1.69E-01	3.18E-02	4.46E+00	4.80E-01	9.36E-01	6.58E-06	9.33E+00	1.32E-03	2.27E-03	2.69E-05	6.32E-04	5.60E+00
26	216-B-45	7.26E-02	5.52E+00	3.23E+00	2.56E-04	1.20E-09	1.24E-03	1.07E-05	5.71E-08	4.84E-10	6.72E-07	5.47E-08	5.39E-02	2.40E-03	6.16E-04	5.49E-02	1.48E-01	2.85E-02	4.00E+00	4.31E-01	8.40E-01	5.90E-06	8.19E+00	1.16E-03	2.00E-03	2.36E-05	5.56E-04	4.92E+00
27	216-B-46	9.90E-02	7.51E+00	4.40E+00	3.49E-04	1.63E-09	1.69E-03	1.45E-05	7.78E-08	6.59E-10	8.48E-07	6.91E-08	6.80E-02	3.04E-03	7.78E-04	6.93E-02	2.02E-01	3.81E-02	5.33E+00	5.75E-01	1.12E+00	7.87E-06	1.12E+01	1.58E-03	2.71E-03	3.22E-05	7.57E-04	6.70E+00
28	216-B-47	5.43E-02	4.13E+00	2.42E+00	1.91E-04	8.96E-10	9.28E-04	7.98E-06	4.28E-08	3.62E-10	4.66E-07	3.80E-08	3.73E-02	1.67E-03	4.27E-04	3.81E-02	1.11E-01	2.09E-02	2.93E+00	3.16E-01	6.15E-01	4.32E-06	6.13E+00	8.64E-04	1.49E-03	1.77E-05	4.15E-04	3.68E+00
29	216-B-48	6.04E-02	4.59E+00	2.69E+00	2.13E-04	9.95E-10	1.03E-03	8.87E-06	4.75E-08	4.02E-10	5.18E-07	4.22E-08	4.15E-02	1.85E-03	4.75E-04	4.23E-02	1.23E-01	2.32E-02	3.25E+00	3.51E-01	6.84E-01	4.80E-06	6.81E+00	9.61E-04	1.66E-03	1.96E-05	4.63E-04	4.09E+00
30	216-B-49	9.89E-02	7.52E+00	4.40E+00	3.48E-04	1.63E-09	1.69E-03	1.45E-05	7.79E-08	6.59E-10	8.48E-07	6.92E-08	6.80E-02	3.04E-03	7.78E-04	6.93E-02	2.02E-01	3.80E-02	5.33E+00	5.75E-01	1.12E+00	7.87E-06	1.12E+01	1.58E-03	2.71E-03	3.22E-05	7.58E-04	6.70E+00
31	216-B-50	4.78E-05	3.60E-03	1.73E-03	2.11E-08	2.49E-05	1.22E-07	7.84E-05	1.95E-08	7.43E-08	1.06E-06	6.44E-05	1.15E-05	4.53E-07	2.66E-07	9.60E-06	2.61E-04	1.09E-03	1.77E-02	4.02E-03	3.04E-02	2.33E-07	2.24E-03	8.97E-07	7.36E-06	2.57E-07	6.43E-06	5.47E+01
32	216-B-51	1.48E-05	1.12E-03	6.57E-04	5.20E-08	2.43E-13	2.52E-07	2.17E-09	1.16E-11	9.84E-14	1.27E-10	1.03E-11	1.02E-05	4.53E-07	1.16E-07	1.03E-05	3.01E-05	5.68E-06	7.96E-04	8.58E-05	1.67E-04	1.17E-09	1.67E-03	2.35E-07	4.05E-07	4.80E-09	1.13E-07	1.00E-03
33	216-B-55	9.93E-06	7.39E-04	3.41E-04	1.89E-10	8.76E-09	1.12E-09	3.06E-09	4.86E-11	1.35E-10	2.32E-09	1.43E-07	9.99E-08	4.17E-09	2.72E-09	9.36E-08	4.21E-06	1.97E-06	4.57E-05	1.06E-05	8.93E-05	7.36E-10	6.43E-05	3.69E-08	2.27E-07	6.97E-09	1.74E-07	1.20E+03
34	216-B-57	1.43E-04	1.08E-02	5.18E-03	6.24E-08	7.46E-05	3.63E-07	2.36E-04	5.84E-08	2.23E-07	3.19E-06	1.93E-04	2.38E-05	9.26E-07	5.66E-07	1.98E-05	6.30E-04	1.77E-03	2.97E-02	6.78E-03	5.24E-02	4.05E-07	6.73E-03	2.69E-06	2.21E-05	7.71E-07	1.91E-05	8.43E+01
35	216-B-59	3.95E-09	2.95E-07	1.36E-07	7.54E-14	3.49E-12	4.46E-13	1.22E-12	1.94E-14	5.39E-14	9.25E-13	5.72E-11	3.98E-11	1.66E-12	1.08E-12	3.73E-11	1.68E-09	7.85E-10	1.82E-08	4.23E-09	3.56E-08	2.94E-13	2.56E-08	1.47E-11	9.07E-11	2.78E-12	6.93E-11	4.77E-01
36	216-B-60	4.70E-08	3.34E-06	1.24E-06	1.64E-13	1.64E-10	4.28E-10	6.69E-10	9.95E-11	1.27E-10	7.29E-05	4.33E-03	3.17E-04	1.21E-05	1.37E-05	2.12E-04	1.74E-09	7.07E-03	6.25E-02	2.20E-02	4.17E-01	3.77E-06	2.93E-06	2.80E-09	4.72E-09	5.09E-10	1.25E-08	1.89E-02
37	216-B-62	3.47E-02	2.72E+00	1.40E+00	3.29E-07	1.97E-05	2.21E-06	4.63E-06	1.30E-07	3.30E-07	2.17E-06	1.34E-04	3.49E-04	1.47E-05	8.36E-06	3.45E-04	9.95E-03	5.59E-03	1.68E-01	3.73E-02	2.35E-01	1.83E-06	2.24E-01	1.11E-04	5.73E-04	2.70E-05	6.39E-04	2.80E+02
38	216-B-63	7.66E-07	5.70E-05	2.63E-05	6.41E-08	6.77E-10	3.13E-07	5.73E-07	3.41E-10	1.24E-11	1.39E-06	2.59E-07	5.83E-02	2.57E-03	8.87E-04	5.91E-02	1.04E-04	1.01E-03	1.59E-02	3.59E-03	2.64E-02	2.00E-07	4.38E-02	2.07E-05	3.61E-05	4.58E-06	1.15E-04	7.98E+03
39	216-C-1	1.99E-03	1.56E-01	8.25E-02	3.64E-10	1.11E-09	4.56E-09	6.96E-09	6.87E-10	8.76E-10	5.09E-04	2.94E-02	2.97E-01	1.28E-02	5.84E-03	3.03E-01	1.16E-05	4.89E-02	4.46E-01	1.53E-01	2.87E+00	2.57E-05	1.42E-01	7.09E-05	2.83E-05	1.52E-06	3.61E-05	2.34E+01
40	216-C-2	0.00E+00	0.00E+00	0.00E+00	2.19E-11	3.41E-16	1.03E-10	1.69E-10	1.88E-13	3.70E-16	1.05E-10	9.17E-11	4.73E-07	1.98E-08	2.35E-08	3.92E-07	6.72E-07	1.14E-05	1.46E-04	4.13E-05	6.87E-04	5.11E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.15E+00
41	216-C-3	3.97E-04	3.12E-02	1.65E-02	1.49E-09	8.49E-15	6.42E-09	9.51E-09	3.08E-11	9.09E-15	2.44E-08	1.55E-08	1.48E-03	6.57E-05	2.07E-05	1.52E-03	3.25E-06	2.20E-05	7.28E-04	1.55E-04	8.77E-04	6.85E-09	2.84E-02	1.42E-05	1.52E-06	8.14E-08	1.92E-06	5.00E+00
42	216-C-4	1.14E-04	8.59E-03	3.86E-03	1.49E-10	1.99E-15	7.18E-10	1.17E-09	7.73E-13	2.08E-15	1.40E-10	2.88E-10	1.13E-06	4.76E-08	3.37E-08	1.06E-06	2.51E-06	3.34E-05	5.97E-04	1.53E-04	1.72E-03	1.48E-08	7.68E-03	5.58E-06	8.45E-07	7.88E-08	1.93E-06	1.70E-01
43	216-C-5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-07	1.97E-07	6.75E-03	3.00E-04	9.51E-05	6.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.89E-02
44	216-C-6	3.15E-04	2.41E-02	1.04E-02	7.39E-08	6.39E-13	3.06E-07	4.48E-07	4.01E-10	6.56E-13	6.48E-08	1.84E-07	8.47E-04	3.21E-05	2.45E-05	5.92E-04	1.36E-04	1.36E-03	2.02E-02	4.76E-03	3.76E-02	2.90E-07	2.10E-02	1.52E-05	2.63E-06	2.35E-07	5.74E-06	5.31E-01
45	216-C-7	0.00E+00	0.00E+00	0.00E+00	6.96E-13	6.24E-18	3.21E-12	4.87E-12	7.00E-15	6.51E-18	1.85E-12	3.33E-12	1.32E-08	5.61E-10	4.19E-10	1.22E-08	1.02E-11	1.02E-10	1.84E-09	4.68E-10	5.15E-09	4.40E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.99E-02
46	216-C-8	0.00E+00	0.00E+00	0.00E+00	6.06E-14	4.95E-19	2.81E-13	4.28E-13	3.67E-16	5.15E-19	9.94E-14	1.81E-13	1.27E-09	5.33E-11	3.27E-11	1.24E-09	2.38E-09	2.23E-08	4.63E-07	1.14E-07	1.01E-06	8.26E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-02
47	216-C-9	7.76E-06	5.78E-04	2.67E-04	1.17E-09	6.85E-09	5.27E-09	8.87E-09	4.72E-11	1.06E-10	3.18E-09	1.16E-07	1.71E-05	7.00E-07	4.57E-07	1.51E-05	1.93E-05	8.80E-05	2.43E-03	5.40E-04	3.74E-03	2.95E-08	2.99E-04	1.63E-07	4.11E-07	1.79E-08	4.16E-07	1.04E+03
48	216-C-10	7.93E-04	6.24E-02	3.30E-02	1.51E-10	1.08E-15	6.84E-10	1.01E-09	1.72E-12	1.12E-15	1.61E-10	6.56E-10	2.18E-06	9.22E-08	5.23E-08	2.18E-06	4.84E-06	4.09E-05	1.24E-03	2.68E-04	1.67E-03	1.29E-08	5.67E-02	2.83E-05	3.04E-06	1.63E-07	3.84E-06	8.97E-01
49	216-N-1	0.00E+00	0.00E+00	0.00E+00	9.98E-10	4.21E-15	4.71E-09	9.23E-09	5.95E-13	5.02E-15	2.13E-09	1.77E-10	1.89E-04	8.46E-06	1.99E-06	1.93E-04	4.78E-08	1.62E-07	2.90E-05	2.63E-06	4.31E-06	2.83E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.47E+02
50	216-N-2	6.48E-07	4.88E-05	2.80E-05	1.32E-09	6.35E-15	7.38E-09	1.71E-08	1.24E-12	1.05E-14	8.58E-11	7.08E-12	7.30E-06	3.26E-07	7.93E-08	7.43E-06	1.09E-06	1.32E-06	2.01E-04	2.04E-05	3.77E-05	2.59E-10	6.18E-05	8.55E-09	1.47E-08	1.74E-10	4.10E-09	7.57E+00
51	216-N-3	6.47E-07	4.88E-05	2.80E-05	1.32E-09	6.36E-15	7.38E-09	1.71E-08	1.24E-12	1.05E-14	9.52E-11	7.68E-12	7.29E-06	3.25E-07	8.65E-08	7.44E-06	1.09E-06	1.32E-06	2.01E-04	2.04E-05	3.76E-05	2.59E-10	6.18E-05	8.56E-09	1.47E-08	1.75E-10	4.11E-09	7.57E+00
52	216-N-4	6.49E-07	4.89E-05	2.80E-05	2.29E-09	1.07E-14	1.19E-08	2.61E-08	1.86E-12	1.57E-14	2.35E-09	1.93E-10	1.95E-04	8.70E-06	2.17E-06	1.98E-04	1.14E-06	1.50E-06	2.30E-04	2.32E-05	4.27E-05	2.94E-10	6.18E-05	8.58E-09	1.48E-08	1.75E-10	4.11E-09	9.47E+02
53	216-N-5	6.47E-07	4.88E-05	2.79E-05	1.32E-09	6.36E-15	7.36E-09	1.71E-08	1.24E-12	1.05E-14	9.52E-11	7.68E-12	7.28E-06	3.25E-07	8.66E-08	7.42E-06	1.09E-06	1.32E-06	2.01E-04	2.04E-05	3.76E-05	2.59E-10	6.18E-05	8.54E-09	1.47E-08	1.75E-10	4.11E-09	7.57E+00
54	216-N-6	6.48E-07	4.89E-05	2.80E-05	2.31E-09	1.05E-14	1.21E-08	2.63E-08	1.83E-12	1.55E-14	2.20E-09	1.83E-10	1.95E-04	8.73E-06	2.05E-06	1.99E-04	1.14E-06	1.48E-06	2.30E-04	2.30E-05	4.20E-05	2.87E-10	6.18E-05	8.57E-09	1.48E-08	1.75E-10	4.11E-09	9.47E+02
55	216-N-7	6.47E-07	4.88E-05	2.80E-05	1.32E-09	6.36E-15	7.38E-09	1.71E-08	1.24E-12	1.05E-14	9.51E-11	7.69E-12	7.30E-06	3.25E-07	8.66E-08	7.44E-06	1.09E-06	1.32E-06	2.01E-04	2.04E-05	3.76E-05	2.59E-10	6.18E-05	8.56E-09	1.47E-08	1.74E-10	4.11E-09	7.57E+00
56	241-B-101	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
57	241-B-103	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
58	241-B-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
59	241-B-107	3.57E-03	2.68E-01	1.27E-01	2.54E-07	5.81E-04	1.26E-05	6.11E-05	1.60E-06	7.28E-06	4.52E-05	2.71E-03	5.27E-04	2.11E-05	1.24E-05	4.92E-04	1.41E-03	5.37E-03	2.40E-01	5.34E-02	3.43E-01	2.42E-06	2.63E-01	1.57E-05	1.14E-04	2.68E-06	7.17E-05	5.30E-02
60	241-B-110	2.84E-03	2.14E-01	1.01E-01	1.13E-07	7.60E-05	6.38E-07	2.36E-04	6.62E-08	2.44E-07	3.56E-06	2.16E-04	4.16E-05	1.69E-06	1.23E-06	3.67E-05	1.52E-03	9.03E-04	1.76E-02	4.42E-03	4.65E-02	3.91E-07	2.35E-02	1.31E-05	6.98E-05	2.73E-06	6.71E-05	3.79E-02
61	241-B-111	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
62	241-B-112	6.88E-03	5.20E-01	2.49E-01	1.65E-07	3.97E-05	9.35E-07	1.12E-04	5.40E-08	1.79E-07	2.75E-06	1.68E-04	7.76E-05	3.22E-06	2.12E-06	7.23E-05	3.11E-03	1.57E-03	3.53E-02	8.36E-03	7.37E-02	6.09E-07	4.68E-02	2.54E-05	1.51E-04	5.27E-06	1.30E-04	7.57E-03
63	241-B-201	5.11E-07	4.95E-05	4.01E-05	4.34E-10	1.46E-15	1.84E-08	3.87E-07	1.44E-11	1.20E-13	1.66E-12	2.67E-12	4.15E-08	1.81E-09	6.75E-10	4.14E-08	1.43E-06	1.09E-07	3.00E-05	2.04E-06	2.21E-06	1.12E-11	3.10E-05	1.34E-09	2.34E-09	1.39E-11	3.25E-10	4.54E-03
64	241-B-203	1.55E-07	1.50E-05	1.22E-05	1.31E-10	6.95E-15	5.58E-09	1.17E-07	4.36E-12	3.65E-14	1.51E-13	2.65E-13	8.03E-09	3.59E-10	8.81E-11	8.12E-09	4.33E-07	3.17E-08	9.06E-06	6.13E-07	6.07E-07	2.89E-12	9.38E-06	4.06E-10	7.11E-10	4.21E-12	9.86E-11	1.14E-03
65	241-B-204	1.17E-09	1.13E-07	9.14E-08	1.45E-12	1.71E-13	4.38E-11	8.81E-10	3.58E-14	1.59E-15	8.19E-13	3.98E-12	1.00E-08	4.18E-10	2.56E-10	9.78E-09	3.56E-09	3.27E-09	1.31E-07	2.01E-08	1.43E-07	1.14E-12	7.03E-08	3.06E-12	5.61E-12	4.01E-14	9.57E-13	1.51E-03
66	241-BX-101	1.67E-02	1.25E+00	5.60E-01	4.09E-08	1.48E-06	2.29E-07	7.53E-07	6.61E-09	2.08E-08	4.20E-07	2.44E-05	1.62E-04	6.87E-06	4.89E-06	1.52E-04	7.82E-04	4.79E-03	8.55E-02	2.18E-02	2.44E-01	2.10E-06	1.05E+00	7.63E-04	1.38E-04	1.15E-05	2.80E-04	1.51E-02
67	241-BX-102	2.21E-03	2.14E-01	1.73E-01	2.72E-05	9.13E-11	1.41E-04	1.37E-06	5.53E-09	4.63E-11	2.88E-05	2.55E-06	3.30E+00	1.49E-01	2.81E-02	3.35E+00	1.28E-02	4.62E-03	1.33E+00	9.01E-02	8.72E-02	4.07E-07	2.78E-01	1.20E-05	2.10E-05	1.24E-07	2.92E-06	3.47E-01
68	241-BX-108	8.93E-03	6.65E-01	3.07E-01	1.80E-07	2.79E-05	1.39E-06	1.48E-05	9.25E-08	3.42E-07	3.55E-06	2.17E-04	1.02E-04	4.25E-06	2.74E-06	9.57E-05	3.84E-03	1.89E-03	4.65E-02	1.08E-02	8.80E-02	7.16E-07	6.08E-02	3.12E-05	2.07E-04	6.31E-06	1.57E-04	9.46E-03
69	241-BX-110	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
70	241-BX-111	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
71	241-BY-103	2.17E-04	1.64E-02	7.85E-03	9.39E-08	1.13E-04	5.45E-07	3.57E-04	8.85E-08	3.38E-07	4.83E-06	2.92E-04	1.91E-05	7.10E-07	4.86E-07	1.56E-05	7.10E-04	3.07E-04	7.63E-03	1.85E-03	1.76E-02	1.43E-07	1.02E-02	4.07E-06	3.34E-05	1.17E-06	2.91E-05	1.51E-03
72	241-BY-105	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
73	241-BY-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	NA
74	241-BY-107	6.51E-04	4.91E-02	2.35E-02	2.82E-07	3.39E-04	1.64E-06	1.07E-03	2.65E-07	1.01E-06	1.45E-05	8.77E-04	5.72E-05	2.13E-06	1.46E-06	4.69E-05	2.13E-03	9.22E-04	2.29E-02	5.55E-03	5.27E-02	4.28E-07	3.06E-02	1.22E-05	1.00E-04	3.51E-06	8.73E-05	4.54E-03
75	241-BY-108	2.17E-04	1.64E-02	7.84E-03	9.39E-08	1.13E-04	5.46E-07	3.57E-04	8.84E-08	3.38E-07	4.83E-06	2.92E-04	1.91E-05	7.09E-07	4.86E-07	1.56E-05	7.10E-04	3.07E-04	7.63E-03	1.85E-03	1.76E-02	1.43E-07	1.02E-02	4.07E-06	3.34E-05	1.17E-06	2.91E-05	1.51E-03
76	216-BY-201	6.14E-04	4.66E-02	2.74E-02	2.17E-06	1.01E-11	1.05E-05	9.02E-08	4.83E-10	4.09E-12	5.27E-09	4.29E-10	4.23E-04	1.89E-05	4.84E-06	4.31E-04	1.25E-03	2.36E-04	3.31E-02	3.57E-03	6.97E-03	4.88E-08	6.94E-02	9.79E-06	1.69E-05	2.00E-07	4.70E-06	3.57E-02
77	241-C-101	3.26E-03	2.43E-01	1.11E-01	2.91E-08	3.02E-06	1.90E-07	4.91E-07	9.02E-09	3.81E-08	3.30E-07	2.00E-05	3.80E-05	1.62E-06	8.46E-07	3.86E-05	1.22E-03	4.81E-04	1.90E-02	3.87E-03	1.81E-02	1.30E-07	2.10E-02	9.26E-06	1.10E-04	2.16E-06	5.71E-05	3.79E-03
78	241-C-105	2.41E-03	1.80E-01	8.14E-02	3.50E-08	1.73E-06	2.46E-07	1.41E-06	1.75E-08	3.51E-08	1.87E-06	1.13E-04	3.77E-05	1.57E-06	1.27E-06	3.29E-05	7.84E-04	9.98E-04	1.60E-02	4.25E-03	5.23E-02	4.53E-07	1.88E-02	1.23E-05	4.41E-05	1.78E-06	4.40E-05	3.79E-03
79	241-C-110	9.62E-05	7.36E-03	4.36E-03	3.47E-07	1.60E-12	1.65E-06	1.03E-06	1.12E-10	9.42E-13	9.20E-10	7.57E-11	7.69E-05	3.44E-06	8.46E-07	7.83E-05	1.95E-04	1.57E-04	2.50E-02	2.46E-03	4.41E-03	3.00E-08	1.07E-02	1.50E-06	2.58E-06	3.06E-08	7.19E-07	7.57E-03
80	241-C-111	3.40E-02	2.67E+00	1.41E+00	7.73E-08	4.22E-13	3.65E-07	4.58E-07	1.14E-10	3.89E-13	1.11E-08	2.76E-08	1.98E-04	8.44E-06	4.44E-06	2.01E-04	2.51E-04	2.52E-03	1.00E-01	2.11E-02	1.11E-01	8.29E-07	2.49E+00	1.21E-03	1.32E-04	6.98E-06	1.65E-04	2.08E-02
81	241-C-201	7.78E-03	6.11E-01	3.24E-01	1.42E-09	1.01E-14	6.46E-09	9.52E-09	1.65E-11	1.05E-14	1.49E-09	6.27E-09	2.03E-05	8.56E-07	4.84E-07	2.03E-05	4.53E-05	3.82E-04	1.17E-02	2.53E-03	1.55E-02	1.19E-07	5.56E-01	2.78E-04	2.98E-05	1.59E-06	3.76E-05	2.08E-03
82	241-C-202	6.36E-03	4.99E-01	2.64E-01	1.16E-09	8.28E-15	5.28E-09	7.78E-09	1.35E-11	8.58E-15	1.21E-09	5.12E-09	1.66E-05	7.00E-07	3.96E-07	1.66E-05	3.71E-05	3.12E-04	9.56E-03	2.06E-03	1.26E-02	9.70E-08	4.55E-01	2.27E-04	2.43E-05	1.30E-06	3.07E-05	1.70E-03
83	241-C-203	6.01E-03	4.72E-01	2.50E-01	1.10E-09	7.83E-15	4.99E-09	7.36E-09	1.28E-11	8.11E-15	1.15E-09	4.84E-09	1.57E-05	6.62E-07	3.74E-07	1.57E-05	3.50E-05	2.95E-04	9.04E-03	1.95E-03	1.19E-02	9.18E-08	4.30E-01	2.15E-04	2.30E-05	1.23E-06	2.91E-05	1.51E-03
84	241-C-204	5.10E-03	4.01E-01	2.12E-01	9.34E-10	6.65E-15	4.24E-09	6.25E-09	1.08E-11	6.88E-15	9.75E-10	4.11E-09	1.33E-05	5.62E-07	3.18E-07	1.33E-05	2.98E-05	2.50E-04	7.68E-03	1.66E-03	1.01E-02	7.79E-08	3.65E-01	1.82E-04	1.95E-05	1.05E-06	2.47E-05	1.32E-03

Table 4-3. Mean Average Liquid Volume Discharged and Contaminant Activity Released for Liquid Waste Release Sites Overlying the 200-BP-5 OU

			H-3	C-14	Ni-59	Ni-63	Co-60	Se-79	Sr-90	Y-90	Zr-93	Nb-93m	Tc-99	Ru-106	Cd-113m	Sb-125	Sn-126	I-129	Cs-134	Cs-137	Ba-137m	Sm-151
Num#	Site ID	Operable_Unit_Name	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci
85	200-E-4	Unassigned 200 Area	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
86	200-E-25	Unassigned 200 Area	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E-03	1.87E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.21E-04	2.09E-04	0.00E+00
87	200-E-28	Unassigned 200 Area	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E-02	1.48E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-03	1.66E-03	0.00E+00
88	200-E-41	Unassigned 200 Area	6.49E-08	1.78E-09	4.63E-10	4.39E-08	8.11E-09	1.27E-10	6.87E-06	6.87E-06	6.94E-09	5.82E-09	4.76E-08	6.32E-15	6.17E-09	1.08E-09	5.06E-10	3.85E-11	2.82E-12	5.89E-05	5.56E-05	3.44E-06
89	200-E-55	Unassigned 200 Area	4.08E-05	7.88E-07	2.33E-07	2.21E-05	9.12E-07	3.80E-08	9.51E-03	9.51E-03	1.85E-06	1.64E-06	1.68E-05	1.42E-15	1.22E-06	3.56E-08	1.44E-07	1.68E-08	3.31E-10	3.78E-02	3.57E-02	1.67E-03
90	200-E-56	Unassigned 200 Area	0.024715	0.010682	0.220336	20.7991	1.56	0.001319	7378.64	7373.84	0.078669	0.063883	0.413385	3.06E-06	0.079192	0.34542	0.0054763	2.47E-05	0.0013084	1659.12	1565.12	1486.63
91	200-E-57	Unassigned 200 Area	3.71E-02	1.60E-02	3.30E-01	3.12E+01	2.34E+00	1.98E-03	1.11E+04	1.11E+04	1.18E-01	9.58E-02	6.21E-01	4.61E-06	1.19E-01	5.18E-01	8.22E-03	3.71E-05	1.97E-03	2.49E+03	2.35E+03	2.23E+03
92	200-E-60	Unassigned 200 Area	9.49E-09	2.17E-10	3.47E-10	3.33E-08	1.75E-09	1.84E-11	1.93E-07	1.93E-07	1.10E-09	8.74E-10	5.83E-09	1.97E-10	1.19E-09	1.63E-09	7.66E-11	3.06E-06	1.82E-09	2.41E-05	2.28E-05	3.59E-07
93	200-E-89	Unassigned 200 Area 1	1.47E-06	3.35E-08	9.31E-09	8.82E-07	9.70E-08	2.02E-09	1.60E-04	1.60E-04	1.05E-07	9.02E-08	8.08E-07	6.08E-14	8.48E-08	1.11E-08	7.86E-09	7.20E-10	3.40E-11	1.34E-03	1.27E-03	6.78E-05
94	200-E-91	Unassigned 200 Area 1	1.47E-06	3.35E-08	9.31E-09	8.82E-07	9.70E-08	2.01E-09	1.60E-04	1.60E-04	1.05E-07	9.02E-08	8.08E-07	6.08E-14	8.48E-08	1.11E-08	7.86E-09	7.20E-10	3.40E-11	1.34E-03	1.27E-03	6.78E-05
95	200-E-92	Unassigned 200 Area 1	1.47E-06	3.35E-08	9.32E-09	8.82E-07	9.70E-08	2.01E-09	1.60E-04	1.60E-04	1.05E-07	9.01E-08	8.09E-07	6.08E-14	8.48E-08	1.11E-08	7.86E-09	7.20E-10	3.40E-11	1.34E-03	1.27E-03	6.78E-05
96	200-E-93	Unassigned 200 Area 2	1.47E-06	3.35E-08	9.32E-09	8.82E-07	9.70E-08	2.02E-09	1.60E-04	1.60E-04	1.05E-07	9.01E-08	8.09E-07	6.08E-14	8.49E-08	1.11E-08	7.86E-09	7.20E-10	3.40E-11	1.34E-03	1.27E-03	6.78E-05
97	200-E-94	Unassigned 200 Area 2	1.47E-06	3.35E-08	9.32E-09	8.82E-07	9.70E-08	2.02E-09	1.60E-04	1.60E-04	1.05E-07	9.01E-08	8.09E-07	6.08E-14	8.48E-08	1.11E-08	7.87E-09	7.20E-10	3.40E-11	1.34E-03	1.27E-03	6.78E-05
98	200-E-95	Unassigned 200 Area 2	4.16E-05	8.05E-07	2.38E-07	2.25E-05	9.32E-07	3.88E-08	9.28E-03	9.29E-03	1.89E-06	1.67E-06	1.72E-05	1.45E-15	1.25E-06	3.64E-08	1.47E-07	1.71E-08	3.38E-10	3.85E-02	3.64E-02	1.70E-03
99	200-E-97	Unassigned 200 Area 2	4.16E-05	8.05E-07	2.38E-07	2.25E-05	9.32E-07	3.88E-08	9.62E-03	9.62E-03	1.89E-06	1.67E-06	1.72E-05	1.45E-15	1.25E-06	3.63E-08	1.47E-07	1.71E-08	3.39E-10	3.86E-02	3.64E-02	1.70E-03
100	200-E-98	Unassigned 200 Area 2	3.47E-05	6.71E-07	1.98E-07	1.88E-05	7.77E-07	3.24E-08	7.98E-03	7.98E-03	1.57E-06	1.39E-06	1.43E-05	1.21E-15	1.04E-06	3.03E-08	1.22E-07	1.43E-08	2.82E-10	3.21E-02	3.04E-02	1.42E-03
101	200-E-99	Unassigned 200 Area 2	1.47E-06	3.37E-08	9.34E-09	8.85E-07	9.84E-08	2.03E-09	1.60E-04	1.60E-04	1.06E-07	9.09E-08	8.13E-07	6.21E-14	8.57E-08	1.14E-08	7.93E-09	7.22E-10	3.45E-11	1.34E-03	1.27E-03	6.80E-05
102	200-E-90	Unassigned 200 Area 1	1.47E-06	3.35E-08	9.31E-09	8.82E-07	9.70E-08	2.01E-09	1.60E-04	1.60E-04	1.05E-07	9.02E-08	8.08E-07	6.08E-14	8.48E-08	1.11E-08	7.87E-09	7.20E-10	3.40E-11	1.34E-03	1.27E-03	6.78E-05
103	200-E-100	Unassigned 200 Area	1.47E-06	3.36E-08	9.34E-09	8.84E-07	9.84E-08	2.03E-09	1.60E-04	1.60E-04	1.06E-07	9.09E-08	8.13E-07	6.22E-14	8.57E-08	1.14E-08	7.92E-09	7.22E-10	3.45E-11	1.34E-03	1.27E-03	6.80E-05
104	UPR-200-E-1	B Plant Zone	5.90E-02	1.95E-03	3.92E-04	5.73E-02	2.27E-03	4.15E-05	5.54E+00	5.52E+00	1.96E-02	1.75E-02	3.13E-03	8.79E-13	1.74E-03	2.77E-05	1.50E-04	1.54E-06	8.57E-09	6.36E+00	6.02E+00	3.48E+00
105	UPR-200-E-16	WTP-ETF-A-C Farm Zone	3.16E-02	2.98E-04	1.17E-03	1.10E-01	2.32E-03	1.23E-07	1.21E-01	1.21E-01	7.36E-06	6.17E-06	5.38E-05	7.30E-13	3.97E-04	8.64E-07	5.08E-07	5.30E-05	2.33E-08	1.43E-01	1.35E-01	5.21E-03
106	UPR-200-E-3	B Plant Zone	2.02E-03	2.68E-05	8.83E-06	1.21E-03	1.05E-04	8.79E-07	2.21E-02	2.21E-02	4.08E-04	3.58E-04	6.68E-05	4.32E-13	5.33E-05	1.53E-06	3.43E-06	5.82E-07	1.79E-09	1.51E-01	1.43E-01	7.00E-02
107	UPR-200-E-6	B Farm Zone	2.34E-02	3.12E-04	1.02E-04	1.42E-02	1.22E-03	1.02E-05	2.59E-01	2.58E-01	4.74E-03	4.18E-03	7.80E-04	5.05E-12	6.22E-04	1.79E-05	4.00E-05	6.82E-06	2.08E-08	1.76E+00	1.66E+00	8.17E-01
108	UPR-200-E-7	B Plant Zone	1.60E-06	5.36E-06	1.40E-06	1.23E-04	4.91E-06	2.43E-07	5.39E-03	5.40E-03	1.37E-04	1.20E-04	2.75E-06	2.03E-13	8.00E-06	2.81E-07	9.34E-07	0.00E+00	7.49E-11	6.28E-03	5.93E-03	5.70E-02
109	UPR-200-E-9	B Farm Zone	2.55E-01	9.89E-03	2.58E-03	2.26E-01	7.69E-03	4.46E-04	1.03E+02	1.03E+02	1.20E-04	1.06E-04	1.55E-01	1.32E-13	1.34E-02	3.98E-04	1.68E-03	1.99E-04	4.24E-06	4.77E+02	4.51E+02	1.65E+01
110	UPR-200-E-38	Unassigned 200 Area 2	4.03E-01	7.75E-02	1.43E-02	1.36E+00	4.90E-01	9.22E-03	5.07E+01	5.07E+01	5.48E-01	4.44E-01	2.94E+00	8.31E-07	5.74E-01	1.36E-01	3.83E-02	1.74E-03	2.49E-04	3.07E+02	2.90E+02	1.21E+02
111	UPR-200-E-41	Unassigned 200 Area 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
112	UPR-200-E-68	WTP-ETF-A-C Farm Zone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
113	UPR-200-E-73	B Farm Zone	8.97E-03	1.50E-04	4.77E-05	4.20E-03	1.67E-04	8.28E-06	8.55E-01	8.58E-01	2.21E-06	1.93E-06	4.00E-03	3.52E-15	2.72E-04	9.54E-06	3.19E-05	4.56E-06	1.09E-07	9.13E+00	8.66E+00	3.03E-01
114	UPR-200-E-74	B Farm Zone	4.58E-08	8.84E-10	2.61E-10	2.48E-08	1.03E-09	4.27E-11	5.08E-06	5.08E-06	2.07E-09	1.84E-09	1.89E-08	1.59E-18	1.37E-09	3.99E-11	1.61E-10	1.88E-11	3.71E-13	4.19E-05	3.94E-05	1.86E-06
115	UPR-200-E-75	B Farm Zone	2.35E-02	3.11E-04	1.03E-04	1.42E-02	1.22E-03	1.02E-05	2.58E-01	2.58E-01	4.75E-03	4.18E-03	7.80E-04	5.08E-12	6.21E-04	1.79E-05	3.99E-05	6.80E-06	2.09E-08	1.77E+00	1.66E+00	8.17E-01
116	UPR-200-E-77	B Plant Zone	4.03E-04	1.08E-05	2.87E-06	2.46E-04	5.23E-06	4.90E-07	8.62E-02	8.58E-02	1.33E-07	1.20E-07	2.38E-04	5.25E-18	1.16E-05	1.52E-07	1.77E-06	1.05E-07	6.47E-10	4.84E-01	4.58E-01	1.86E-02
117	UPR-200-E-78	Solid Waste Zone	5.03E-05	2.18E-05	4.50E-04	4.24E-02	3.18E-03	2.70E-06	1.50E+01	1.50E+01	1.60E-04	1.30E-04	8.42E-04	6.20E-09	1.61E-04	7.09E-04	1.12E-05	5.05E-08	2.68E-06	3.39E+00	3.19E+00	3.03E+00
118	UPR-200-E-79	B Farm Zone	1.82E-02	1.07E-03	1.67E-04	1.71E-02	1.21E-03	4.18E-05	8.82E+00	8.81E+00	3.84E-03	3.43E-03	1.25E-02	1.65E-12	1.41E-03	3.89E-05	1.58E-04	1.75E-05	3.25E-07	3.68E+01	3.48E+01	1.91E+00
119	UPR-200-E-80	B Plant Zone	4.48E-04	1.20E-05	3.20E-06	2.73E-04	5.81E-06	5.45E-07	9.55E-02	9.54E-02	1.55E-07	1.39E-07	2.64E-04	1.13E-17	1.28E-05	1.67E-07	1.97E-06	1.17E-07	7.29E-10	5.38E-01	5.08E-01	2.06E-02
120	UPR-200-E-81	Unassigned 200 Area 2	2.29E+01	1.46E-01	1.07E+00	1.03E+02	2.82E+00	6.59E-05	7.34E+01	7.35E+01	3.80E-03	2.98E-03	2.74E-02	9.66E-08	2.75E-01	2.87E-03	2.72E-04	2.38E-02	1.85E-04	8.60E+01	8.12E+01	2.71E+00
121	UPR-200-E-82	Unassigned 200 Area 2	1.94E-01	3.73E-02	6.90E-03	6.55E-01	2.36E-01	4.44E-03	2.44E+01	2.44E+01	2.64E-01	2.14E-01	1.42E+00	4.00E-07	2.76E-01	6.53E-02	1.85E-02	8.39E-04	1.20E-04	1.48E+02	1.40E+02	5.80E+01
122	UPR-200-E-84	B Plant Zone	6.72E-02	3.94E-08	9.86E-09	9.18E-07	1.99E-07	3.85E-09	1.20E-04	1.20E-04	2.30E-07	1.91E-07	1.21E-06	6.05E-14	2.03E-07	3.00E-08	1.59E-08	3.80E-06	1.14E-11	4.58E-05	4.32E-05	1.18E-04
123	UPR-200-E-85	B Plant Zone	4.92E-02	9.40E-03	1.74E-03	1.65E-01	5.92E-02	1.12E-03	6.24E+00	6.16E+00	6.68E-02	5.41E-02	3.57E-01	1.01E-07	7.06E-02	1.65E-02	4.71E-03	2.09E-04	3.03E-05	3.73E+01	3.50E+01	1.46E+01
124	UPR-200-E-86	WTP-ETF-A-C Farm Zone	7.21E-01	1.31E-01	3.74E-02	3.54E+00	1.26E+00	1.57E-02	1.69E+02	1.69E+02	9.34E-01	7.58E-01	4.92E+00	3.47E-06	9.55E-01	2.88E-01	6.51E-02	2.61E-03	1.65E-02	1.98E+04	1.87E+04	3.81E+02
125	UPR-200-E-87	B Plant Zone	4.59E-09	1.03E-05	2.69E-06	2.29E-04	4.86E-06	4.59E-07	1.65E-03	1.65E-03	0.00E+00	0.00E+00	9.29E-07	2.19E-14	1.08E-05	1.41E-07	1.65E-06	4.11E-10	2.56E-12	1.89E-03	1.79E-03	3.20E-01
126	UPR-200-E-105	Unassigned 200 Area 2	5.31E-01	7.04E-03	2.32E-03	3.21E-01	2.77E-02	2.32E-04	5.83E+00	5.83E+00	1.07E-01	9.45E-02	1.76E-02	1.15E-10	1.40E-02	4.04E-04	9.03E-04	1.54E-04	4.71E-07	3.99E+01	3.76E+01	1.85E+01
127	UPR-200-E-107	Unassigned 200 Area 2	1.16E-04	4.49E-06	1.17E-06	1.03E-04	3.50E-06	2.03E-07	4.69E-02	4.69E-02	5.45E-08	4.82E-08	7.07E-05	6.00E-17	6.09E-06	1.81E-07	7.66E-07	9.06E-08	1.93E-09	2.17E-01	2.05E-01	7.52E-03
128	UPR-200-E-108	Unassigned 200 Area 2	1.92E-02	3.20E-04	1.02E-04	8.98E-03	3.58E-04	1.77E-05	1.84E+00	1.84E+00	4.74E-06	4.14E-06	8.55E-03	7.46E-15	5.83E-04	2.05E-05	6.78E-05	9.76E-06	2.34E-07	1.96E+01	1.85E+01	6.47E-01
129	UPR-200-E-109	Unassigned 200 Area 2	3.48E-03	1.35E-04	3.52E-05	3.08E-03	1.05E-04	6.08E-06	1.41E+00	1.41E+00	1.63E-06	1.44E-06	2.12E-03	1.80E-15	1.83E-04	5.43E-06	2.30E-05	2.72E-06	5.78E-08	6.51E+00	6.15E+00	2.26E-01
130	UPR-200-E-110	Unassigned 200 Area 2	1.17E-01	1.56E-03	5.12E-04	7.10E-02	6.09E-03	5.13E-05	1.29E+00	1.29E+00	2.37E-02	2.09E-02	3.89E-03	2.53E-11	3.10E-03	8.93E-05	1.99E-04	3.41E-05	1.04E-07	8.82E+00	8.31E+00	4.08E+00
131	UPR-200-E-116	Unassigned 200 Area 2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
132	UPR-200-E-133	Unassigned 200 Area 2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
133	UPR-200-E-141	Unassigned 200 Area 2	6.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.77E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total			2.42E+04	1.45E+02	2.86E+00	2.86E+02	2.33E+01	5.01E-01	3.22E+04	3.22E+04	2.54E+01	2.21E+01	1.62E+02	4.37E-05	1.87E+01	2.36E+00	1.92E+00	2.62E-01	4.53E-02	6.22E+04	5.88E+04	2.50E+04

	Eu-152	Eu-154	Eu-155	Ra-226	Ra-228	Ac-227	Pa-231	Th-229	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Np-237	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Am-241	Am-243	Cm-242	Cm-243	Cm-244	Volume Discharge
Num#	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	Mean_Ci	(ML)
85	0.00E+00	0.00E+00	0.00E+00	2.11E-13	1.30E-18	9.41E-13	1.34E-12	3.51E-15	1.34E-18	2.38E-13	1.67E-12	3.47E-09	1.49E-10	7.67E-11	3.56E-09	4.25E-12	1.33E-11	5.38E-10	1.08E-10	4.73E-10	3.37E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.75E-02
86	0.00E+00	0.00E+00	0.00E+00	4.74E-13	1.28E-17	2.31E-12	4.23E-12	2.49E-15	1.42E-17	3.88E-12	1.32E-12	1.27E-08	5.19E-10	8.95E-10	9.17E-09	1.08E-08	3.73E-07	3.43E-06	1.10E-06	2.52E-05	1.69E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.39E-02
87	0.00E+00	0.00E+00	0.00E+00	2.48E-12	1.49E-16	1.24E-11	2.86E-11	1.63E-14	1.71E-16	3.49E-11	1.10E-11	1.06E-07	4.04E-09	1.02E-08	7.28E-08	1.13E-07	2.82E-06	2.71E-05	7.67E-06	2.27E-04	9.67E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.86E-01
88	2.64E-10	1.97E-08	9.89E-09	1.94E-13	1.50E-13	1.08E-12	2.52E-12	1.01E-15	2.32E-15	5.04E-14	2.46E-12	8.50E-10	3.79E-11	9.76E-12	8.66E-10	2.29E-10	2.24E-10	2.99E-08	3.13E-09	6.97E-09	5.00E-14	1.01E-08	1.87E-12	6.03E-12	1.45E-13	3.57E-12	2.20E-02
89	6.18E-08	4.66E-06	2.67E-06	1.27E-10	6.30E-16	7.07E-10	1.64E-09	1.28E-13	1.03E-15	1.46E-11	5.89E-12	5.90E-07	2.62E-08	8.25E-09	5.94E-07	1.45E-07	8.82E-07	2.83E-05	4.52E-06	5.31E-05	3.45E-10	5.89E-06	8.16E-10	1.40E-09	1.67E-11	3.92E-10	2.31E-01
90	0.299366	23.5339	12.4764	5.49E-08	3.90E-13	2.49E-07	3.67E-07	6.36E-10	4.04E-13	5.72E-08	2.42E-07	0.000779	3.30E-05	1.86E-05	0.0007815	0.0017467	0.0146879	0.450791	0.097269	0.595718	4.58E-06	21.436	0.010695	0.001146	6.14E-05	0.001452	7.55E-02
91	4.50E-01	3.54E+01	1.87E+01	8.22E-08	5.86E-13	3.73E-07	5.50E-07	9.54E-10	6.07E-13	8.58E-08	3.62E-07	1.17E-03	4.94E-05	2.79E-05	1.17E-03	2.62E-03	2.21E-02	6.76E-01	1.46E-01	8.94E-01	6.85E-06	3.22E+01	1.61E-02	1.72E-03	9.21E-05	2.17E-03	1.13E-01
92	6.62E-11	5.38E-09	2.88E-09	9.91E-16	9.89E-13	1.63E-14	2.37E-12	2.03E-15	7.58E-15	2.43E-13	1.48E-11	1.93E-12	7.54E-14	7.89E-14	1.63E-12	2.34E-11	3.95E-11	7.94E-10	1.93E-10	2.47E-09	1.57E-14	6.84E-10	1.94E-13	1.72E-12	4.98E-14	1.28E-12	5.20E-03
93	3.82E-09	2.87E-07	1.51E-07	4.48E-12	1.44E-12	2.50E-11	5.81E-11	1.22E-14	2.23E-14	6.31E-13	2.36E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.37E-09	4.77E-09	6.88E-07	7.07E-08	1.42E-07	9.96E-13	2.19E-07	3.50E-11	8.72E-11	1.74E-12	4.25E-11	2.32E-01
94	3.82E-09	2.87E-07	1.51E-07	4.48E-12	1.44E-12	2.50E-11	5.81E-11	1.22E-14	2.23E-14	6.30E-13	2.36E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.37E-09	4.78E-09	6.88E-07	7.06E-08	1.42E-07	9.96E-13	2.20E-07	3.50E-11	8.72E-11	1.74E-12	4.25E-11	2.32E-01
95	3.82E-09	2.87E-07	1.51E-07	4.48E-12	1.44E-12	2.50E-11	5.82E-11	1.22E-14	2.23E-14	6.31E-13	2.36E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.37E-09	4.77E-09	6.88E-07	7.07E-08	1.42E-07	9.98E-13	2.19E-07	3.50E-11	8.73E-11	1.74E-12	4.25E-11	2.32E-01
96	3.82E-09	2.87E-07	1.51E-07	4.48E-12	1.44E-12	2.50E-11	5.81E-11	1.22E-14	2.23E-14	6.31E-13	2.36E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.37E-09	4.78E-09	6.88E-07	7.07E-08	1.42E-07	9.96E-13	2.19E-07	3.51E-11	8.72E-11	1.74E-12	4.25E-11	2.32E-01
97	3.82E-09	2.87E-07	1.51E-07	4.48E-12	1.44E-12	2.50E-11	5.82E-11	1.22E-14	2.23E-14	6.30E-13	2.36E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.37E-09	4.78E-09	6.88E-07	7.06E-08	1.42E-07	9.97E-13	2.19E-07	3.50E-11	8.72E-11	1.74E-12	4.25E-11	2.32E-01
98	6.30E-08	4.76E-06	2.73E-06	1.29E-10	6.40E-16	7.21E-10	1.67E-09	1.31E-13	1.04E-15	1.40E-11	5.66E-12	5.99E-07	2.66E-08	8.17E-09	6.04E-07	1.44E-07	8.24E-07	2.81E-05	4.40E-06	4.82E-05	3.25E-10	6.01E-06	8.33E-10	1.43E-09	1.70E-11	3.99E-10	2.32E-01
99	6.31E-08	4.76E-06	2.72E-06	1.29E-10	6.44E-16	7.22E-10	1.67E-09	1.31E-13	1.05E-15	1.47E-11	5.91E-12	6.01E-07	2.67E-08	8.40E-09	6.06E-07	1.47E-07	8.87E-07	2.87E-05	4.57E-06	5.33E-05	3.46E-10	6.02E-06	8.33E-10	1.44E-09	1.70E-11	4.00E-10	2.19E-01
100	5.25E-08	3.97E-06	2.27E-06	1.08E-10	5.36E-16	6.01E-10	1.39E-09	1.09E-13	8.72E-16	1.22E-11	4.89E-12	5.01E-07	2.23E-08	6.97E-09	5.05E-07	1.22E-07	7.32E-07	2.39E-05	3.79E-06	4.38E-05	2.86E-10	5.01E-06	6.94E-10	1.20E-09	1.42E-11	3.32E-10	2.32E-01
101	3.86E-09	2.90E-07	1.52E-07	4.48E-12	1.47E-12	2.50E-11	5.81E-11	1.24E-14	2.28E-14	6.39E-13	2.42E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.38E-09	4.79E-09	6.88E-07	7.07E-08	1.42E-07	9.99E-13	2.20E-07	3.52E-11	8.80E-11	1.76E-12	4.32E-11	1.92E-01
102	3.82E-09	2.87E-07	1.51E-07	4.48E-12	1.44E-12	2.50E-11	5.81E-11	1.22E-14	2.23E-14	6.30E-13	2.36E-11	1.98E-08	8.84E-10	2.27E-10	2.02E-08	4.37E-09	4.78E-09	6.88E-07	7.06E-08	1.42E-07	9.97E-13	2.20E-07	3.50E-11	8.73E-11	1.74E-12	4.25E-11	2.37E-01
103	3.86E-09	2.90E-07	1.52E-07	4.48E-12	1.47E-12	2.50E-11	5.82E-11	1.24E-14	2.28E-14	6.39E-13	2.42E-11	1.98E-08	8.85E-10	2.27E-10	2.02E-08	4.38E-09	4.78E-09	6.88E-07	7.07E-08	1.42E-07	9.99E-13	2.20E-07	3.51E-11	8.80E-11	1.76E-12	4.32E-11	2.37E-01
104	4.30E-05	4.14E-03	3.37E-03	3.03E-07	1.02E-12	9.07E-07	1.88E-05	6.96E-10	5.86E-12	1.86E-09	1.66E-10	2.08E-04	9.33E-06	1.77E-06	2.10E-04	7.09E-05	3.74E-04	1.08E-01	7.22E-03	7.08E-03	3.28E-08	2.12E-03	6.71E-08	1.16E-07	6.73E-10	1.56E-08	2.04E-02
105	7.14E-07	5.17E-05	2.25E-05	1.62E-10	1.74E-15	7.91E-10	1.74E-09	2.73E-13	2.16E-15	8.96E-11	4.24E-12	1.91E-06	8.14E-08	4.35E-08	1.96E-06	3.61E-07	1.70E-05	9.63E-04	2.01E-04	8.70E-04	6.24E-09	1.25E-03	1.39E-08	2.35E-08	4.40E-10	1.15E-08	3.30E-04
106	3.83E-06	2.67E-04	1.22E-04	2.90E-09	1.88E-14	8.74E-09	1.91E-07	1.30E-11	1.09E-13	6.04E-11	4.58E-12	3.34E-06	1.48E-07	4.95E-08	3.42E-06	1.54E-06	1.65E-07	1.63E-05	2.29E-06	5.32E-06	4.01E-11	1.71E-04	1.96E-08	3.38E-08	4.11E-10	9.72E-09	3.85E-03
107	4.48E-05	3.14E-03	1.41E-03	3.38E-08	2.19E-13	1.02E-07	2.23E-06	1.52E-10	1.28E-12	7.09E-10	5.33E-11	3.92E-05	1.73E-06	5.77E-07	4.00E-05	1.79E-05	1.93E-06	1.90E-04	2.69E-05	6.19E-05	4.73E-10	2.00E-03	2.31E-07	3.99E-07	4.86E-09	1.13E-07	1.89E-02
108	2.72E-06	2.00E-04	1.10E-04	8.75E-10	5.16E-15	9.59E-09	2.15E-07	1.29E-11	1.10E-13	2.19E-11	1.72E-12	1.44E-06	6.37E-08	1.95E-08	1.47E-06	1.51E-06	2.53E-05	2.86E-03	3.62E-04	7.95E-04	5.78E-09	1.06E-04	1.64E-08	2.82E-08	3.41E-10	8.00E-09	4.16E-02
109	6.04E-04	4.59E-02	2.69E-02	2.13E-06	9.96E-12	1.03E-05	8.87E-08	4.75E-10	4.03E-12	5.27E-09	4.30E-10	4.23E-04	1.88E-05	4.83E-06	4.31E-04	1.23E-03	8.80E-04	1.23E-01	1.33E-02	2.59E-02	1.82E-07	6.81E-02	9.62E-06	1.66E-05	1.97E-07	4.62E-06	1.89E-04
110	2.24E-02	1.67E+00	7.70E-01	4.30E-07	2.00E-05	2.55E-06	6.96E-06	1.11E-07	3.09E-07	5.31E-06	3.28E-04	2.25E-04	9.41E-06	6.12E-06	2.11E-04	9.58E-03	4.41E-03	1.03E-01	2.39E-02	1.99E-01	1.63E-06	1.37E-01	7.73E-05	5.17E-04	1.57E-05	3.91E-04	7.00E-02
111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00E+00
112	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
113	1.44E-05	1.06E-03	5.86E-04	2.15E-08	1.27E-13	1.25E-07	1.29E-09	8.40E-12	7.16E-14	1.66E-09	1.29E-10	1.07E-04	4.78E-06	1.47E-06	1.10E-04	2.30E-05	1.60E-05	1.80E-03	2.29E-04	5.01E-04	3.68E-09	1.61E-03	2.48E-07	4.27E-07	5.19E-09	1.22E-07	1.73E-04
114	6.92E-11	5.24E-09	3.00E-09	1.41E-13	6.78E-19	7.86E-13	1.82E-12	1.32E-16	1.12E-18	7.84E-15	6.39E-16	6.28E-10	2.79E-11	7.19E-12	6.38E-10	1.16E-10	1.41E-10	2.15E-08	2.18E-09	4.02E-09	2.77E-14	6.60E-09	9.06E-13	1.58E-12	1.88E-14	4.40E-13	3.85E-05
115	4.49E-05	3.14E-03	1.42E-03	3.38E-08	2.19E-13	1.02E-07	2.24E-06	1.52E-10	1.28E-12	7.06E-10	5.34E-11	3.90E-05	1.72E-06	5.78E-07	3.99E-05	1.79E-05	1.93E-06	1.90E-04	2.70E-05	6.17E-05	4.70E-10	2.00E-03	2.31E-07	3.98E-07	4.80E-09	1.14E-07	1.93E-03
116	2.33E-07	2.23E-05	1.81E-05	2.15E-09	7.19E-15	1.25E-08	1.45E-10	5.80E-13	4.85E-15	9.52E-11	8.40E-12	1.09E-05	4.88E-07	9.25E-08	1.10E-05	1.34E-06	4.88E-07	1.40E-04	9.42E-06	9.09E-06	4.25E-11	2.91E-05	1.25E-09	2.18E-09	1.29E-11	3.05E-10	3.47E-05
117	6.12E-04	4.82E-02	2.54E-02	1.12E-10	7.96E-16	5.08E-10	7.48E-10	1.30E-12	8.26E-16	1.17E-10	4.94E-10	1.58E-06	6.70E-08	3.79E-08	1.60E-06	3.58E-06	2.99E-05	9.19E-04	1.98E-04	1.21E-03	9.30E-09	4.38E-02	2.18E-05	2.34E-06	1.25E-07	2.96E-06	1.54E-04
118	6.49E-05	4.94E-03	2.88E-03	2.07E-07	9.44E-13	9.23E-07	2.82E-06	1.61E-10	1.36E-12	6.09E-10	4.71E-11	3.91E-05	1.73E-06	5.15E-07	3.99E-05	1.08E-04	1.60E-04	2.01E-02	2.37E-03	4.86E-03	3.56E-08	6.07E-03	8.16E-07	1.41E-06	1.65E-08	3.91E-07	3.85E-03
119	2.57E-07	2.49E-05	2.01E-05	2.38E-09	8.02E-15	1.39E-08	1.66E-10	6.43E-13	5.39E-15	1.05E-10	9.29E-12	1.20E-05	5.42E-07	1.03E-07	1.22E-05	1.49E-06	5.39E-07	1.55E-04	1.05E-05	1.01E-05	4.71E-11	3.23E-05	1.40E-09	2.43E-09	1.42E-11	3.42E-10	3.85E-03
120	7.00E-04	5.38E-02	2.97E-02	3.15E-07	2.43E-03	4.90E-05	2.46E-04	6.67E-06	3.04E-05	1.89E-04	1.13E-02	1.57E-03	6.12E-05	3.86E-05	1.41E-03	1.82E-04	1.66E-02	6.88E-01	1.62E-01	1.17E+00	8.23E-06	7.58E-01	2.02E-05	3.15E-05	1.66E-06	5.10E-05	1.36E-01
121	1.08E-02	8.03E-01	3.70E-01	2.07E-07	9.62E-06	1.23E-06	3.35E-06	5.34E-08	1.49E-07	2.55E-06	1.58E-04	1.08E-04	4.53E-06	2.94E-06	1.02E-04	4.61E-03	2.12E-03	4.96E-02	1.15E-02	9.58E-02	7.88E-07	6.61E-02	3.71E-05	2.49E-04	7.58E-06	1.88E-04	9.84E-03
122	1.77E-08	1.31E-06	6.00E-07	2.38E-10	1.46E-15	1.06E-09	1.51E-09	3.95E-12	1.51E-15	1.74E-11	1.23E-10	2.54E-07	1.09E-08	5.61E-09	2.61E-07	5.17E-06	3.18E-06	1.28E-04	2.58E-05	1.13E-04	8.06E-10	1.69E-04	7.80E-08	9.32E-07	1.83E-08	4.84E-07	6.43E-03
123	2.74E-03	2.03E-01	9.41E-02	5.23E-08	2.43E-06	3.09E-07	8.53E-07	1.34E-08	3.81E-08	6.51E-07	3.97E-05	2.73E-05	1.15E-06	7.42E-07	2.57E-05	1.15E-03	5.33E-04	1.26E-02	2.89E-03	2.44E-02	2.01E-07	1.70E-02	9.30E-06	6.03E-05	1.83E-06	4.74E-05	2.48E-03
124	7.14E-02	5.55E+00	2.85E+00	6.78E-07	4.00E-05	4.47E-06	9.41E-06	2.64E-07	6.75E-07	4.44E-06	2.72E-04	7.06E-04	2.98E-05	1.70E-05	7.03E-04	2.02E-02	1.15E-02	3.45E-01	7.50E-02	4.74E-01	3.68E-06	4.58E-01	2.27E-04	1.19E-03	5.47E-05	1.31E-03	6.58E-02
125	3.98E-06	3.84E-04	3.12E-04	3.38E-09	1.13E-14	1.44E-07	3.02E-06	1.12E-10	9.40E-13	1.55E-12	1.37E-13	1.77E-07	7.98E-09	1.51E-09	1.80E-07	1.12E-05	8.87E-03	2.58E+00	1.74E-01	1.69E-01	7.94E-07	2.41E-04	1.04E-08	1.83E-08	1.07E-10	2.56E-09	2.88E-02
126	1.01E-03	7.07E-02	3.21E-02	7.63E-07	4.95E-12	2.31E-06	5.05E-05	3.43E-09	2.90E-11	1.60E-08	1.21E-09	8.81E-04	3.88E-05	1.31E-05	9.01E-04	4.05E-04	4.37E-05	4.29E-03	6.08E-04	1.40E-03	1.06E-08	4.53E-02	5.21E-06	8.97E-06	1.09E-07	2.56E-06	8.71E-02
127	2.75E-07	2.09E-05	1.22E-05	9.67E-10	4.53E-15	4.69E-09	4.03E-11	2.16E-13	1.83E-15	2.40E-12	1.95E-13	1.92E-07	8.58E-09	2.20E-09	1.96E-07	5.61E-07	4.00E-07	5.61E-05	6.04E-06	1.18E-05	8.27E-11	3.10E-05	4.38E-09	7.55E-09	8.94E-11	2.10E-09	1.89E-05
128	3.11E-05	2.27E-03	1.25E-03	4.59E-08	2.72E-13	2.67E-07	2.77E-09	1.80E-11	1.53E-13	3.52E-09	2.76E-10	2.31E-04	1.02E-05	3.14E-06	2.35E-04	4.92E-05	3.42E-05	3.87E-03	4.89E-04	1.08E-03	7.84E-09	3.45E-03	5.32E-07	9.17E-07	1.11E-08	2.59E-07	7.42E-04
129	8.24E-06	6.26E-04	3.66E-04	2.90E-08	1.36E-13	1.41E-07	1.21E-09	6.48E-12	5.49E-14	7.19E-11	5.86E-12	5.76E-06	2.57E-07	6.59E-08	5.87E-06	1.68E-05	1.20E-05	1.68E-03	1.81E-04	3.53E-04	2.48E-09	9.29E-04	1.31E-07	2.26E-07	2.68E-09	6.30E-08	5.68E-04
130	2.24E-04	1.57E-02	7.09E-03	1.69E-07	1.10E-12	5.09E-07	1.12E-05	7.59E-10	6.40E-12	3.53E-09	2.66E-10	1.95E-04	8.62E-06	2.90E-06	1.99E-04	8.96E-05	9.66E-06	9.46E-04	1.35E-04	3.10E-04	2.35E-09	9.99E-03	1.15E-06	1.98E-06	2.41E-08	5.67E-07	1.93E-02
131	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
132	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
133	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.99E-10	7.06E-11	5.90E-05	2.61E-06	8.01E-07	6.02E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.08E-04
Total	1.82E+00	1.40E+02	7.55E+01	2.30E-03	3.92E-03	1.13E-02	2.62E-02	1.26E-05	4.21E-05	2.42E-02	1.34E+00	1.55E+01	6.69E-01	4.65E-01	1.44E+01	1.48E+00	7.62E+00	2.83E+02	3.86E+01	4.52E+02	3.07E-03	1.49E+02	4.63E-02	3.11E-02	1.67E-03	4.17E-02	5.72E+05

Source: Derived from RPP-26744, *Hanford Soil Inventory Model, Rev. 1.*

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Table 4-4. Waste Sites Having Affected or Continuing to Affect Groundwater

Waste Sites	Contaminants	Derived Activity/ Concentration Released to Soil Column	Derived Liquid Release (L)
Highly Contaminated Waste Stream Sites within the B Complex			
UPR-200-E-131 (near 241-BX-102 SST)	Uranium Technetium-99 Nitrate Tritium Iodine-129	29,100 mg/L 6,560,400 pCi/L 11,000 mg/L 11,089,100 pCi/L 2,900 pCi/L	346,750
Moderately Contaminated Waste Stream Sites within the B Complex			
BY Cribs	Technetium-99 Nitrate Cyanide Cobalt-60 Iodine-129	3,798,800 pCi/L 198,600 mg/L Not provided 188,000 pCi/L 4,870 pCi/L	33,810,000
216-B-50 Crib	Tritium	2,307,00 pCi/L	54,739,900
216-B-57 Crib	Tritium	2,309,00 pCi/L	84,331,000
216-B-7 A&B Cribs	Technetium-99 Nitrate Chromium	35 to 420,800 pCi/L 4,800 to 86,100 mg/L 22 to 415 mg/L	44,617,500
216-B-8 Crib	Technetium-99 Nitrate Chromium Iodine-129	3,400 pCi/L 4,800 to 79,800 mg/L 22 to 261 mg/L 151 to 4,940 pCi/L	35,269,100
Undocumented release near waste site 241-B-105	Tributyl phosphate waste that contains the same constituents as the BY Cribs	Not derived	280,090
Moderately Contaminated Waste Stream Sites near B Plant			
216-B-12 Crib	Uranium Nitrate Tritium	54.2 mg/L (insignificant) 0.5 to 8,280 mg/L 0.14 to 8,270,000 pCi/L	520,444,400

Table 4-4. Waste Sites Having Affected or Continuing to Affect Groundwater

Waste Sites	Contaminants	Derived Activity/ Concentration Released to Soil Column	Derived Liquid Release (L)
216-B-5 injection well	Uranium Nitrate Strontium-90 Cesium-137 Plutonium-239	0.271 to 0.465 mg/L 4,600 to 40,000 mg/L 203,600 to 312,200 pCi/L 234,000 to 358,500 pCi/L 177,400 to 2,383,500 pCi/L	32,090,000
Sites Contaminated by UPRs and Other			
B Pond	Tritium Iodine-129	19 to 484,000 pCi/L <1 pCi/L (contribution from PUREX may not have been completed)	282,689,400,000
Gable Mountain Pond (216-A-25)	Nitrate Strontium-90	0.6 mg/L (undefined for UPR) 0.2 to 14,900 pCi/L	293,899,038,000
216-B-2-1 and -2 Ditches	Fractionation waste Nitrate	Not derived	Not derived
Highly Contaminated Waste Stream Sites at WMA C			
WMA C	PUREX (technetium-99 and nitrate) and scavenged waste (same contaminants as the BY Cribs) appear to have impacted groundwater, but sources have yet to be defined.	Because sources are undefined, concentrations are uncertain; however, current sites meeting the concentration requirements discussed above are provided for potential comparisons.	Not derived
UPR-200-E-81 east of Well 299-E27-23	Technetium-99 Nitrate	201,446 pCi/L 42,616 mg/L	136,260
UPR-200-E-82 north of Well 299-E27-4	Technetium-99 Nitrate	143,861,328 pCi/L 77,700 mg/L	9841
UPR-200-E-86 northwest of Well 299-E27-23	Technetium-99 Nitrate	70,276,528 pCi/L 19,224 mg/L	65,802
241-C-101	Technetium-99 Nitrate	59,375,377 pCi/L 13,284 mg/L	3,785
241-C-105	Technetium-99 Nitrate	59,815,087 pCi/L 30,210 mg/L	3,785

Table 4-4. Waste Sites Having Affected or Continuing to Affect Groundwater

Waste Sites	Contaminants	Derived Activity/ Concentration Released to Soil Column	Derived Liquid Release (L)
241-C-110	Technetium-99 Nitrate	3,212,828 pCi/L 171,069 mg/L	7,571

Note: This table is based on information provided in RPP-26744, *Hanford Soil Inventory Model, Rev. 1*.

PUREX = Plutonium-Uranium Extraction (Plant)

UPR = unplanned release

WMA = waste management area

4.2.1.1 BY Cribs

The BY Cribs are located north of the B-BX-BY Tank Farms (Figures 4-2 and 4-4). The cribs received scavenged waste (Appendix B of WMP-28945). At the time of discharge, some of the transport properties of the various waste components were unknown, and cribbing requirements were targeted at the mobility of cesium-137 and strontium-90. Thus, the liquid discharge volume was limited for each crib (ranging between 2,100,000 and 6,740,000 L [558,000 and 1,780,000 gal]) to ensure that these two radionuclides would not reach groundwater. In addition, prior to disposal, ferrocyanide was used to precipitate cesium-137 and strontium-90 from the liquid waste in the tanks, further reducing the possibility of these radionuclides entering groundwater. Because the transport properties of cobalt-60 and technetium-99 were unknown at the time, and possibly the understanding of their percentage in the waste inventory was also unknown, these constituents were not considered in the cribbing criteria. It was later discovered that cobalt-60 was complexed by cyanide, allowing it to be transported through 82.3 m (270 ft) of the vadose zone and into the groundwater. The 2013 groundwater activity concentrations of cobalt-60 are below the DWS beneath this site and throughout the OU, which is attributed to the short half-life of cobalt-60 and the substantial amount of time that has passed since disposal.

Based on groundwater monitoring results, contaminants exceeding the DWSs include cyanide, nitrate, technetium-99, and tritium. The derived average mass activities/concentrations for these contaminants, when discharged to the soil column, were approximately 0.6 g/L, 200 g/L, 3.8 µCi/L, and 2.3 µCi/L, respectively (RPP-26744). Other contaminants either were absorbed by the soil column or are decayed to low or nondetectable concentrations. Further information pertaining to the vadose zone is summarized in Appendix C of WMP-28945 (also see DOE/RL-92-70, *Phase I Remedial Investigation Report for 200-BP-1 Operable Unit*). The ratio of these inventories correlates with that found in groundwater today, with the exception of tritium. Tritium mainly results from the 216-B-50 Crib, which is the northwestern crib within the BY Cribs area. This crib received substantial volumes of liquid condensate waste as part of the in-tank solidification process. The mean total liquid condensate waste volume sent to the 216-B-50 Crib was 54,700,000 L (14,450,000 gal) (RPP-26744). The nature and extent of cyanide, nitrate, technetium-99, and tritium in groundwater are discussed in Section 4.4.

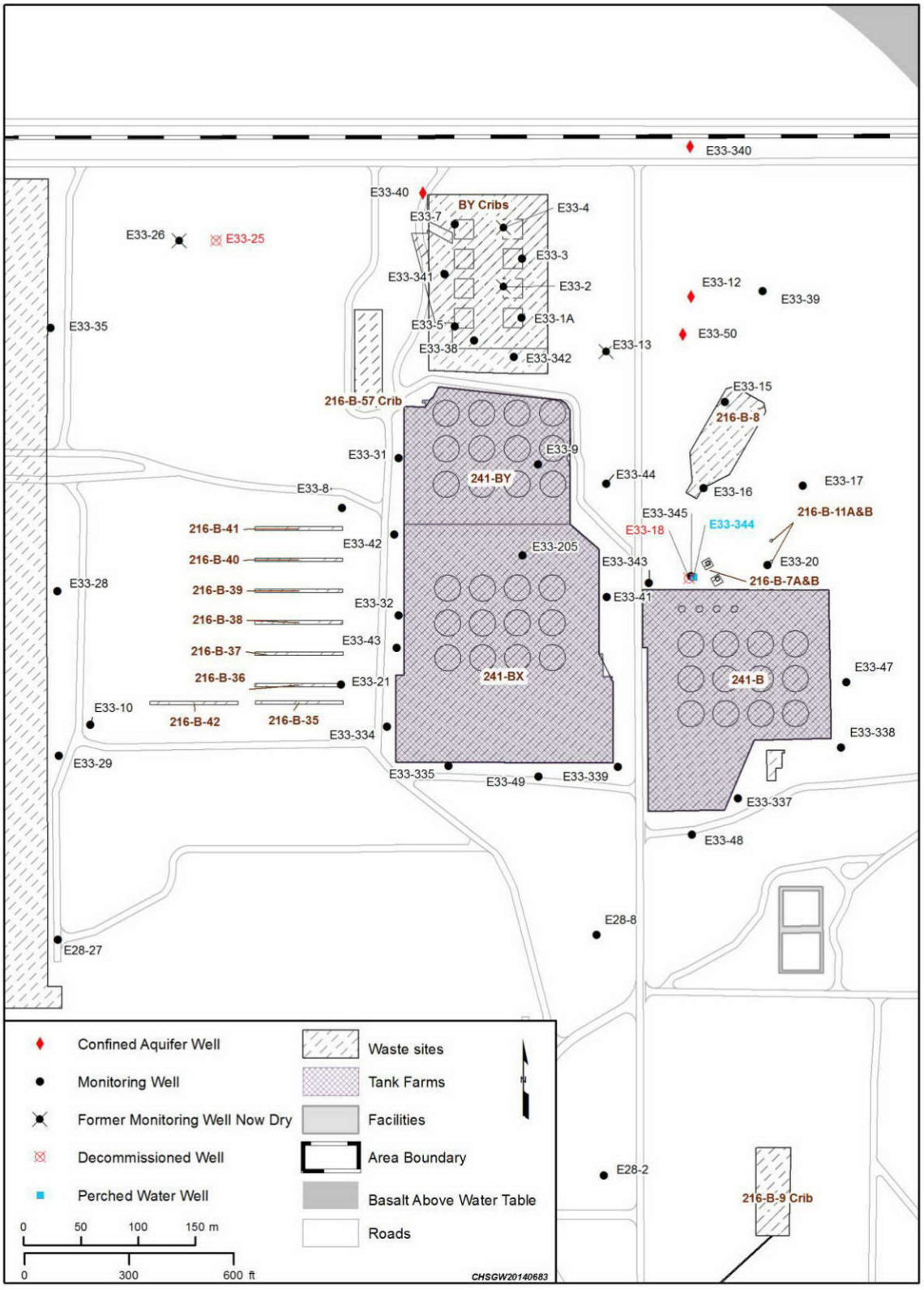


Figure 4-4. Waste Sites and Associated Groundwater Monitoring Wells for the B Complex Area of the 200-BP-5 OU

4.2.1.2 216-B-7A&B Cribs

The 216-B-7A&B Cribs are located north of the B Tank Farm and south of the 216-B-8 Crib (Figures 4-2 and 4-4). The cribs operated during two processing eras: the first from 1946 to 1954, and the second from 1966 to 1967. The total liquid volume received during the first process disposal era was 43.5 million L (11.5 million gal) of B Plant liquid waste effluent. Most of the liquid waste resulted from the 224 Building and was composed mainly of wastes associated with the lanthanum fluoride/plutonium concentration process. Additional information on this process is provided in Appendix A of WMP-28945 (also see HW-10475, *Hanford Engineer Works Technical Manual*). Only nitrate and technetium-99 appear to impact the unconfined aquifer. These contaminants are further discussed in Section 4.4.

4.2.1.3 216-B-8 Crib

The 216-B-8 Crib is located north of the B Tank Farm (Figures 4-2 and 4-4). The crib received total of 35.3 million L (9.3 million gal) of liquid waste from two separations processes (from the 224-B Building and second-cycle decontamination waste). Both of these processes are summarized in Appendix A of WMP-28945 (also see HW-10475). The derived liquid waste discharge concentrations were high for one groundwater contaminant (nitrate at 4 to 80 g/L) (RPP-26744), which is consistent with descriptions of second-cycle decontamination waste, in which most of the fission products and uranium were removed prior to the plutonium decontamination process. Another discharged contaminant with a high concentration was chromium, which ranged between 21 and 261 mg/L (RPP-26744). The chromium that was discharged possibly contained some Cr(VI), which was used to oxidize plutonium during the separations process. Although arsenic was not associated with the waste discharged to this site, it is detected at elevated concentration in groundwater beneath this site. The cause of the local elevated arsenic in groundwater appears to stem from acid discharges to the crib, which were used to increase the vadose zone drainage at this site. An accidental discharge of amorphous bismuth phosphate second-cycle cake waste resulted in poor drainage conditions at this waste site. To increase drainage, hydrochloric and acetic acid were discharged to this crib (WMP-28945, Appendix D, and HW-17088, *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington*). Soil washing experiments have shown that arsenic associated with natural occurring pyrite is dissolved in hydrochloric acid (Wilkin and Ford, 2002, "Use of Hydrochloric Acid for Determining Solid-Phase Arsenic Partitioning in Sulfidic Sediments"). The acid solutions likely mobilized the naturally occurring arsenic from sediment that was then transported to groundwater. Arsenic is discussed further in Section 4.4.

4.2.1.4 216-B-9 Crib

The 216-B-9 Crib is located south of the B Tank Farm (Figure 4-3). The crib received 36 million L (9.5 million gal) of liquid waste from cell drainage Tank 5-6 in B Plant. The derived liquid waste discharge concentrations were high for one groundwater contaminant (nitrate at 4 µg/L) (RPP-26744). Only minor contributions to groundwater from this site have been observed, and this site is not discussed further.

4.2.1.5 216-B-12 Crib

The 216-B-12 Crib is located south of LLWMA-1 (Figure 4-3). The site received process condensate (water condensed from closed systems that have been in direct contact with radioactive material) during the uranium recovery process from 1952 to 1957. The derived average liquid waste volume received at the crib during the uranium recovery process was 371.5 million L (98.2 million gal) (RPP-26744). Process condensate contained nitrate, ammonia, and volatile radionuclides such as carbon-14, iodine-129, ruthenium-106, and tritium (HW-19140); however, RI analytical results in 2010 found that only nitrate, tritium, and uranium were elevated in groundwater near this waste site. The estimated average nitrate concentration sent to this crib ranged between 7.6 and 8.3 g/L; tritium activity ranged between 5.4 and

8.2 μCi/L; and the average uranium concentrations were 54,000 μg/L (RPP-26744). The levels of contamination and volumes sent to the crib are suspected to be sufficient to account for the contamination in the lower portion of the low-permeability Ringold sediment aquifer, as discovered during RI drilling and depth-discrete sampling at Wells 299-E28-30 and 299-E29-54. The 216-B-12 Crib is identified as a source of nitrate, tritium, and uranium from the earlier era of disposal, deep in the unconfined aquifer (DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010*). In addition, the crib also received B Plant process condensate from 1967 to 1973. The derived average liquid waste volume received during the fission fractionation recovery process was 149 million L (39.4 million gal) (RPP-26744). The process condensate was generated from the 22-1 Concentrator Tank for the cesium separation process and the 26-2 Concentrator Tank for the cerium promethium separation process (ISO-100, *Waste Management Technical Manual*). The average mean contaminant concentrations in liquid waste sent to the 216-B-12 Crib during this era were minimal (RPP-26744).

4.2.1.6 216-B-57 Crib

The 216-B-57 Crib is located northwest of the BY Tank Farm (Figures 4-2 and 4-4). The site received condensate from the in-tank solidification process from the BY Tank Farm (similar to the 216-B-50 Crib discussed previously). As with the 216-B-50 Crib, the 216-B-57 Crib received an elevated average derived tritium activity level of 2.3 μCi/L (RPP-26744). The amounts of other contaminants were much lower due to the more efficient removal processes employed during this era at the PUREX Plant and B Plant compared to the early 1950s processes at U Plant. Elevated concentrations of tritium at this crib have infiltrated, and continue to infiltrate, into the groundwater and are discussed further in Section 4.4.

4.2.2 Reverse Wells

WMP-28945 identified two reverse wells, 216-B-5 and 216-B-6, located in the B Plant aggregate area as known or suspected sources of groundwater contamination. The reverse wells were used to inject wastewater into the ground at a greater depth than possible with cribs or French drains. As with other large releases (e.g., cribs), discharges to these two reverse wells were notable: 32,100,000 and 6,000,000 L (8,700,000 and 1,590,000 gal), respectively (mean average based on RPP-26744). Releases associated with the 216-B-5 Reverse Well have also been documented in the past (WMP-28945) and are summarized below. The RI data results during drilling at Well 299-E29-54 are also summarized for the 216-B-6 Reverse Well.

4.2.2.1 216-B-5 Reverse Well

The 216-B-5 Reverse Well (Figure 4-2) was used to discharge early 224 Building lanthanum fluoride/bismuth phosphate cross-over waste from cell drainage (WMP-28945). The waste stream also contained wastes from Cell 5-6 of the 221 Building (HW-10475). Because the reverse well screen extended into the aquifer, many of the contaminants discharged to the well that readily absorb to the sediments are still detected in this area, including cesium-137, plutonium-239/240, and strontium-90. These contaminants are consistent with the release inventory provided in RPP-26744. One additional contaminant, fluoride, is still detected in monitoring Well 299-E28-24, located approximately 7 m (23 ft) southeast of the 216-B-5 Reverse Well. This well is screened approximately 7.6 to 9.1 m (25 to 30 ft) below the water table. Fluoride was used in the form of hydrofluoric acid in early plutonium separation processes, and waste associated with these processes was discharged to the 216-B-5 Reverse Well.

4.2.2.2 216-B-6 Reverse Well

The 216-B-6 Reverse Well (Figure 4-3) was used to discharge sources of decontamination sinks and sample waste from the 222-B Building from 1945 to 1949 (WMP-28945). The depth of the reverse well screen within the vadose zone was uncertain, with three possible locations: 22.9 m (75 ft), 49.1 m (161 ft), or 92.1 m (302 ft) bgs. According to RPP-26744, radionuclide inventories were high for

cesium-137 (1.1 μCi/L), plutonium-239 (559 pCi/L), and strontium-90 (0.13 μCi/L); nonradiological inventories for chromium (416 mg/L) and nitrate (9.7 g/L) were also substantial. In addition, this waste site was ranked high for radionuclide inventories in PNL-6456, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford, Vol 1 – Evaluation Methods and Results*. As a result, one RI borehole was drilled and sampled approximately 3 m (9.8 ft) from the 216-B-6 Reverse Well. Vadose zone sample results found elevated cesium-137, plutonium-239, and strontium-90 at 22.8 to 23.3 m (74.7 to 76.4 ft) bgs, indicating the depth of the screen interval. Deeper vadose zone sample results were mainly below detection levels or background soil concentrations (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*). The shallowest groundwater results ranged from background to below detection levels for most constituents. The few detected radionuclides (tritium and technetium-99) were substantially below the DWSs (4,300 and 15 pCi/L, respectively). Thus, it appears the liquid volume source may not have been as large as recorded in RPP-26744.

4.2.3 Ditches and Ponds

Discharges to ditches and surface ponds (e.g., 216-B-2 Ditches, Gable Mountain Pond, B Pond, 216-C-9 Pond, and 216-N Ponds) mainly consisted of cooling water with only trace levels of contamination. The 216-B-2 Ditches were open, unlined ditches that conveyed the cooling water/steam condensate wastewater stream from the 207-B Retention Basin to the B Pond system. The trace levels of contamination were low enough that the liquid wastes did not contain concentrations above current DWSs. However, small UPRs (e.g., equipment malfunctions) of highly concentrated radionuclides from various separation plants were concentrated enough to cause elevated groundwater contaminant concentrations, even with the large liquid volumes being discharged (e.g., groundwater beneath the 216-B-2 Ditches, B Pond and Gable Mountain Pond). These sites are further discussed below.

4.2.3.1 B Pond

B Pond is located east of the 200 East Area, along the southern boundary of the 200-BP-5 OU (Figure 4-2). The pond consists of a main pond and three expansion ponds. Discharges to the pond began in 1945 and were terminated in 1997. During that time, approximately 282.7 billion L (74.7 billion gal) of wastewater (primarily the noncontact streams of steam condensate and cooling water) were discharged. Although portions of several UPRs were disposed to B Pond, only iodine-129 and tritium activities are still present in groundwater at levels just above DWSs. The main UPRs in which portions of the waste were transferred to B Pond are discussed in greater detail for the 216-B-2 Ditches and Gable Mountain Pond. The localized groundwater plumes of tritium and iodine-129 are discussed in Section 4.4.

4.2.3.2 Gable Mountain Pond

Gable Mountain Pond is located north of the 200 East Area and south of Gable Mountain (Figure 4-2). Discharges to the pond began in January 1957 and were terminated in January 1987. During that time, the pond received 307 billion L (81.1 billion gal) of liquid waste (DOE/RL-95-59). During the first 10 years of service, the pond received primarily cooling water from the PUREX Plant and condensate cooling water from Tank 241-A-401 (A Tank Farm). In June 1964, a leak from the cooling coil of the first-cycle acid waste storage tank (F-15) in the PUREX Plant released mixed fission products that were conveyed to the pond (ARH-780, *Chronological Record of Significant Events in Chemical Separations Operations*; ARH-231). Pond water samples collected from Gable Mountain Pond in June 1964, after the release, were at 48 million pCi/L gross-beta (RL-SA-15, *Radiation Control of Accidentally Contaminated Seepage Ponds*). Subsequent pond water results showed that the activity had decreased four orders of magnitude within 4 months of the release. The release included the longer-lived radionuclides cesium-137 and strontium-90. Strontium-90 concentrations peaked in the groundwater in 1997 and have been decreasing

since that time, but they remain above the 8 pCi/L DWS. Localized groundwater plumes of strontium-90 and nitrate have persisted in this area and are further discussed in Section 4.4. Cesium-137 has not been detected at high concentrations, most likely due to the higher distribution coefficient of cesium-137 compared to strontium-90.

4.2.3.3 216-B-2 Ditch

Three man-made ditches (216-B-2-1, 216-B-2-2, and 216-B-2-3) were used during operations to transfer B Plant cooling water to B Pond. The first ditch, 216-B-2-1, was constructed in 1945 and operated until 1964, when it was contaminated from discharges associated with UPR-200-E-32 (HW-79768, *Chemical Processing Department Monthly Report for November 1963*). The second ditch, 216-B-2-2, was constructed as a replacement for the 216-B-2-1 Ditch and operated from 1964 to 1970. The second ditch was backfilled in 1970 due to UPR-200-E-138 (RHO-CD-673, *Handbook 200 Areas Waste Sites*). In 1970, the third ditch, 216-B-2-3, was excavated to replace the 216-B-2-2 Ditch and operated until 1994.

The main UPR contaminants at the 216-B-2-1 and 216-B-2-2 Ditches are nitrate and strontium-90; these contaminants are associated with partially refined fractionation product releases. The product contained high levels of stronitium-90 activity and was being temporarily stored in a nitric acid solution at the time of the releases (ISO-986, *B-Plant Phase III Flowsheets*). Some of the product appeared to be conveyed to B Pond based on the increased nitrate concentration at Well 699-42-42A (located south of B Pond) in January 1971, with concentrations increasing to 97 mg/L. The elevated concentrations persisted until March, and by May 1971, the concentrations were at 41 mg/L; by February 1972, the nitrate concentrations had declined to 11 mg/L.

In 1986, blockage of the back end of the 216-B-2-3 Ditch was discovered when cooling water began infiltrating into an open exaction within the 218-E-12B Burial Ground (SD-WM-TI-260, *Water Inflow Investigation at the 218-E-12A and 218-E-12B Burial Grounds*). Observations identified in this report determined less than 20 percent of the liquid waste (mostly cooling water) entering the ditch continued to B Pond. The remainder, approximately 9.4 million L/d (2.5 million gal/d), percolated into the coarse sands and gravels lining the ditch. No dates were provided in SD-WM-TI-260 regarding the duration of these conditions; therefore, it is uncertain how much liquid percolated into the vadose zone sediments. However, sufficient liquid loss occurred to extend approximately 60 m (197 ft) north into the south end of Trench 36 within the 218-E-12B Burial Ground. SD-WM-TI-260 discusses the results of an investigation to determine the extent of saturated vadose zone conditions near Trench 36. The investigation found that the saturated head declined in elevation approximately 1.5 m (4.9 ft) north of the 216-B-2-3 Ditch. The investigation also found nitrate concentrations increasing at Well 299-E34-1, located to the north/northwest of the release. The increased nitrate concentrations appear to have been associated with remobilization of liquid wastes containing nitric acid associated with the UPRs at the 216-B-2-1 and 216-B-2-2 Ditches, located north of the 216-B-2-3 Ditch. The nitrate plume is discussed further in Section 4.4.2.3.

4.2.4 Single-Shell Tanks and Ancillary Equipment Leaks

Assessments completed at the B-BX-BY Tank Farms and C Tank Farm have determined that releases at these facilities have impacted groundwater. Although the source release volumes were much smaller than the intentional discharges to the surrounding cribs and trenches, other types of releases in the area (including possible leaking underground waterlines or large precipitation events) may have aided in driving some of these high-activity releases to the groundwater. A summary of the specific or suspect sources of groundwater contamination are summarized below.

4.2.4.1 Waste Management Area B-BX-BY SSTs and Ancillary Equipment

Leaks and spills associated with SSTs and ancillary equipment located within the B-BX-BY Tank Farms (Figure 4-3) have contributed cyanide, nitrate, technetium-99, tritium, and uranium to groundwater. Groundwater contamination in this area may persist as the result of an extensive, contaminated, leaky perched water horizon in this area. Other potential contributing sources in this area are described in DOE/RL-2012-53, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area B-BX-BY*.

4.2.4.2 Waste Management Area C SSTs and Ancillary Equipment

Leaks and spills associated with the SSTs and ancillary equipment located within the C Tank Farm (Figure 4-2) have contributed cyanide, nitrate, and technetium-99 to the groundwater (DOE/RL-2011-01).

4.2.5 Other Waste Sites Overlying the 200-BP-5 Operable Unit Potentially Impacting Groundwater

Various landfills regulated under CERCLA (e.g., 218-E-2, 218-E-2A, 218-E-5, 218-E-5A, 218-E-9, and 218-E-12A) have potentially contributed to the vadose zone contamination overlying the 200-BP-5 OU. Potential for groundwater contamination from these sites is likely small compared to that of the liquid waste sites overlying the 200-BP-5 OU.

4.2.6 Conclusions

Based on the various types of waste sites overlying the 200-BP-5 OU, discharges associated with moderate-activity liquid crib waste sites (e.g., BY Cribs) from the early to mid-1950s have affected the largest area of groundwater within the 200-BP-5 OU. Outside of the B Complex, only a few sites had sufficient radiological and chemical inventories to affect groundwater within the upper unconfined aquifer. These sites include B Plant (including the 216-B-5 Reverse Well and the 216-B-12 Crib), Gable Mountain Pond, and the B Pond (Figure 4-2). In addition, some UPRs (i.e., small-volume, high-activity wastes) have also impacted groundwater but currently at a lesser areal extent. The contaminants of greatest importance include nitrate, technetium-99, and uranium due to their mobility, current areal extent and activity/concentration levels, and remaining inventory within the vadose zone.

4.3 Soils and Vadose Zone

This RI report is focused on groundwater and is not intended to address contamination in the vadose zone or surface soils.

4.4 Unconfined Aquifer

The discussion in this section focuses on the nature and extent of contamination observed and inferred in the unconfined aquifer based on groundwater data collected and evaluated within the 200-BP-5 OU. The information is based on the historical data review completed for the 200-BP-5 DQO process (WMP-28945), the 200-BP-5 RI/FS work plan (DOE/RL-2007-18), and data collected for this RI. Figure 4-1 shows the 2013 extent of contaminant plumes in the 200-BP-5 OU. Contaminant cross sections are provided in the following subsections and in Appendix D.

Surveillance monitoring since the late 1940s has shown varying degrees of groundwater contamination from certain sites. By 1959, a substantial plume of radiological contamination (mapped as total beta activity) had developed within the northwestern portion of 200 East Area, beneath the B Complex (HW-SA-1729, *A Review of Radioactive Waste Disposal to the Ground at Hanford, November 1959*). Maps of the contaminant distribution were created in reports throughout the years, and some examples are

provided in Appendix D of WMP-28945. Further discussion of overlying liquid waste sites is provided in Section 4.2.

As discussed in Section 3.6.2.3, groundwater mounds associated with large-volume discharges in the Central Plateau and the 100 Areas greatly altered the groundwater gradient (both direction and magnitude) within the 200-BP-5 OU during operations. For example, the groundwater mound near Gable Mountain Pond (wastewater discharge of approximately 10 to 15 billion L/yr [2.6 to 4 billion gal/yr] from 1959 to 1972), combined with the mound generated by cooling water discharges from 100-K Area reactor operations (approximately 12+ billion L/yr [3.2+ billion gal/yr]), prevented contaminated groundwater beneath the 200 East Area from migrating rapidly north toward Gable Gap until the early 1970s. Following discontinuation of cooling water discharges in the 100-K Area, and with decreased discharges to Gable Mountain Pond (3 to 5 billion L/yr [7.9 million to 1.3 billion gal/yr] from 1973 to 1976), contaminated groundwater from the 200 East Area began to migrate northward toward Gable Gap. However, contaminant migration to the north was slowed from 1977 to 1985, when increased production and discharges to Gable Mountain Pond resumed, ranging between 10 to 23 billion L/yr (2.6 to 6.1 billion gal/yr). Finally, with the deactivation of Gable Mountain Pond, contaminant migration toward Gable Gap continued until mid-2011, when groundwater levels within the 200 East Area had declined to a level below the high Columbia River spring stages (DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*, Section 3.4). From mid-2011 to 2014, the flow direction within the 200 East Area has maintained a south-southeast groundwater flow direction. Groundwater contamination in the 200-BP-5 OU north of Gable Gap no longer exceeds DWSs or groundwater cleanup levels.

Contaminant plume behavior within the 200-BP-5 OU has also been strongly influenced by changes in water levels and corresponding aquifer thickness in response to changing water table elevations. In the B Complex, activities/concentrations have decreased as groundwater elevations increased and have increased as groundwater elevations declined over the years (Figure 4-5); nitrate beneath the BY Cribs is an example of this trend. Increasing concentrations of nitrate were observed in groundwater a few years after discharges to Gable Mountain Pond were terminated (e.g., mid-1980s). Contaminant concentrations increased, until peaking between 2009 and 2011 (Figure 4-5); these peak concentrations coincided with very slow groundwater flow that was occurring, as groundwater flow was shifting from a northwest to a southeast flow direction. As shown in Figure 4-6, the flow direction changed in the northwestern portion of the 200 East Area from a northerly flow direction (represented by an azimuth of 360 degrees) to a southerly flow direction (represented by an azimuth of 180 degrees). The change in flow direction was calculated using information from a low-gradient monitoring network (Figure 4-7) in the 200 East Area. As the southerly flow gradient magnitude increased in 2012 (Figure 4-6), the level of contamination decreased beneath the BY Cribs and at other sites (Figure 4-5). In addition, correlating the flow spatially over time provides additional evidence of southerly (i.e., toward the southeast at the B Complex) migration of technetium-99 from the BY Cribs since mid-2011 (Figures 4-8 and 4-9). Examination of the groundwater flow conditions has led to an improved conceptual understanding of contributing sources to groundwater.

Although high-volume wastewater releases to ponds near the 200 East Area created large groundwater recharge mounds producing radial groundwater flow away from the discharge points, this high-volume wastewater also provided sufficient pressure head to drive contamination into (and at certain locations, through) low-permeability sediments.

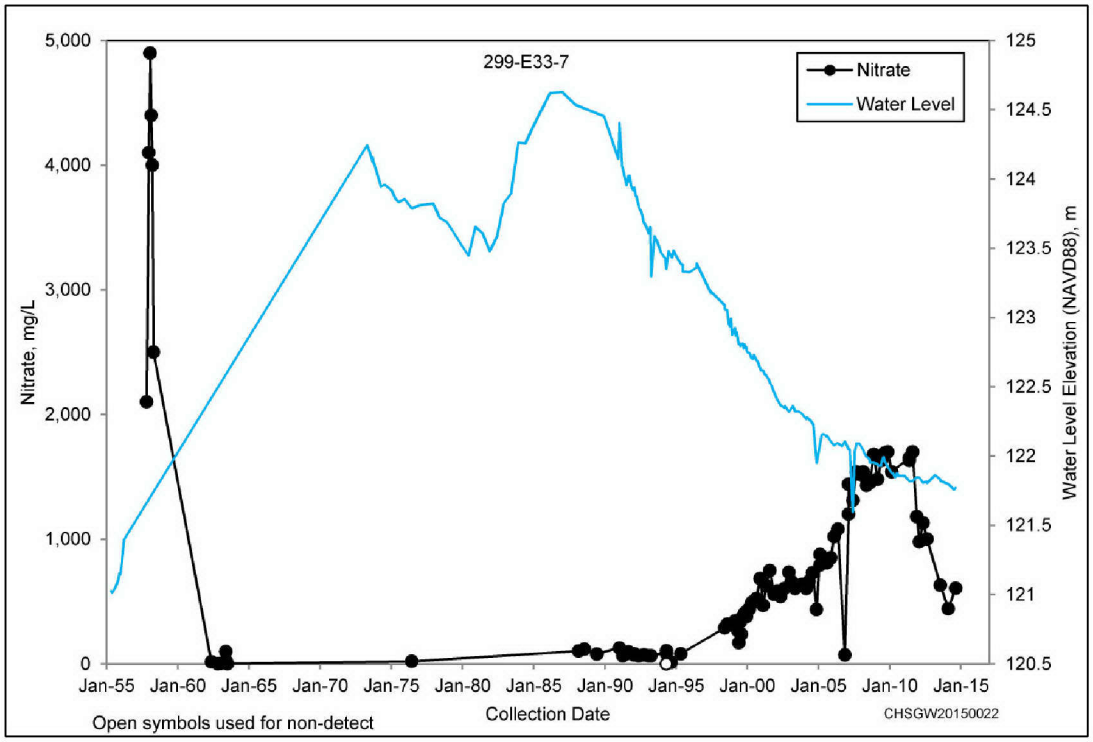


Figure 4-5. Comparison of Nitrate Groundwater Concentrations with Groundwater Levels beneath the BY Cribs at Well 299-E33-7

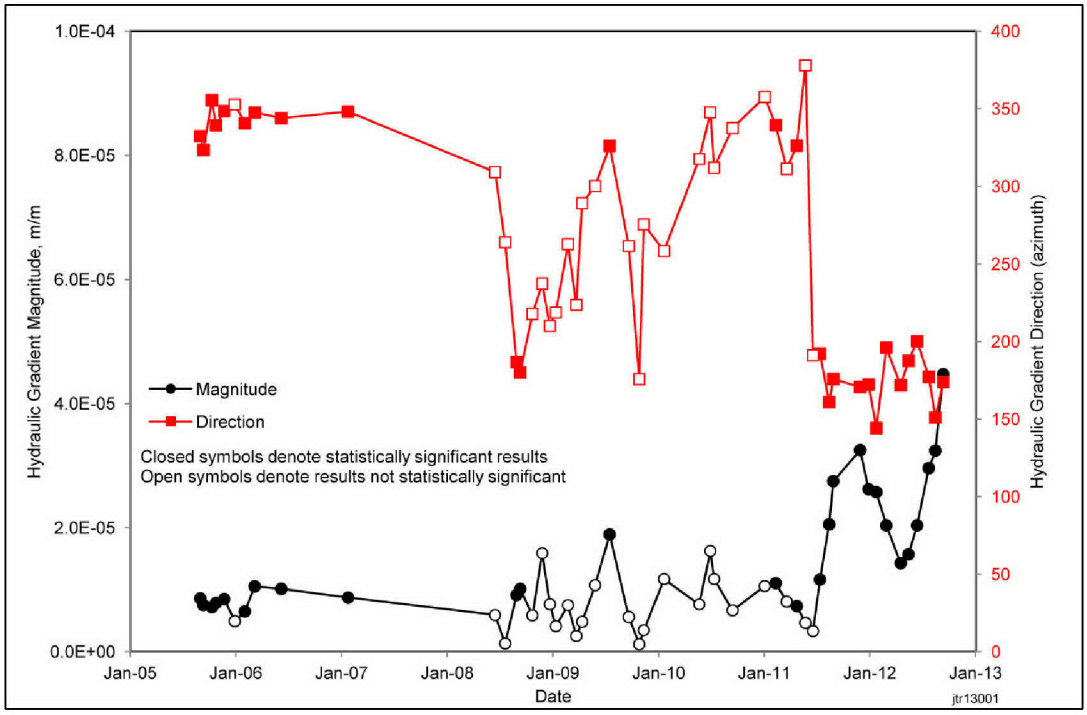


Figure 4-6. Water Table Gradient Magnitude and Groundwater Flow Direction Based on the Low-Gradient Monitoring Network

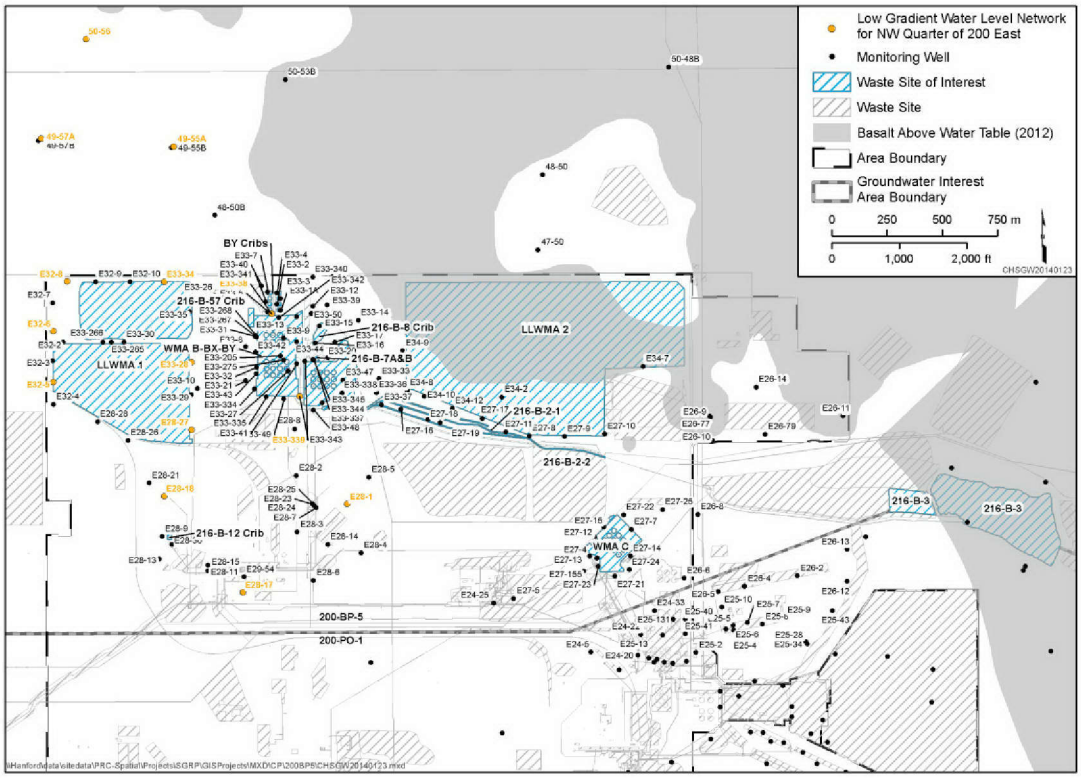


Figure 4-7. Spatial Distribution of the Low-Gradient Monitoring Network in the Northwest Quarter of the 200 East Area and 600 Area to the North

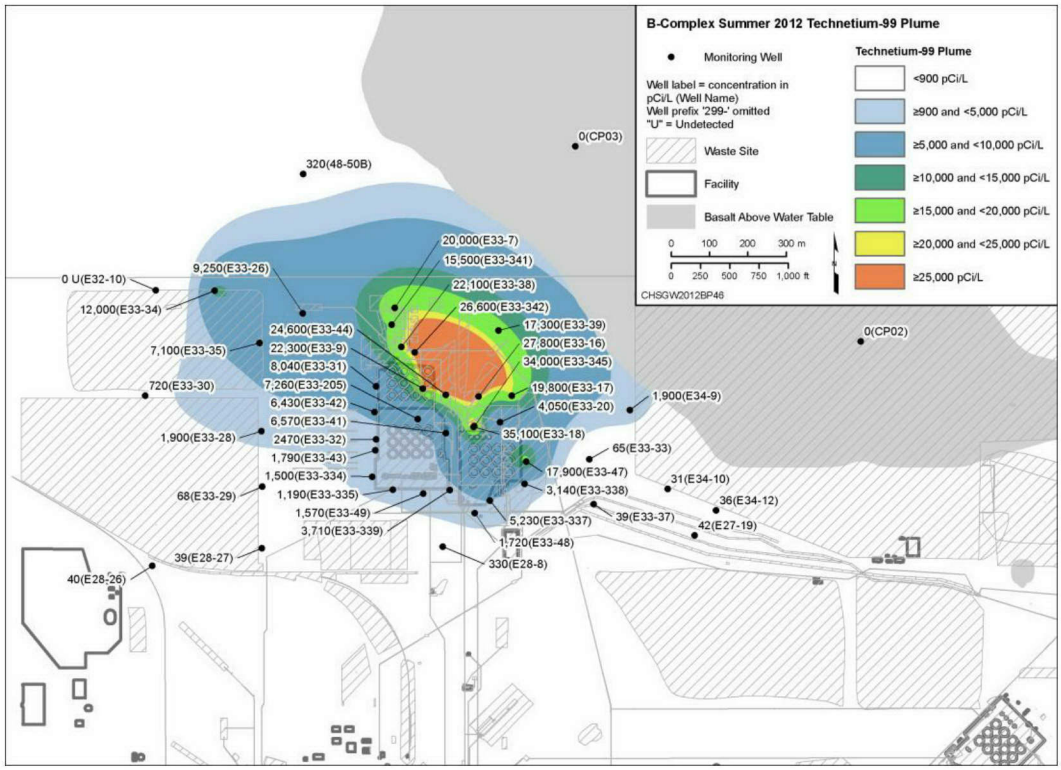


Figure 4-8. Technetium-99 Groundwater Plume Extending from beneath the BY Cribs, 2012

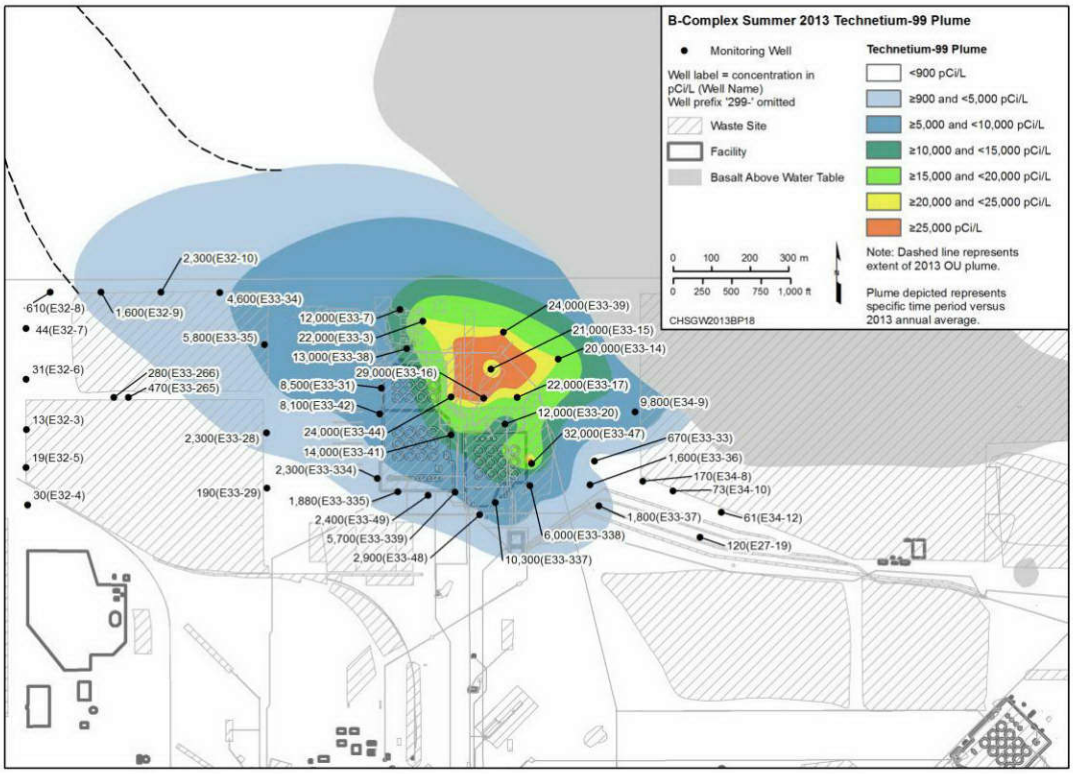


Figure 4-9. Technetium-99 Groundwater Plume Extending from beneath the BY Cribs, 2013

The primary sites where contamination has been shown to persist within the OU are the B Complex, B Plant (including the 216-B-5 Reverse Well and the 216-B-12 Crib), Gable Mountain Pond, and B Pond. Past UPRs at two high-activity underground storage areas, WMA B-BX-BY (e.g., B-BX-BY Tank Farms) and WMA C (e.g., C Tank Farm), have also affected groundwater quality over the past couple of decades and have shown varying degrees of groundwater contamination. Figures 4-1 and 4-2 show the waste sites and associated groundwater plumes that contributed to this contamination, and Figure 4-3 shows the groundwater monitoring wells for the 200-BP-5 OU.

The following subsections discuss the nature and extent of contamination associated with the 15 contaminants that exceed either the DWSs or the groundwater cleanup levels (MTCA Method B). In general, the more mobile contaminants covering the largest areal extent are discussed first, followed by less mobile contaminants that have been identified with smaller areal extents.

4.4.1 Technetium-99

Technetium-99 is a fission product common to many of the nuclear fuel reprocessing waste streams. Substantial technetium-99 activity was released in two areas within the 200-BP-5 OU: B Complex and WMA C (discussed further in Section 4.2). Releases from three sites have been determined to impact groundwater at the B Complex, while at least two defined liquid process waste releases at WMA C have been determined to impact groundwater. It is noted that due to the similarity of chemical composition for many of the releases associated with WMA C, defining the specific sources impacting groundwater at WMA C is not possible at this time. The following subsections discuss characteristics associated with the releases, migration pathways, and extent of technetium-99 in the groundwater from these areas.

4.4.1.1 B Complex

Technetium-99 activity exceeding the DWS at the B Complex has been present since discharges occurred in the 1950s. Three primary B Complex sources appear to be associated with technetium-99 contamination in this area: the BY Cribs, UPRs associated with the 241-BX-102 SST, and a pump release near the 241-B-105 SST. The largest, most extensive, and persistent source of technetium-99 activity at the B Complex has been the scavenged waste supernatant released to the BY Cribs (Figures 4-2 and 4-4). As discussed in Section 4.2, the BY Cribs liquid waste releases were associated with reprocessed high-activity waste to create storage space in the B-BX-BY Tank Farms due to limited tank storage capacity. The other two releases affecting groundwater were low-volume UPRs of high-activity liquid waste.

Liquid waste discharges containing technetium-99 at the BY Cribs were estimated at 3.8 µCi/L (RPP-26744). As shown in Figure 4-10, the technetium-99 groundwater activity beneath the BY Cribs increased to nearly 40,000 pCi/L at Wells 299-E33-7 and 299-E33-38 in 2009 and 2010. Similarly, the estimated average activity release of technetium-99 at the 241-BX-102 UPR was 6 µCi/L (RPP-26744). Technetium-99 in groundwater at Well 299-E33-18 (near the 241-BX-102 release) also approached 40,000 pCi/L in early 2013.

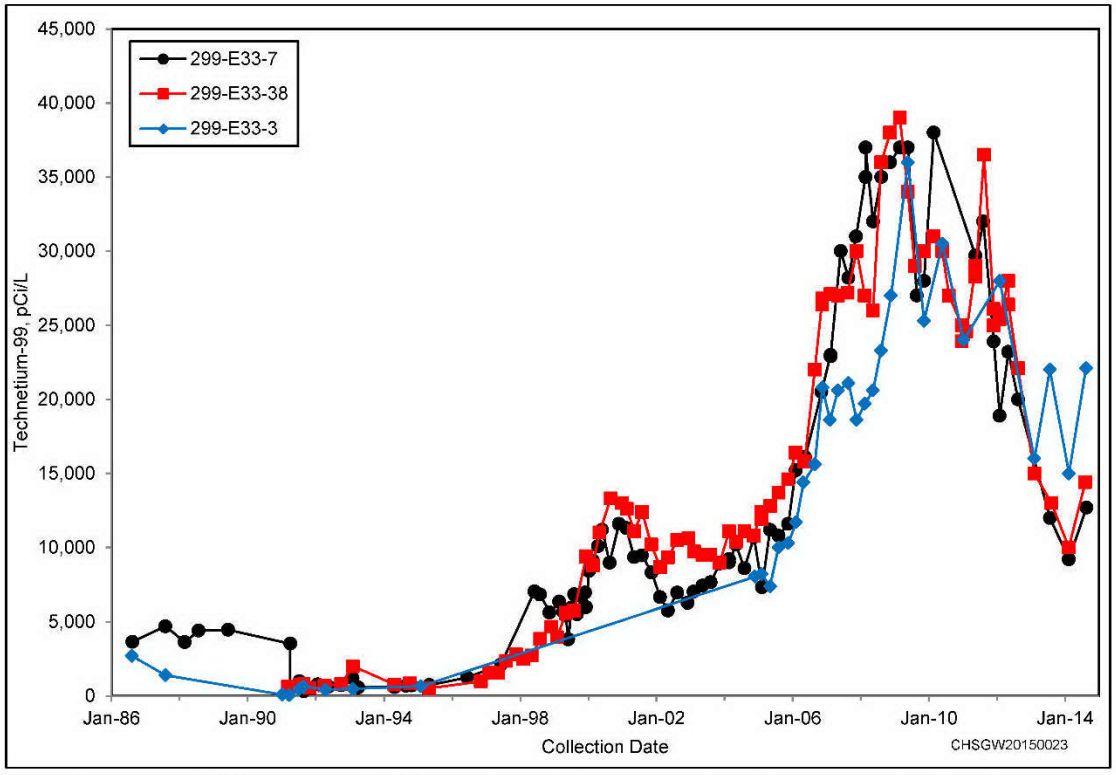


Figure 4-10. Technetium-99 Groundwater Contaminant Levels beneath the BY Cribs

Figure 4-11 provides a 2010 cross-section interpretation of contamination extending from the BY Cribs to the south side of the BX Tank Farm. Although technetium-99 activity associated with the BY Cribs and the 241-BX-102 Tank is similar, the source of technetium-99 in individual wells can be differentiated based on technetium-99-to-nitrate ratios. Figure 4-12 shows a greater technetium-99-to-nitrate ratio at Well 299-E33-18, which is associated with the 241-BX-102 UPR, as compared to Well 299-E33-38, which is located beneath and associated with BY Crib releases. The technetium-99-to-nitrate ratio at Well 299-E33-344, located within the perched horizon, mainly reflects the 241-BX-102 UPR liquid waste based on the similar technetium-99-to-nitrate ratio at Well 299-E33-18 (Figure 4-12). Groundwater quality effects from the 241-BX-102 UPR have been observed since the early to mid-1990s. The technetium-99-to-nitrate relationship is discussed further in PNNL-19277, as well as other diagnostic comparisons differentiating contaminants from the 241-BX-102 UPR from other B Complex waste sites.

A third site, an unplanned pump release near the 241-B-105 Tank, also impacted groundwater within the B Tank Farm (DOE/RL-2012-53). Technetium-99 activity in the groundwater reached approximately 30,000 pCi/L at Well 299-E33-47 in 2013 (Figure 4-9). The lower technetium-99 activity in groundwater at Well 299-E33-47 (from the pump release near the 241-B-105 Tank) is thought to be attributed to smaller release volumes near the 241-B-105 Tank and a thicker aquifer, as compared to the UPRs associated with the 241-BX-102 Tank and releases associated with the BY Cribs. Groundwater quality effects from this release have only been observed since 2010.

Releases from the BY Cribs in the 1950s have migrated north (based on historical groundwater elevations) and currently extend from south to northwest of Well 699-53-55C (Figure 1-3). Despite the lack of sample results for technetium-99 prior to the late 1980s, nitrate (a co-contaminant with technetium-99) results during the 1950s at Well 299-E33-7 suggest that substantial technetium-99 groundwater contamination was also present in the 1950s below the BY Cribs (Figure 4-5). Co-contaminants associated with the BY Cribs (e.g., cyanide, cobalt-60, nitrate, and technetium-99) were also detected in Well 699-50-53A during the 1990s (DOE/RL-95-59). These co-contaminants are currently detected in Wells 699-53-55B and 699-53-55C, indicating past migration to the northwest. Part of the migration to the north likely occurred in the mid-1950s due to a combination of discharges to the 216-B-2 Ditch and 216-B-12 Crib from 1955 through 1957. Combined, these two sites received 24.1 billion L (6.3 billion gal), and no active ponds were directly north of the 200 East Area at this time (the N Ponds were discontinued in 1952). However, beginning in 1957, discharges to Gable Mountain Pond and the resulting recharge mound beneath the pond, combined with the extensive recharge mound originating at the 116-K-2 Trench, increased water levels, which acted as a hydraulic barrier for northerly and northwesterly flow. This hydraulic barrier remained until 1985, when a decision was made to deactivate Gable Mountain Pond. Reduced discharge volumes and corresponding lower groundwater elevations in 1985 and 1986 led to a northwesterly groundwater flow. The extent of contamination in this area has remained nearly the same since the mid-1990s.

Figure 4-13 shows the 2009 extent of technetium-99 exceeding the DWS within the unconfined aquifer to the northwest of the 200 East Area, slightly northwest of Well 699-50-59. From 1985 to mid-2011, this was the preferential contaminant migration pathway, extending toward Gable Butte/Gable Mountain Gap. Figure 4-14 provides cross-sectional aerial traces, as presented in this subsection and in Appendix D. Since the groundwater flow direction change in mid-2011, technetium-99 activity levels north of the 200 East Area have declined, and the areal extent of technetium-99 above DWS has contracted back toward the 200 East Area. The reduced areal extent of technetium-99 north of the 200 East Area is best noted by comparing the 2009 extent shown in Figure 4-13 with the 2013 plume extent shown in Figure 4-1.

Technetium-99 has also migrated through the uppermost basalt formation into the upper confined aquifer at Well 299-E33-12 (Figure 4-15). The mechanism of migration was through the unsealed borehole adjacent to the well casing. It is uncertain whether downward migration into Well 299-E33-12 was due to the density of the BY Cribs liquid waste. However, during 1954 when discharges were occurring at the BY Cribs, 216-B-7A&B Cribs, 216-B-8 Crib, and 216-B-11 French Drain, the potentiometric head of the Rattlesnake Ridge interbed was on average greater than 0.4 m (1.3 ft) higher than the unconfined aquifer (Figure 4-16). In addition, the potentiometric head in the Rattlesnake Ridge interbed appeared to increase coincident with the increasing water elevations in the unconfined aquifer, as shown by the upward trend in 1956 at Well 299-E33-12 (Figure 4-16). When the potentiometric head-level measurements were again recorded in 1965 for Well 299-E33-12, the potentiometric head was 0.4 m (1.3 ft) higher than the level measured in Well 299-E33-20 (screened in the unconfined aquifer), which was located next to Well 299-E33-18. From 1965 to 1979, when Well 299-E33-12 was properly sealed, the potentiometric head in the confined unit continued to have a greater elevation than the water table of the unconfined aquifer. This information suggests that the potentiometric head in the basalt-confined unit was greater than the unconfined aquifer during the time when the Rattlesnake Ridge interbed potentiometric head elevations were not recorded. This also suggests that the density of the scavenged waste from the BY Cribs was sufficient to migrate downward during a time of upward hydraulic head. This conceptual contaminant migration mechanism is consistent with the reconstructed density of the simulated scavenged waste (1.21 g/mL), as discussed in WHC-SD-EN-TA-003, *Potential Groundwater Contamination from High Density Wastes Disposed at the BY Cribs, 200-BP-1 CERCLA Operable Unit.*

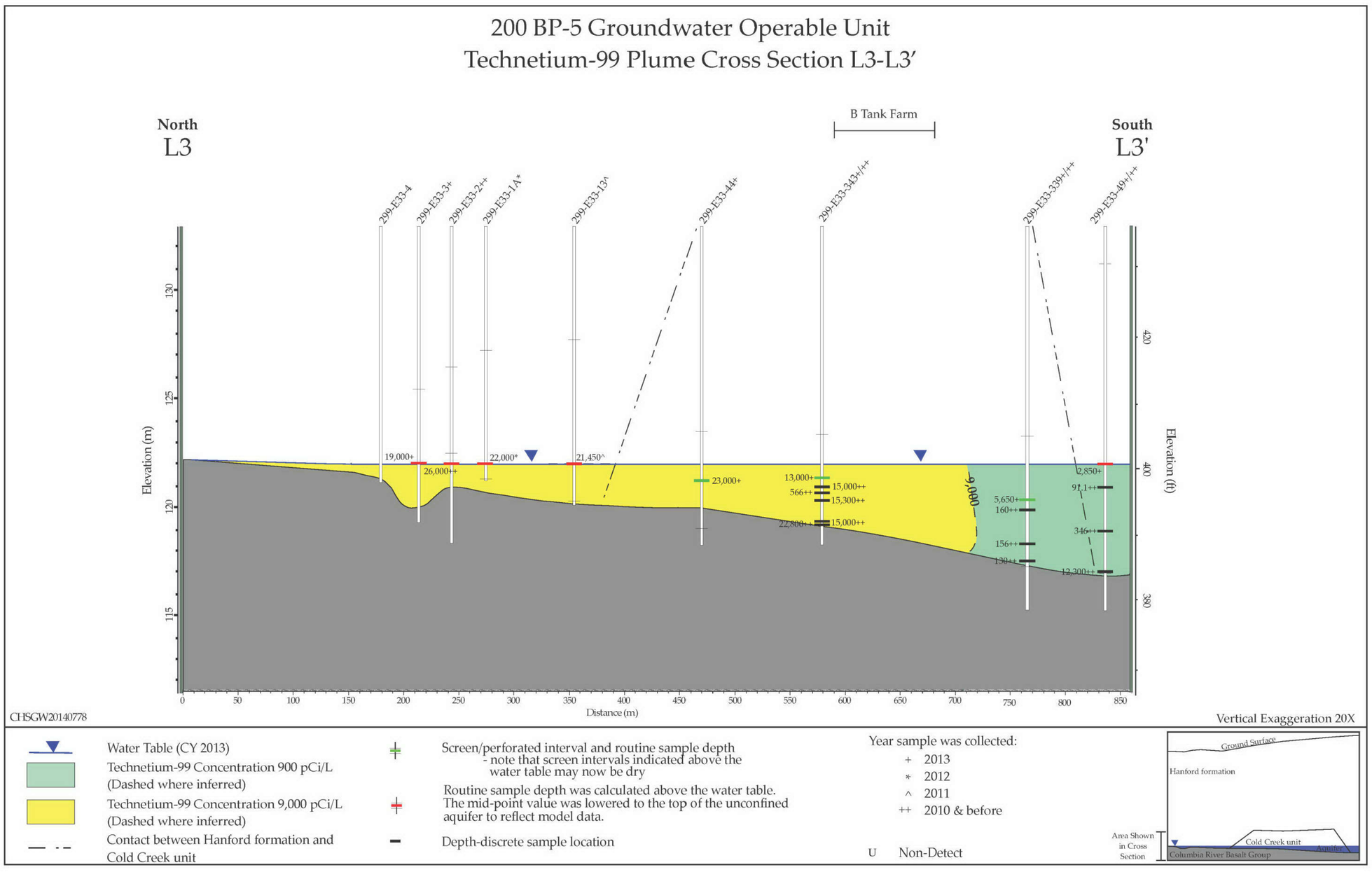
The density of the scavenged waste may also explain the recent elevated technetium-99 activity reported at Well 299-E28-24; activity increased from 56 pCi/L in 2012 to 12,500 pCi/L in June 2014. This well is screened between 7.6 and 9.1 m (25 to 30 ft) below the water table. Elevated technetium-99 is not observed in other wells in this area (299-E28-3, 299-E28-23, and 299-E28-25), which have longer screens and are mainly screened across the upper portion of the unconfined aquifer.

Two RI wells, 299-E33-50 and 299-E33-340, were installed in the basalt-confined aquifer to determine the extent of technetium-99 migration from Well 299-E33-12. Technetium-99 activity at these two wells has generally been lower than 60 pCi/L (Figure 4-15), indicating the elevated technetium-99 activity at Well 299-E33-12 is localized. Note the groundwater samples for technetium-99 collected during drilling of Well 299-E33-340 were above the DWS and comparable to the unconfined aquifer at this location. After well completion and development, subsequent groundwater samples were well below the DWS for technetium-99. The results of groundwater samples collected during drilling of Well 299-E33-340 appear to reflect carry-down of contamination during drilling.

4.4.1.2 Waste Management Area C

Technetium-99 activity exceeding the DWS at WMA C has been present since 2002, and two different sources appear to be associated with the technetium-99 groundwater contamination. The highest technetium-99 activity was initially located to the west of WMA C but has appeared to be migrating to the southeast since 2012. As of 2013, the highest technetium-99 activity was detected at Well 299-E27-21 (Figure 4-3).

Beneath WMA C, elevated technetium-99 activity was detected in the first sample collected at Well 299-E27-14, located along the southeast side of WMA C (Figure 4-3). The first sample was collected in July 1991 with an activity of 140 pCi/L. The activity in this well slowly increased in early 1997 and first exceeded the DWS in March 2001 (Figure 4-17). A large increase in technetium-99 activity was also observed in Well 299-E27-7 (located on the east side of WMA C) in May 2001 (Figure 4-17). Technetium-99 activity exceeding the DWS on the west side of WMA C was first observed in September 2002 at Well 299-E27-13 (Figure 4-18).



Note: See Figure 4-14 for cross-section areal extent.

Figure 4-11. North-South Cross-Section L3-L3' of Technetium-99 Plume from the BY Cribs to the BX Tank Farm

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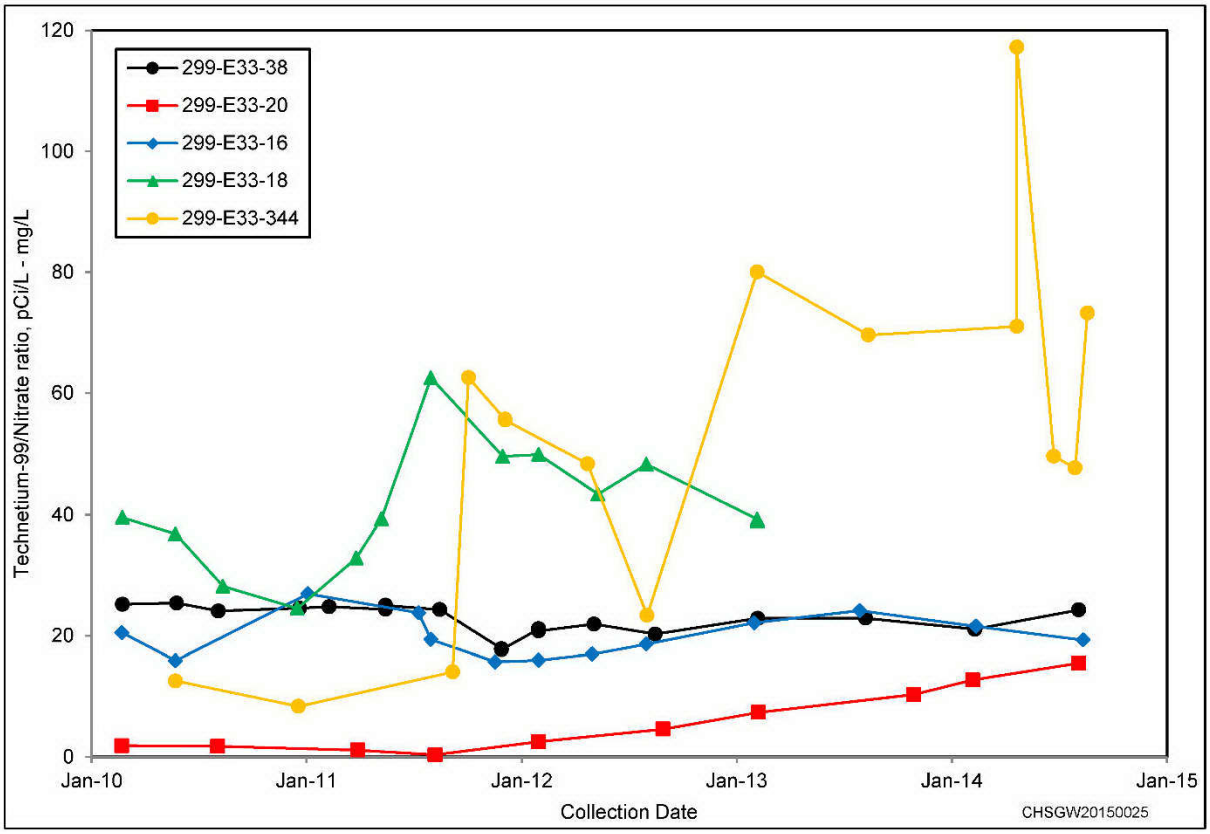


Figure 4-12. Technetium-99-to-Nitrate Ratio Comparisons for Wells near Liquid Waste Releases in the B Complex

Three major differences are noted in the technetium-99 activity and the relationship to other contaminants on the southeast side versus the west side of WMA C, suggesting different sources for contamination in those two areas of the WMA.

The first major difference in regard to the technetium-99 activity in WMA C is that the technetium-99 trend over time was nearly stable in southeast Wells 299-E27-14 and 299-E27-24 between 2002 and 2012 (Figure 4-17), while notable increases were observed along the west side of WMA C at Wells 299-E27-13 and 299-E27-23 (Figure 4-18).

The second major difference is that the technetium-99-to-nitrate ratios are different in these two areas. Technetium-99-to-nitrate ratio in Wells 299-E27-14 and 299-E27-24 remained near 50 through 2012, while the technetium-99-to-nitrate ratio in Wells 299-E27-13 and 299-E27-23 is currently at least five times higher than observed in 2008. The reason for the lower ratios at Wells 299-E27-14 and 299-E27-24 is the lower technetium-99 activity and higher nitrate concentrations. The groundwater technetium-99-to-nitrate ratios at Wells 299-E27-14 and 299-E27-24 are similar to the ratios seen in wells beneath the BY Cribs, suggesting a similar source material as beneath the BY Cribs. Further discussion on the technetium-99-to-nitrate ratios is provided in SGW-56777, *WMA C October Through December 2013 Quarterly Groundwater Monitoring Report*.

The third major difference in regard to technetium-99 activity in WMA C is that more cyanide is present in Wells 299-E27-14 and 299-E27-24 versus the wells to the west. Analyses indicate that a ferrocyanide-derived waste is affecting groundwater at Wells 299-E27-14 and 299-E27-24, while the technetium-99 plume on the west side of WMA C is more representative of PUREX-derived liquid waste.

Both technetium-99 and nitrate have migrated throughout the 15.5 m (51 ft) unconfined aquifer, based on results from Wells 299-E27-24 and 299-E27-155, which are screened along the bottom of the aquifer.

In 2010, depth-discrete groundwater samples were collected in three wells (299-E27-4, 299-E27-21, and 299-E27-23) to evaluate the variability of contamination within the aquifer to the west and south of WMA C. The depth-discrete data in two of these wells (299-E27-4 and 299-E27-21) (Figure 4-19) revealed increasing contamination with depth, similar to samples collected during drilling at Well 299-E27-155 in 2007 (Figure 4-20). The depth-discrete groundwater results in Well 299-E27-23 were different from the results from the other two wells, with similar contamination throughout the vertical profile (Figure 4-19).

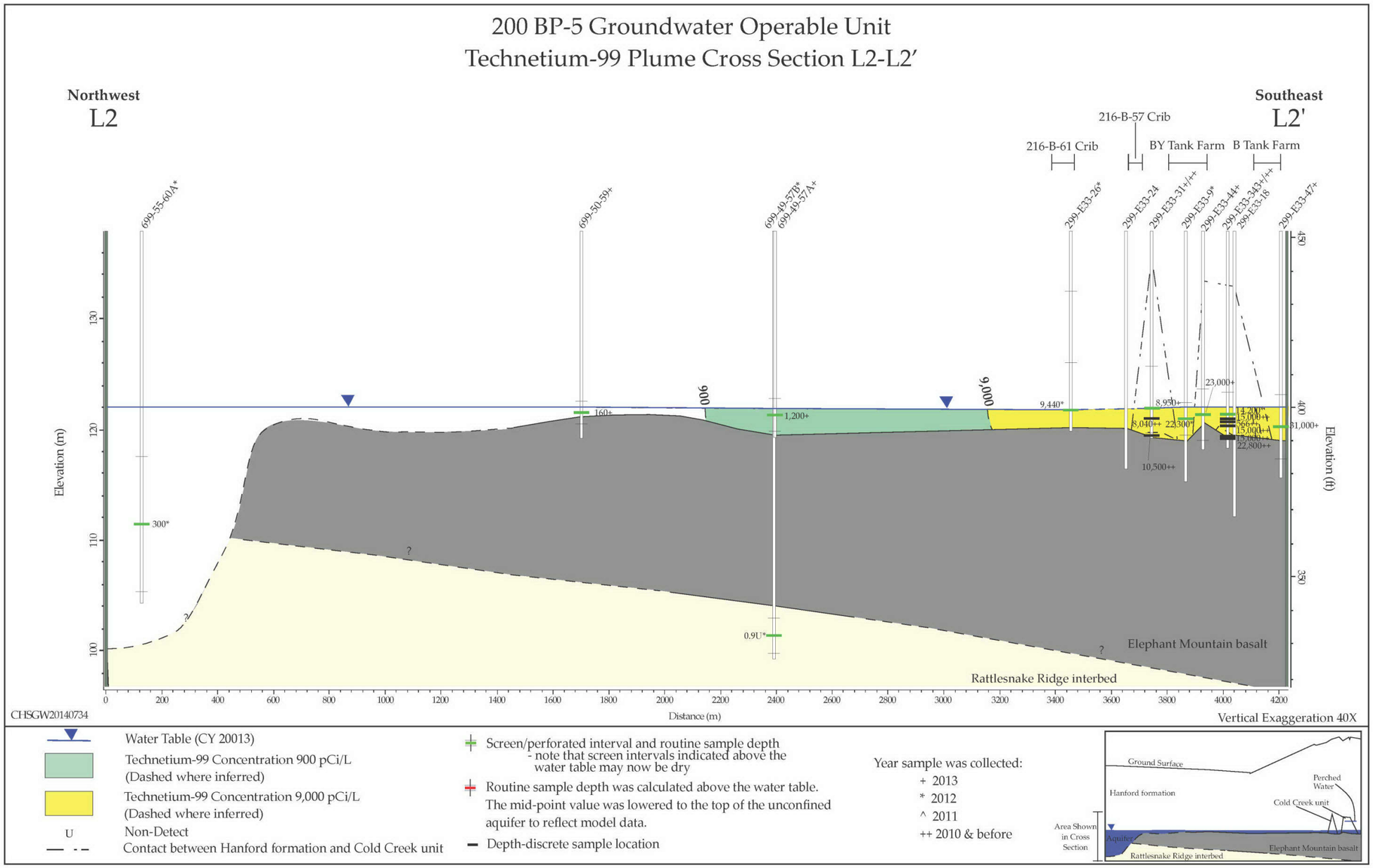
The center of the elevated technetium-99 plume at Well 299-E27-23 shifted to Well 299-E27-21 from 2012 to 2013 (Figure 4-21). This appears to be related to the groundwater flow direction change in mid-2011 in the northwest corner of the 200 East Area (Figure 4-6). Since that time, technetium-99 has been increasing at Well 299-E27-21 (Figure 4-21). In addition, the technetium-99-to-nitrate ratio at Well 299-E27-21 in December 2013 was nearly identical to the technetium-99-to-nitrate ratio observed at Well 299-E27-23 when technetium-99 was near its peak in June 2010. These observations indicate that a change in groundwater flow direction occurred to the southeast in mid-2011.

4.4.2 Nitrate

Nitrate, which originated primarily from the disposal of large volumes of nitric acid associated with nuclear fuel reprocessing waste, is elevated in the groundwater at five separate near-field areas within the 200-BP-5 OU:

- Wells at the B Complex, extending northwest beyond the 200 East Area near Well 699-49-57A and north to Wells 699-53-55B and 699-53-55C near Gable Gap
- Wells monitoring B Plant
- Wells near the 216-B-2-2 Ditch
- Wells at WMA C
- Wells monitoring Gable Mountain Pond

The majority of the sites are associated with UPRs. Only the BY Cribs and the 216-B-12 Crib were sites of intentional discharges of highly concentrated nitrate liquid waste. The following subsections discuss the characteristics associated with the releases, the migration pathways, and the extent of nitrate in the groundwater from these sites.



Note: See Figure 4-11 for cross-section areal extent.

Figure 4-13. Northwest-Southeast Cross-Section L2-L2' of Technetium Plume

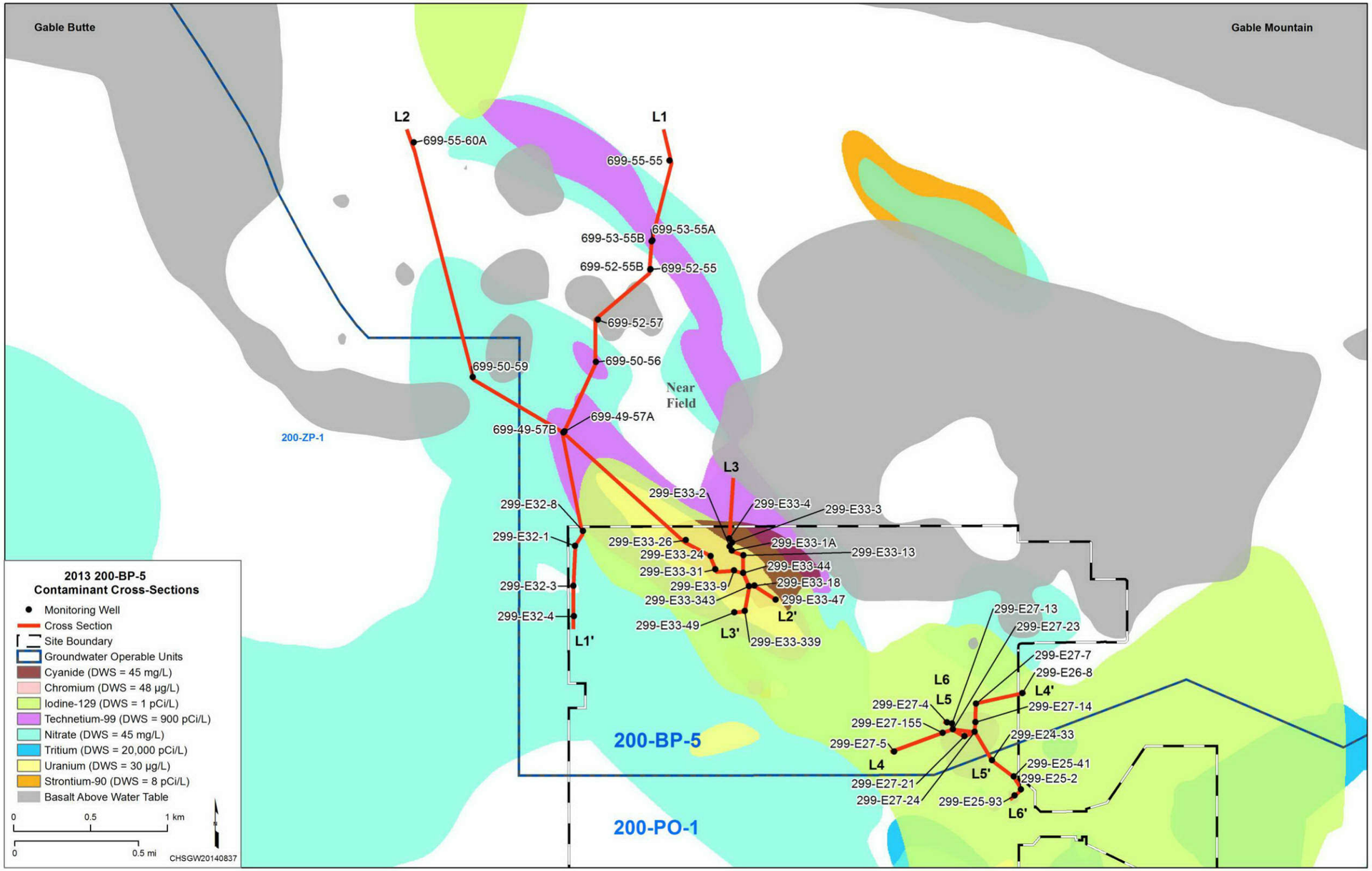


Figure 4-14. Location of Five Cross Sections Showing Contaminant Distribution in the 200-BP-5 OU

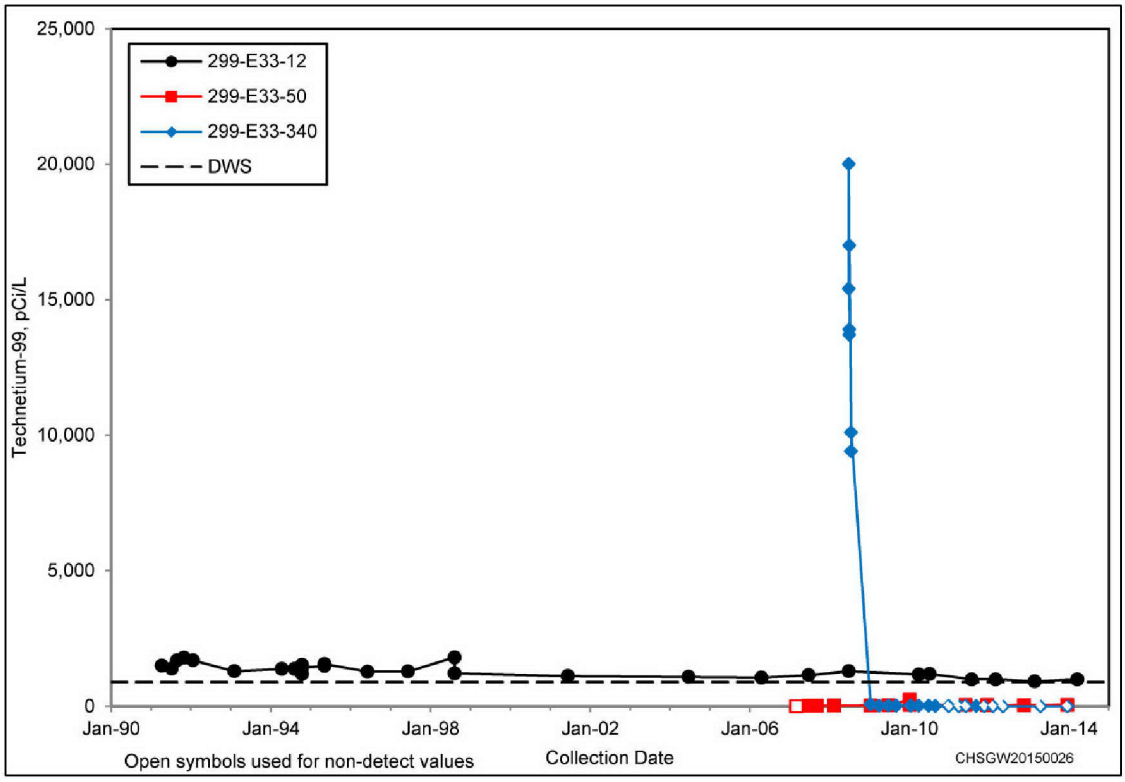


Figure 4-15. Technetium-99 Activity in Wells 299-E33-12, 299-E33-50, and 299-E33-340

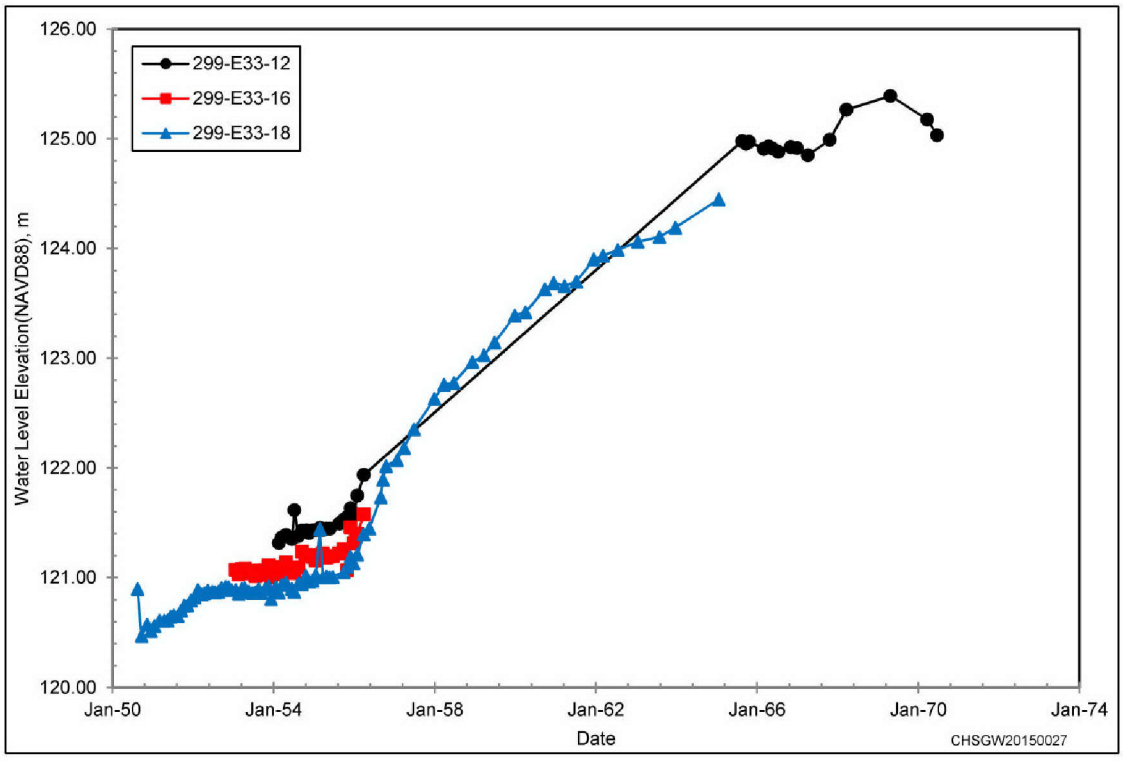


Figure 4-16. Water Levels at Wells 299-E33-12, 299-E33-16, and 299-E33-18

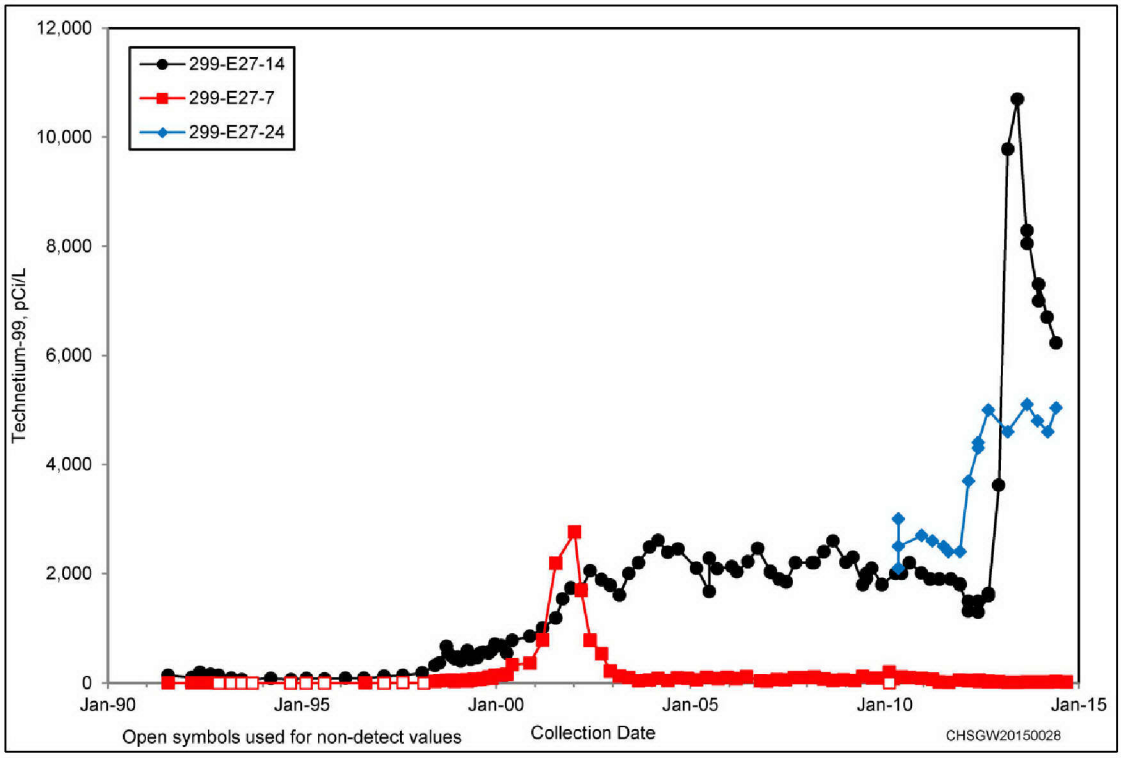


Figure 4-17. Technetium-99 Activity in Wells 299-E27-7, 299-E27-14, and 299-E27-24 on East and Southeast Side of WMA C

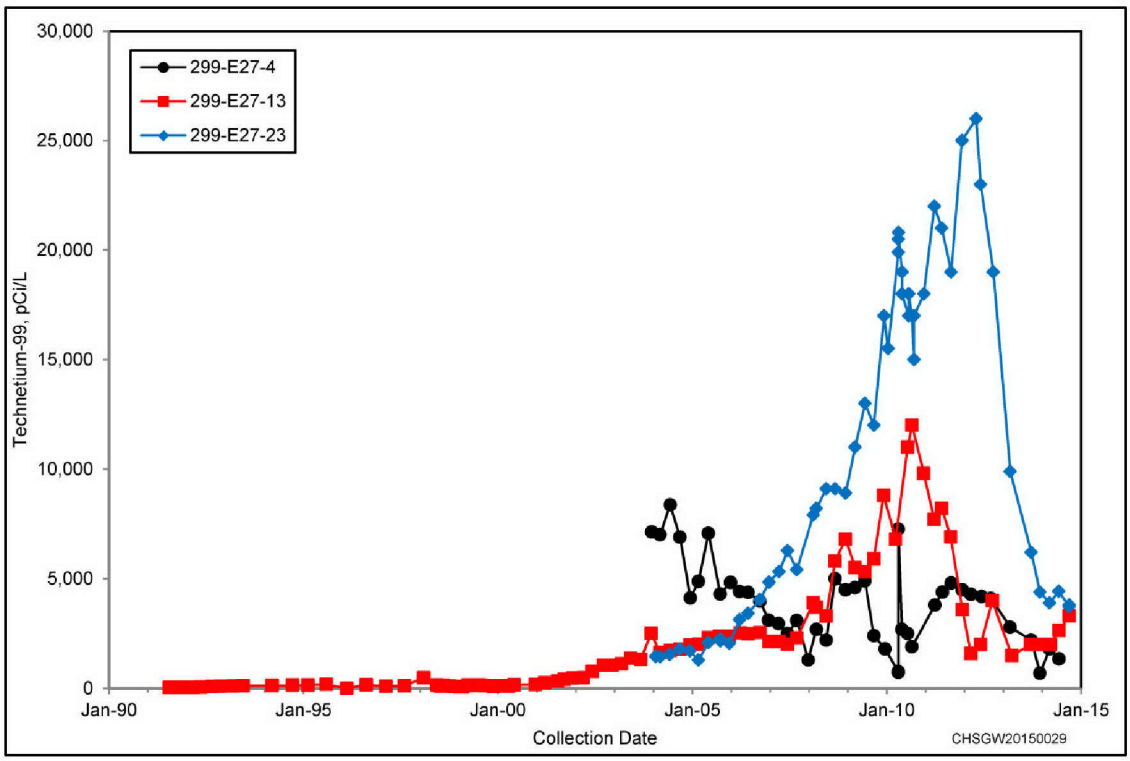


Figure 4-18. Technetium-99 Activity in Wells 299-E27-4, 299-E27-13, and 299-E27-23 on West Side of WMA C

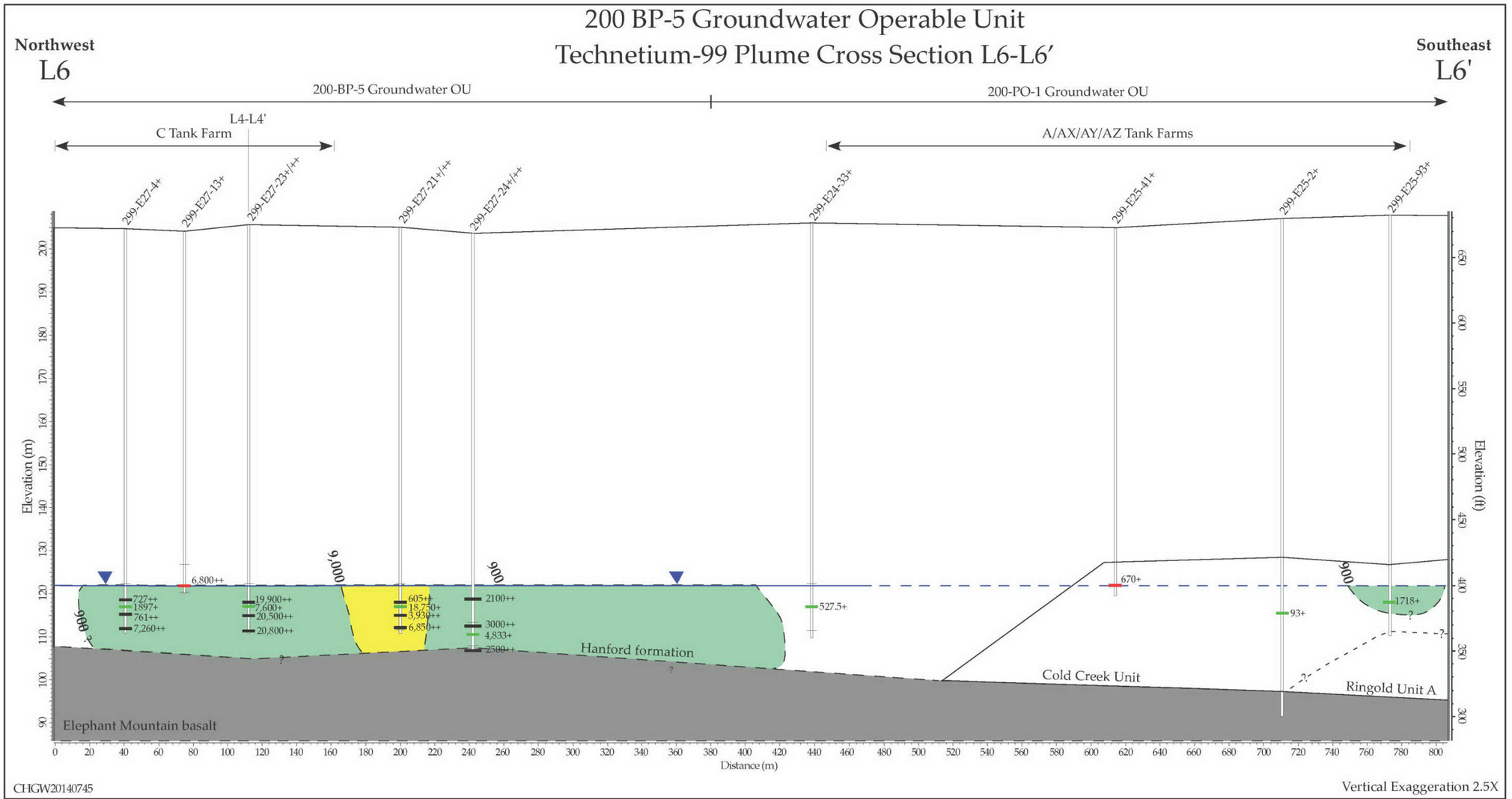


Figure 4-19. Northwest-Southeast Cross-Section L5-L5' of Technetium Plume

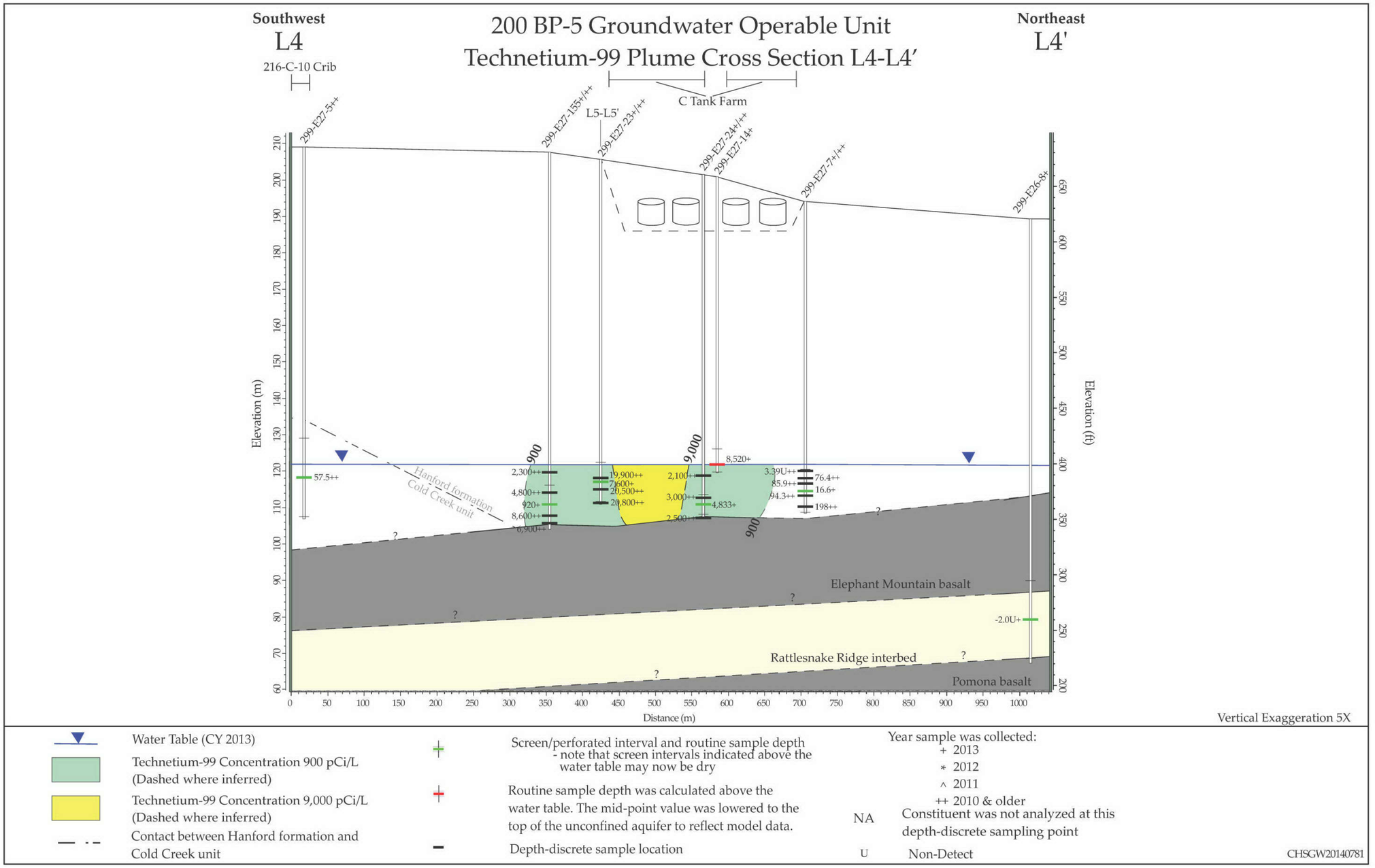


Figure 4-20. Southwest-Northeast Cross Section L4-L4' of Technetium Plume

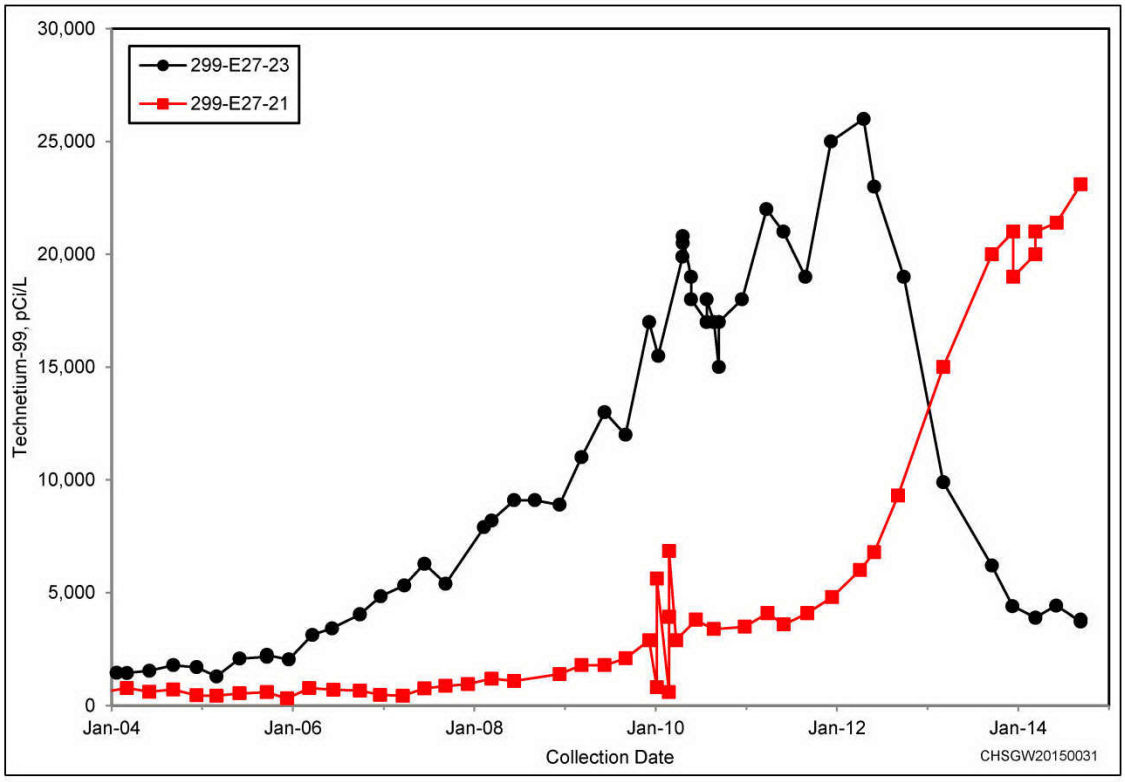


Figure 4-21. Technetium-99 Concentrations in Wells 299-E27-21 and 299-E27-23

4.4.2.1 B Complex

Nitrate exceeding the DWS at the B Complex has been present since low-activity waste discharges began in the 1940s. Three primary B Complex sources currently appear to be responsible for the majority of groundwater nitrate contamination in this area: the BY Cribs, 241-BX-102 UPR, and a release near the 241-B-105 SST. The most extensive and persistent source of nitrate contamination at the B Complex has been the BY Cribs (Figures 4-1 and 4-4). As discussed in Section 4.2, the BY Cribs liquid waste releases were associated with reprocessed high-activity waste to create storage space in the B-BX-BY Tank Farms due to limited tank capacity. The other two notable releases affecting groundwater were low-volume UPRs of high-concentration liquid waste. Less concentrated contributors of nitrate include the 216-B-7A&B and 216-B-8 Cribs. Although other waste sites in the area have also released nitrate, the volume and concentrations associated with these releases were either an order of magnitude less in concentration and/or volume and, therefore, are only considered to be minor contributors to the plumes within the B Complex.

Since groundwater sample collection began near the B Complex, nitrate concentrations have been the highest near the BY Cribs. In the late 1950s, concentrations ranged between 37 to 13,000 mg/L. Nitrate was sampled intermittently near the BY Cribs until the 1980s. In the late 1980s and early 1990s, regular sampling resumed at some wells beneath the BY Cribs. Nitrate concentrations continued to increase until leveling off in 2010. Concentrations of up to 1,700 mg/L were reported in wells below the BY Cribs between 2010 and 2012. The high concentrations are likely from continued transport of nitrate from the vadose zone, nearly stagnant groundwater flow, and the significant decrease in the aquifer thickness (e.g., 2 m [6.6 ft] or less). The groundwater elevation decline was associated with operation reductions and eventual termination, which resulted in a 3.1 m (10 ft) drop in the water elevation in the 200 East Area from the late 1980s to 2013. Note that the high concentrations from 2010 through 2012 were about

an order of magnitude less than the maximum concentrations in the 1950s, with about the same water table elevation at present as were observed in the 1950s. A 2010 north-south cross section of the nitrate plume in the B Complex is provided in Figure 4-22.

Further to the southeast, substantial nitrate concentrations (e.g., 46 to 170 mg/L) were reported in Well 299-E27-1 near the Semiworks Facility in the early 1960s (Figure 4-3); however, the concentrations were likely associated with the 216-C-1 Crib, as this crib received an average derived nitrate disposal concentration ranging between 10 and 14 g/L from 1952 to 1957. The total volume of liquid waste received was 23,400,000 L (6,181,626 gal), which was calculated at approximately 30 times the vadose pore space capacity beneath this crib. This site was investigated in 2010 with an RI borehole/well (299-E24-25), and nitrate concentrations were found to be less than DWS throughout the vertical extent of the aquifer.

Based on nitrate concentrations measured in Well 699-50-53A, the preferential groundwater flow direction during the mid- to late 1950s was considered to be northward from the BY Cribs toward Well 699-50-53A. Water level elevations between Well 299-E33-14 (east of the BY Cribs) and Well 699-50-53A indicate a north flow direction until the latter part of 1959 (Figure 4-23). In 1959, increased liquid discharges to Gable Mountain Pond and the 116-K-2 Trench appeared to be responsible for the flattening water table. The conceptual extent of nitrate near Well 699-50-53A (sample dry since the mid-1990s) in 2013 is shown in Figure 1-3; the extent is based on the mid-1990s nitrate concentrations at Well 699-50-53A and the 2013 nitrate concentrations at Wells 699-53-55C and 699-55-57 (Figure 4-24). The decrease between Wells 699-50-53A and 699-53-55C is due to the increased aquifer thickness at Well 699-53-55C (approximately five times thicker) (Figure 4-25).

As Gable Mountain Pond discharges were diminished in 1985 and discontinued in 1987, groundwater flow from the B Complex began to migrate to the northwest instead of northward. A significant nitrate plume migrated toward Gable Gap. The 2010 extent of the plume is shown in Figure 4-26, and the 2013 extent is shown in 1-3.

As the water table in 200 East Area returns to pre-Hanford operation levels, the water table has declined below high Columbia River spring stages. The lower 200 East Area water table and the transmissive saturated sand and gravels deposited by the ancestral Columbia River provide a pathway (paleochannel) for the propagation of high Columbia River levels into the 200 East Area. The head propagation diminishes along the saturated paleochannel but is still observed in water level differences along the pathway between the river and the 200 East Area wells. Since mid-2011, a south-southeast flow direction has been maintained in the northwest corner of the 200 East Area. This groundwater flow reversal has resulted in a contraction of the nitrate plume extent northwest of the 200 East Area and decreasing nitrate concentrations beneath the BY Cribs. In addition, the high-concentration area that was previously beneath the BY Cribs from 2009 to 2011 has migrated to the southeast similar to technetium-99, as discussed in Section 4.4.1.1.

Near the BY Cribs, ferrocyanide scavenged waste was also known to have migrated from the vadose zone, through the unconfined aquifer and the uppermost basalt formation, and into the upper confined aquifer at Well 299-E33-12. The mechanism of migration was through the unsealed borehole adjacent to the well casing. Well 299-E33-12 was properly sealed by perforating the carbon-steel casing with a cement grout seal in 1979. Similar to technetium-99 (described in Section 4.4.1.1), two RI wells, 299-E33-50 and 299-E33-340, were installed in the confined aquifer and have shown low nitrate concentrations, indicating only localized contamination at Well 299-E33-12.

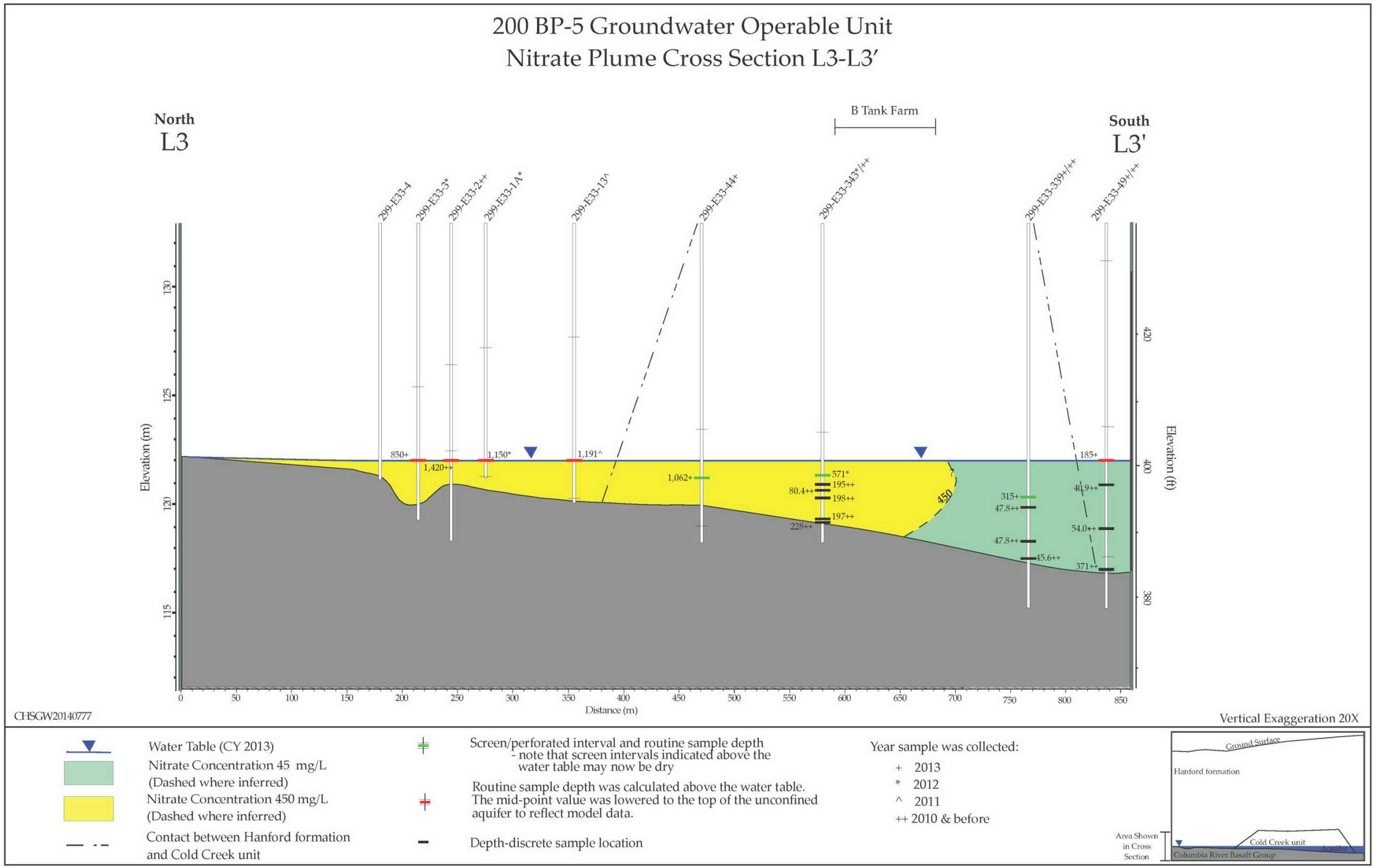


Figure 4-22. North-South Cross-Section L3-L3' of Nitrate Plume

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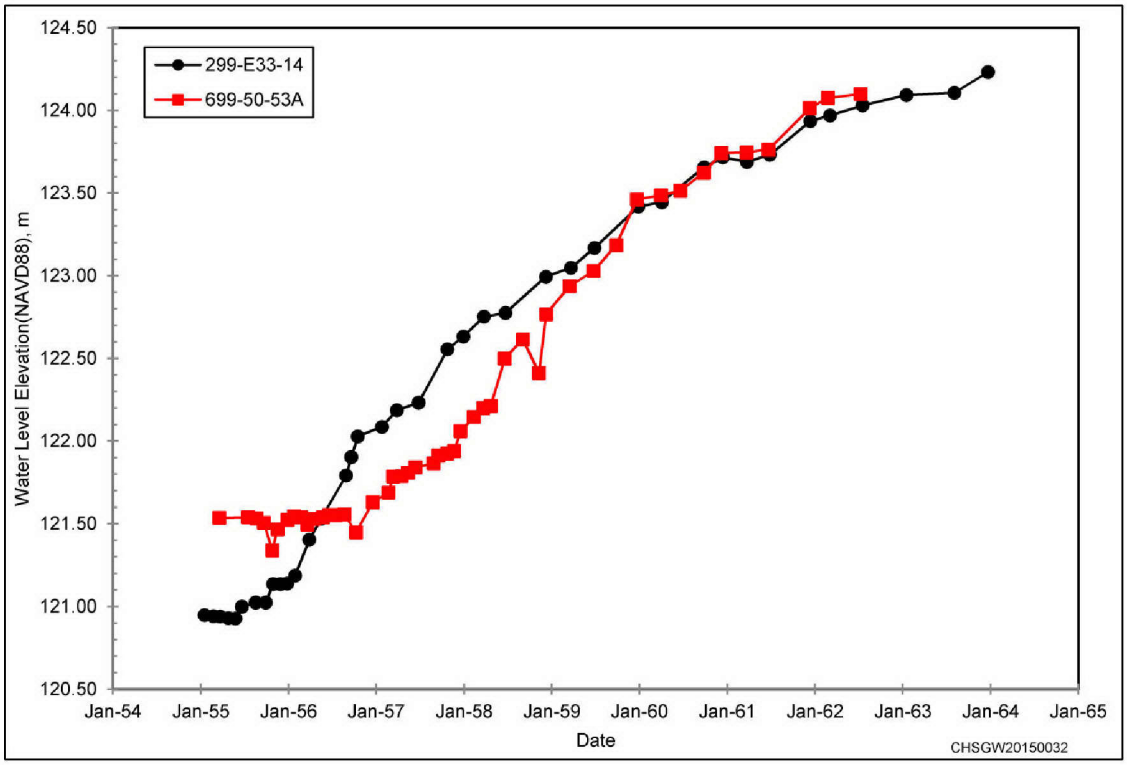

Figure 4-23. Water Elevation Trend Plot between Wells 299-E33-14 and 699-50-53A, East of the BY Cribs

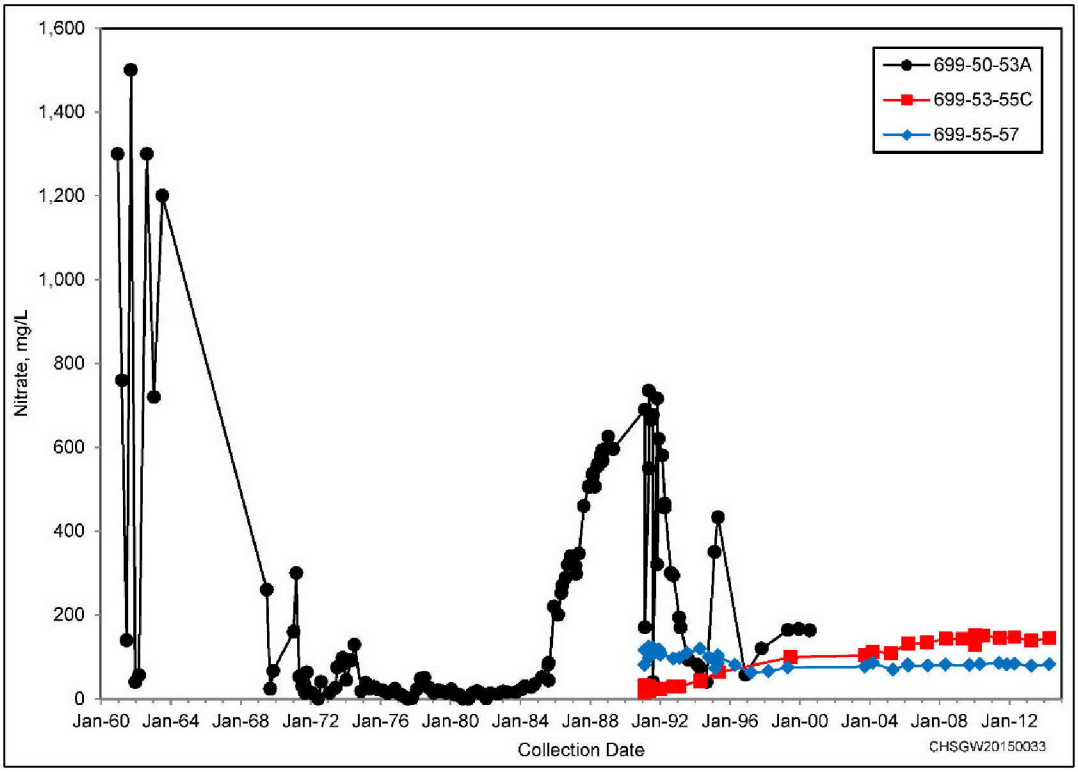

Figure 4-24. Nitrate Concentrations in Wells 699-50-53A, 699-53-55C, and 699-55-57, 1985 through 2013

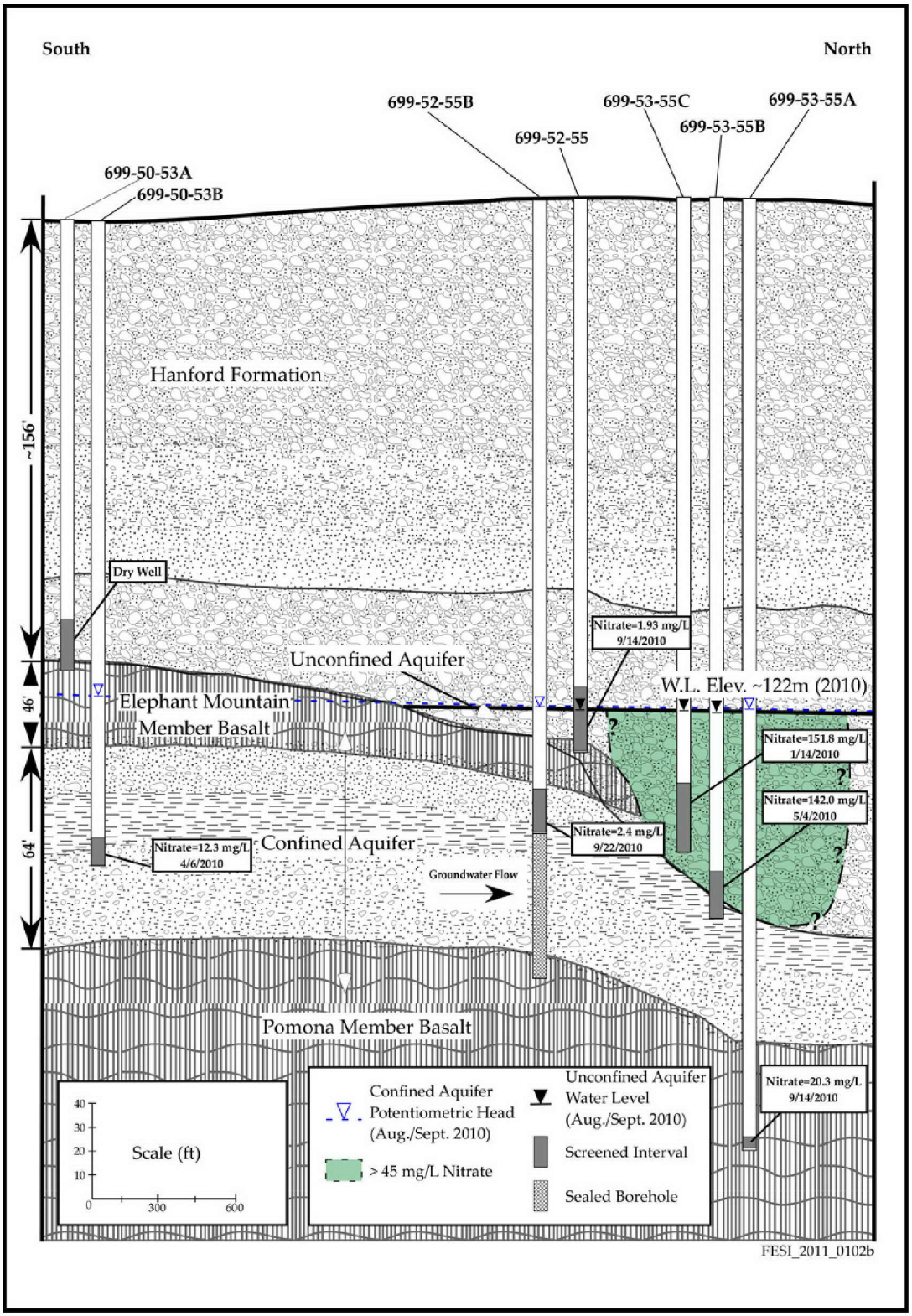

Figure 4-25. Conceptual Model of Nitrate Plume Migration at the Basalt Window near Well 699-53-55

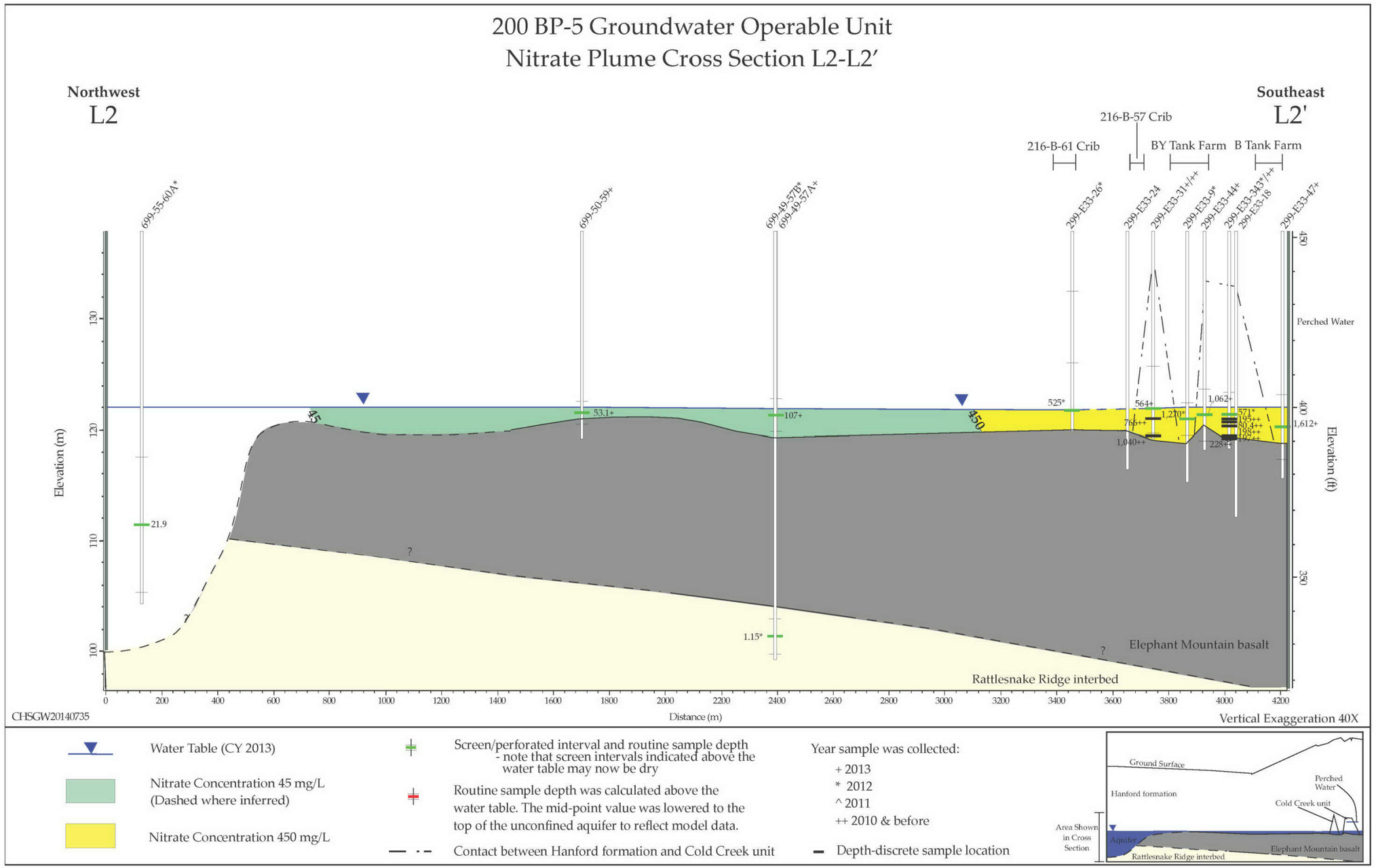

Figure 4-26. Northwest-Southeast Cross Section of L2-L2' Nitrate Plume

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4.4.2.2 B Plant

Nitrate exceeding the DWS beneath the B Plant area was first detected in the 1950s. One primary source, the 216-B-12 Crib, appears to be responsible for the highest nitrate contamination in this area. Historical groundwater monitoring results suggest three primary sources of nitrate in the B Plant area that have impacted groundwater: 216-B-5 Reverse Well (in the 1940s), 216-B-12 Crib (in the 1950s), and 216-B-62 Crib (in the 1970s and 1980s). None of these sites appear to be continuing sources of contamination; however, nitrate concentrations still exceeding 10 times the DWS in this area appear to be related to early releases from the 216-B-12 Crib.

The 216-B-12 Crib was activated in 1952. The first groundwater well near the crib, 299-E28-9, was installed in 1957. The first groundwater sample from this well (in October 1957) had a nitrate concentration of 1,500 mg/L (Figure 4-27). A maximum concentration of 5,500 mg/L was detected in April 1958. By October 1957, approximately 370 million L (98.2 million gal) of liquid process condensate waste containing nitrate (average nitrate concentration of 7 to 8 g/L) had been disposed to this crib (RPP-26744). By comparison, this crib received about 42 percent of the total nitrate inventory disposed to all nine of the BY Cribs with less than one-half of the waste site surface area. Over time, continued discharges to the 216-B-12 Crib may have provided sufficient hydraulic head to drive nitrate contamination into the deeper, less permeable portion of the Ringold sediments within the unconfined aquifer. In 2010, RI depth-discrete sampling at Well 299-E28-30 displayed nitrate contamination as high as 822 mg/L (Figure 4-28).

Nitrate in the deeper portion of the unconfined aquifer beneath the 216-B-12 Crib and B Plant appears to be migrating eastward and may be associated with the nitrate concentrations observed in 2013 at Well 299-E28-24 (near the 216-B-5 Reverse Well) (Figure 4-29). This well is screened between 7.6 and 9.1 m (25 to 30 ft) below the water table. Significantly high nitrate concentrations (greater than 10 times the DWS) are not observed in other wells in this area, which have longer screens and are mainly screened across the upper portion of the unconfined aquifer.

4.4.2.3 216-B-2 Ditches

Nitrate concentrations exceeding the DWS beneath the 216-B-2 Ditches (Figures 4-1 and 4-3) have been present since 1997 (Figure 4-30). As discussed in Section 4.2.3, large volumes of mainly cooling water infiltrated into the sand-and-gravel-lined 216-B-2-3 Ditch and apparently remobilized nitric acid from two previous UPRs (UPR-200-E-32 and UPR-200-E-138). As a result, it appears that groundwater nitrate concentrations exhibited a substantial increase in 1997 at Well 299-E34-7 (located approximately 400 m [1,323 ft] north of the 216-B-2-2 Ditch) (Figure 4-30). Nitrate concentrations at Well 299-E34-7 peaked at 142 mg/L in 2002. Since the notable nitrate increases in 1997 at Well 299-E34-7, other wells near the 216-B-2-2 Ditch have also shown increased nitrate concentrations (Figure 4-30). The 2013 nitrate plume defined by the DWS in this area is shown in Figure 1-3.

4.4.2.4 Waste Management Area C

Nitrate concentrations exceeding the DWS at WMA C have been present since the early 2000s. At least two different sources appear to be associated with the nitrate groundwater contamination, both associated with WMA C: releases of ferrocyanide scavenged waste, and PUREX Plant liquid waste. The ferrocyanide scavenged waste contained significant amounts of nitrate and has been shown to exceed two times the DWS at WMA C. During PUREX Plant operations, nitric acid was recovered as a cost-savings process; thus, released liquid waste from this process only approaches or slightly exceeds the DWS. Both plumes have extended to the bottom of the aquifer at WMA C.

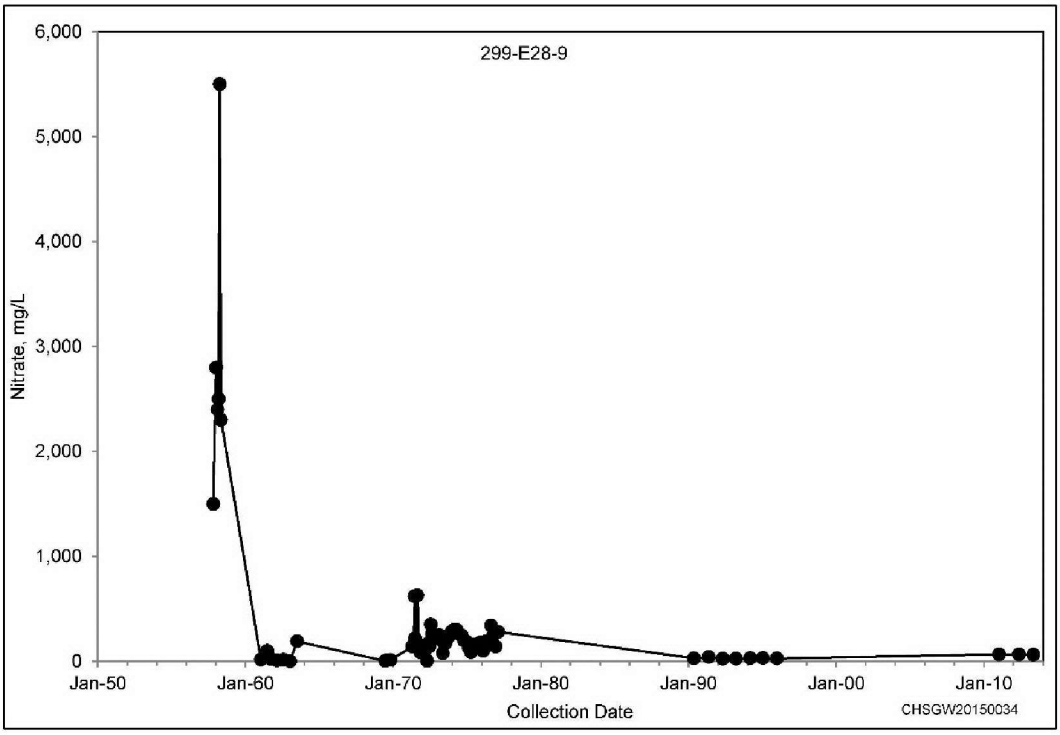

Figure 4-27. Nitrate Concentrations in Well 299-E28-9

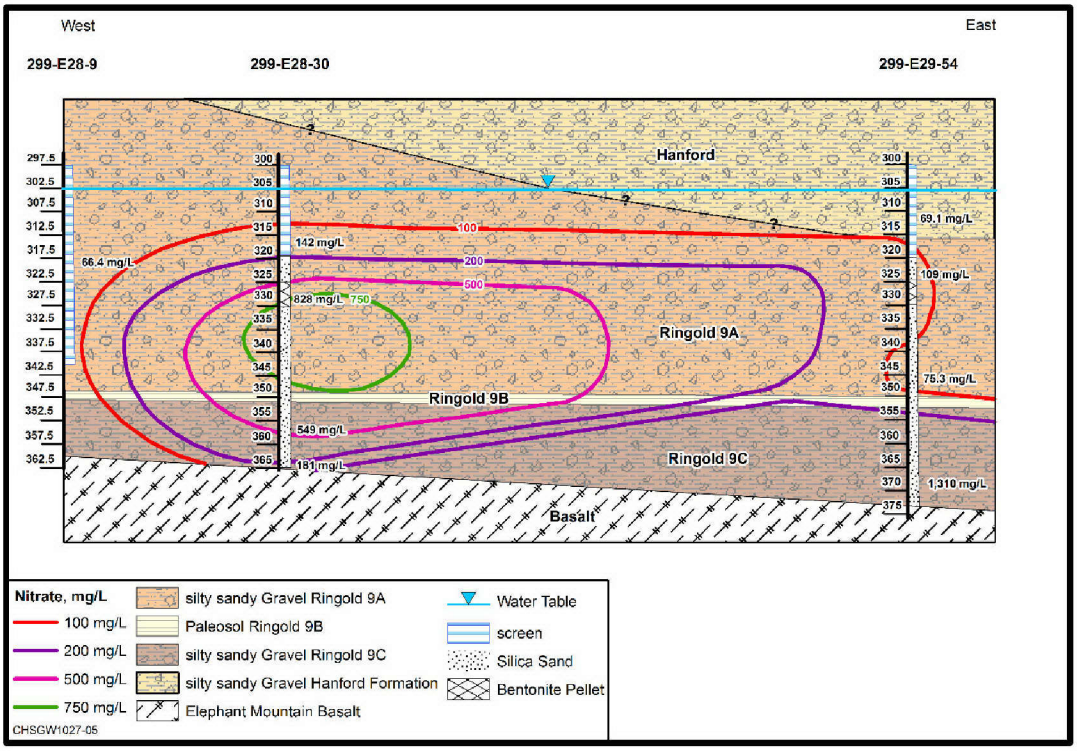

Figure 4-28. Conceptual Nitrate Distribution Based on Depth-Discrete Samples during Drilling at Wells 299-E28-30 and 299-E29-54 in 2010

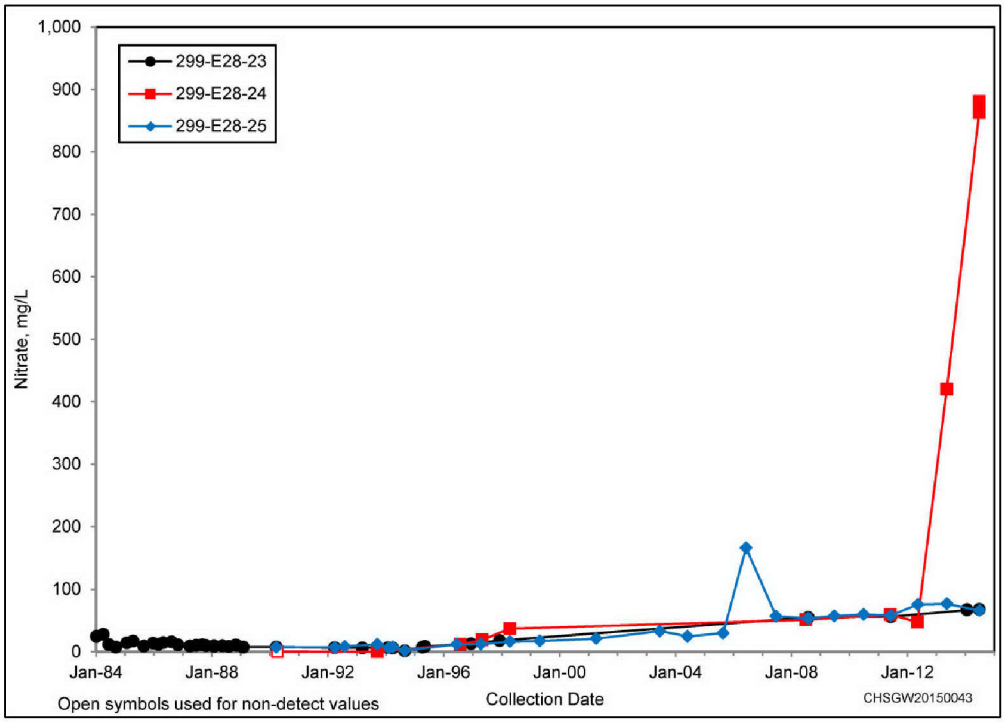

Figure 4-29. Nitrate Concentrations in Wells 299-E28-23, 299-E28-24, and 299-E28-25 near the 216-B-5 Reverse Well

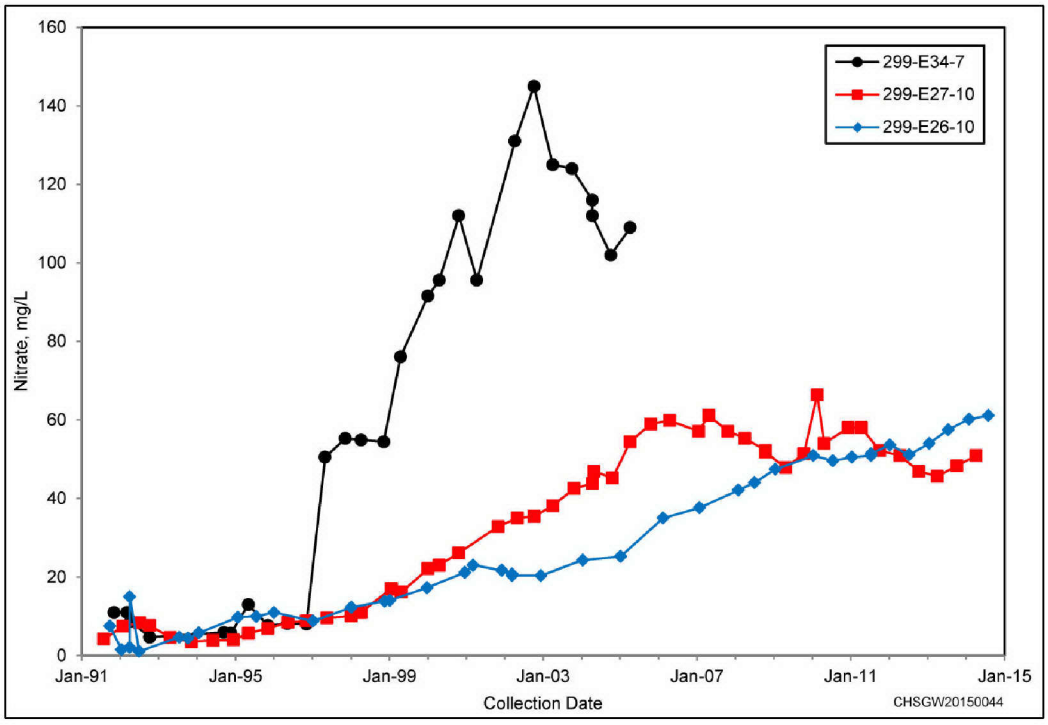

Figure 4-30. Nitrate Concentrations in Wells 299-E34-7, 299-E27-10, and 299-E26-10 near the 216-B-2 Ditches

The highest groundwater nitrate concentrations are located to the southeast of WMA C, near Well 299-E27-14 (Figures 4-1 and 4-3). Nitrate concentrations at Well 299-E27-14 increased from 12.4 mg/L in the fall of 1998 to the DWS by June 2003 (Figure 4-31). Since 2006, high-concentration peaks have occurred in the fall. Nitrate concentrations at Well 299-E27-24 (average of 70 mg/L), located approximately 60 m (197 ft) south of Well 299-E27-14, are generally 20 to 30 mg/L less than those detected at Well 299-E27-14. When compared with the other WMA C monitoring wells, the nitrate results and chemical ratios (cyanide to nitrate ratio) (Figure 4-32) at Wells 299-E27-14 and 299-E27-24, indicate a local source of nitrate affecting groundwater near these wells.

Two wells (299-E27-24 and 299-E27-155) installed between 2007 and 2010 indicate that nitrate contamination appears to have preferentially migrated down through the aquifer near WMA C. Well 299-E27-24 was installed in the spring of 2010, and depth-discrete samples were collected during drilling at depths of approximately 3.9, 10, and 15.6 m (12.9, 32.9, and 51.1 ft) beneath the water table. The nitrate analytical results increased with depth, ranging from just below the DWS for the first interval, 59.4 mg/L at the intermediate depth, and 73.1 mg/L in the deepest sample interval. Further west of WMA C, groundwater nitrate samples at Well 299-E27-155 were first collected in 2007 when the well was drilled. The samples were collected at 3.4, 7.9, 14.1, and 16.5 m (11, 26.5, 46.5, and 54 ft) below the water table. Results for this well also increased with depth, from 20 mg/L near the surface to values equivalent to the DWS at the bottom of the aquifer.

The depth-discrete groundwater samples collected during the drilling of Wells 299-E27-24 and 299-E27-155 are consistent with 2010 depth-discrete samples collected at Wells 299-E27-4, 299-E27-7, 299-E27-21, and 299-E27-23. Depth-discrete results from several of these wells are provided in Figure 4-33. In general, the results indicated increasing concentrations with depth, except at Well 299-E27-14 where high concentrations indicate that this well is near a nitrate source beneath WMA C.

4.4.2.5 Gable Mountain Pond

Gable Mountain Pond was located to the north of the 200 East Area (Figure 4-3). Nitrate concentrations exceeding the DWS beneath the former Gable Mountain Pond were first observed in the mid-1980s and have been continuously present since the early 1990s (Figure 4-34). Nitrate concentrations beneath the former Gable Mountain Pond have decreased steadily since the mid-1990s, with the highest concentrations detected in Wells 699-53-47A/B and 699-53-48A/B. These wells are located in the southeastern portion of the former Gable Mountain Pond, where the pipeline outfall was located.

The aquifer thickness beneath the site ranges from 2 to 13 m (6 to 45 ft), with the thinnest part of the aquifer near the abandoned outfall pipe and the deepest part of the aquifer to the northwest. All of the wells are screened in the upper 4 m (13 ft) of the aquifer. Concentrations at Well 699-54-49, near the central portion of the former pond, declined to approximately 51 mg/L as of July 2013 (Figure 4-34). This well is screened across half of the aquifer, and the aquifer thickness at the well site is approximately 6 m (20 ft).Currently and historically, nitrate concentrations decrease to the northwest of Gable Mountain Pond as the aquifer thickness increases (e.g., nitrate concentrations over time detected in Well 699-55-50C [Figure 4-35]). The 2013 plume extent is shown in Figure 1-3.

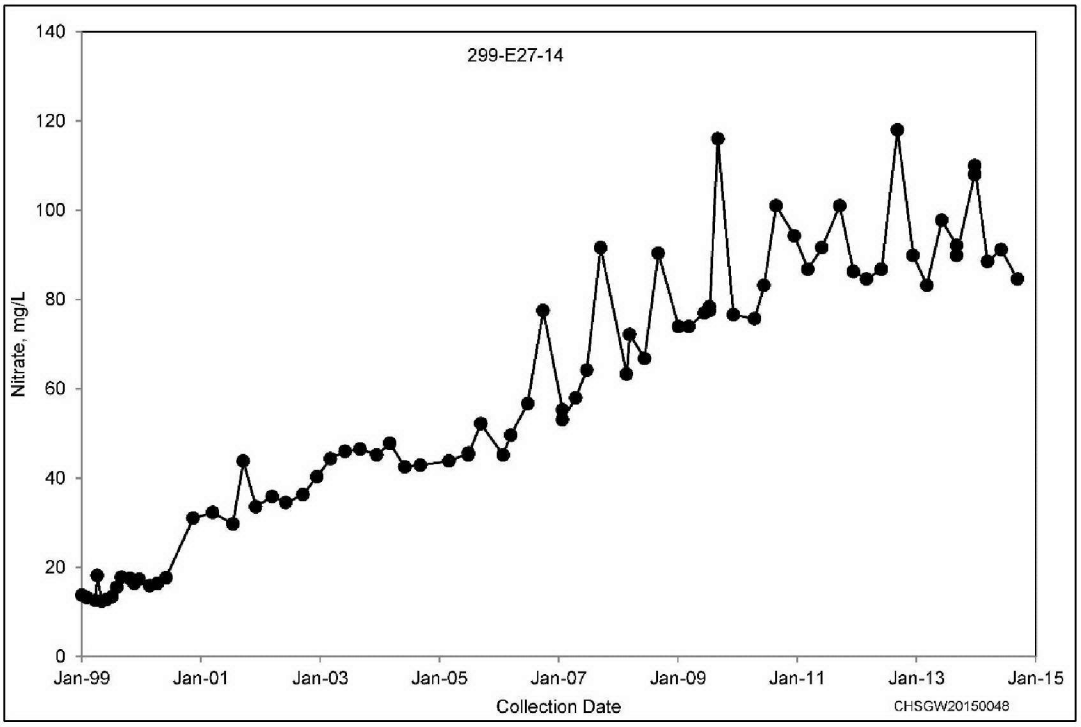

Figure 4-31. Nitrate Concentrations in Well 299-E27-14, Located along the WMA C Southeast Border

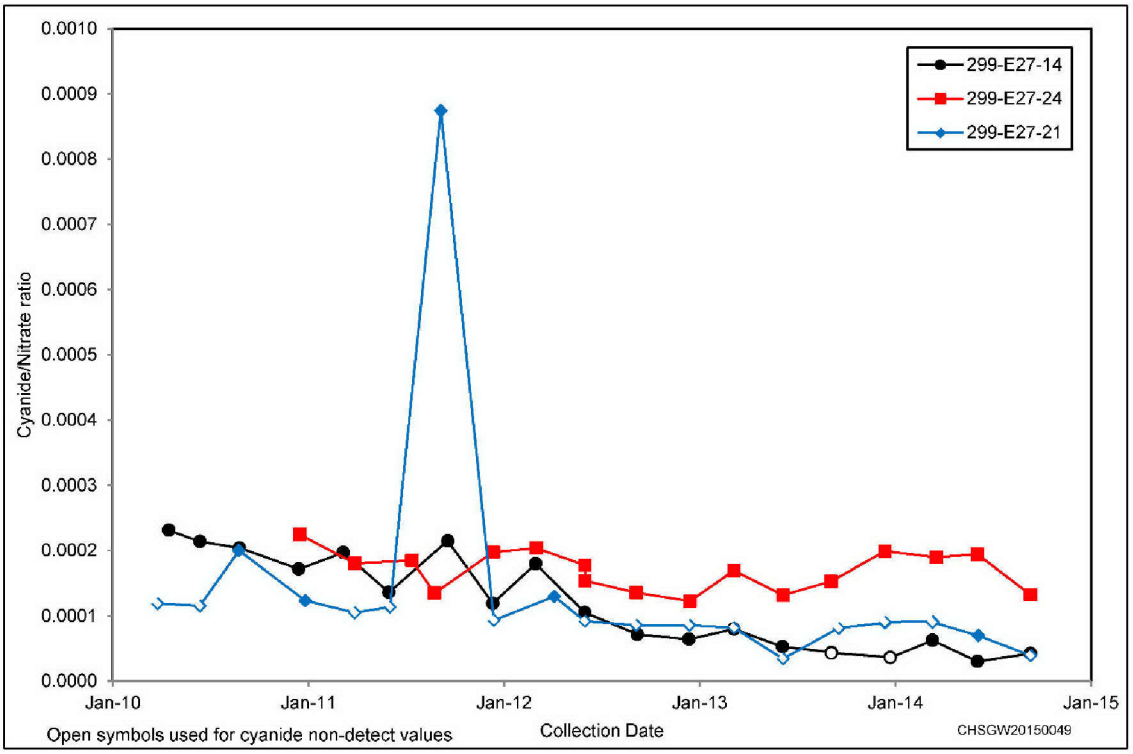

Figure 4-32. Cyanide-to-Nitrate Ratio Comparison at Wells 299-E27-14, 299-E27-21, and 299-E27-24

4.4.3 Iodine-129

High iodine-129 activity was released in two areas overlying the OU: the B Complex and WMA C (RPP-26744). Although several sites within these areas had considerable iodine-129 inventory, observations indicate that these sites have not substantially affected groundwater quality. The majority of the iodine-129 currently present within the OU appears to have migrated from the 200-PO-1 OU in the mid- to late 1980s and early 1990s. The 2013 distribution of iodine-129 above the 1 pCi/L DWS is shown in Figure 4-1. Elevated groundwater levels of iodine-129 also exist beneath B Pond, although not consistent with the inventory described in RPP-26744. The iodine-129 present at B Pond appears to be associated with discharges from the PUREX Plant (located within the 200-PO-1 OU), as considerable levels of iodine-129 are present beneath the 216-A-29 Ditch leading to B Pond.

4.4.3.1 B Complex

Iodine-129 activity exceeding the DWS at the B Complex has been present since the late 1980s (Figure 4-36). Three possible B Complex sources for iodine-129 in groundwater are the BY Cribs, the 241-BX-102 release (UPR-200-E-5), and the release near the 241-B-105 Tank. These sources were considered the most likely to impact groundwater due to high-activity iodine-129 that was released, which ranged from approximately 3,000 to 5,000 pCi/L (RPP-26744). In addition, these three potential sources of iodine-129 were evaluated because other mobile contaminants from these sources are currently impacting groundwater (e.g., technetium-99).

High levels of iodine-129 released from the 241-BX-102 UPR did not appear to notably impact groundwater based on the comparison of other contaminants that also had high-inventory release volumes, high contaminant levels within the perched water horizon, and were not associated with waste sites beyond the extent of the perched water horizon. The two contaminants meeting these criteria were uranium and fluoride. Wells 299-E33-343, 299-E33-344, and 299-E33-18 provide contaminant results for comparison in the perched horizon and the unconfined aquifer. Based on the observations associated with these contaminants, contaminant levels are generally one to two orders of magnitude lower in the unconfined aquifer than in the perched horizon. This difference is attributed to the mixing of contaminated infiltrating pore water from the perched horizon with less contaminated aquifer water. In addition, the mixing is not one-to-one because of the larger volume of water in the aquifer than infiltrating pore water.

Uranium, sourced from the 241-BX-102 UPR, ranged between 27,000 and 100,000 µg/L in the perched horizon since 2011 at Well 299-E33-344. Even higher uranium pore water results were collected within the perched horizon during drilling at Well 299-E33-343 (PNNL-19277). However, the highest uranium concentrations in groundwater have been 5,500 µg/L at Well 299-E33-343. By comparison, there is at least an order-of-magnitude difference in pore water results versus groundwater for uranium.

Fluoride, sourced from the 216-B-7A&B Cribs, ranged between 5,000 and 107,000 µg/L in the perched horizon at Well 299-E33-344. The highest fluoride concentration in the unconfined aquifer has never exceeded 500 µg/L. By comparison, there is at least an order-of-magnitude difference in pore water results versus groundwater for iodine-129.

Based on this evaluation, iodine-129, which has never exceeded 5 pCi/L in the perched horizon, would not be expected to exceed 0.5 pCi/L in the groundwater. Also, because the iodine-129 inventories are similar for the BY Cribs and the 241-BX-102 UPR, it appears that iodine inventories for these likely sources are not sufficient to impact groundwater at levels above the DWS. However, based on the discussion in Section 4.4.3.2, iodine-129 migration from the 200-PO-1 OU appears to be a likely alternative for the elevated iodine-129 currently found in the B Complex.

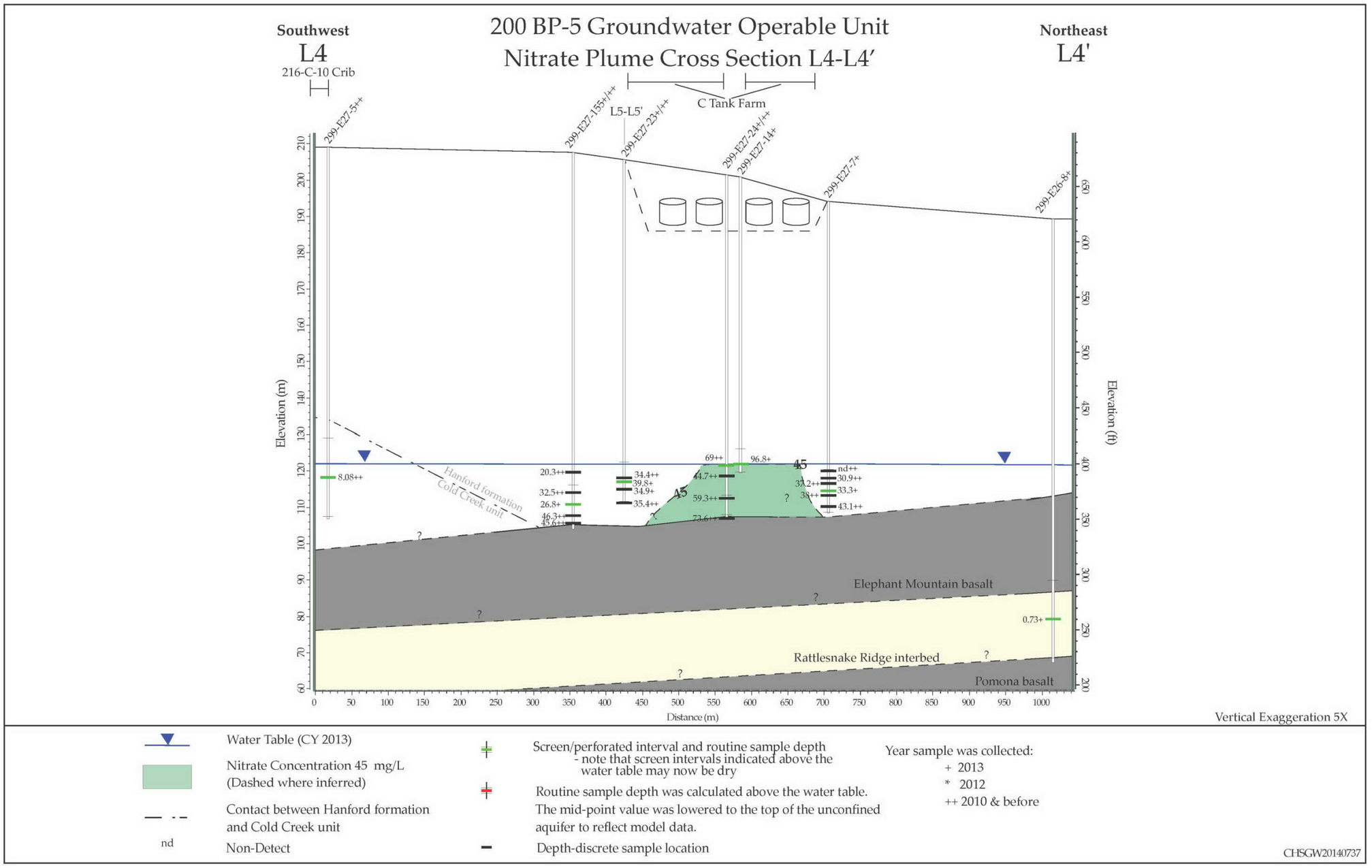

Figure 4-33. Southwest-Northwest Cross Section of L4-L4' Nitrate Plume

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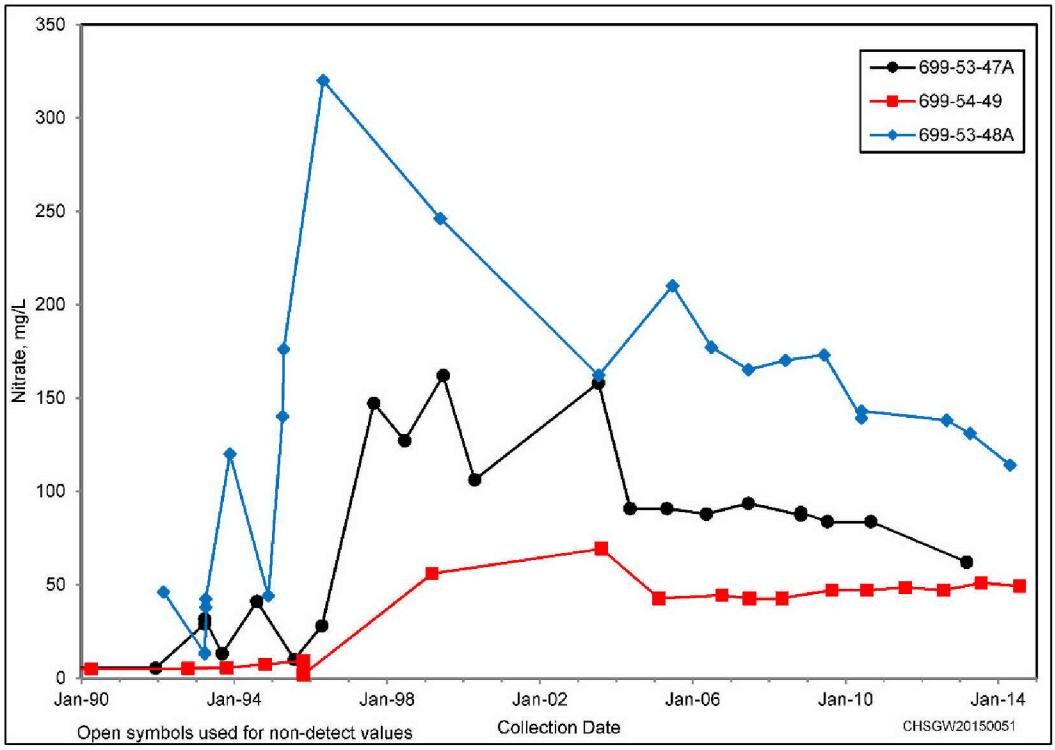

Figure 4-34. Nitrate Concentrations in Wells 699-53-47A, 699-54-49, and 699-53-48A

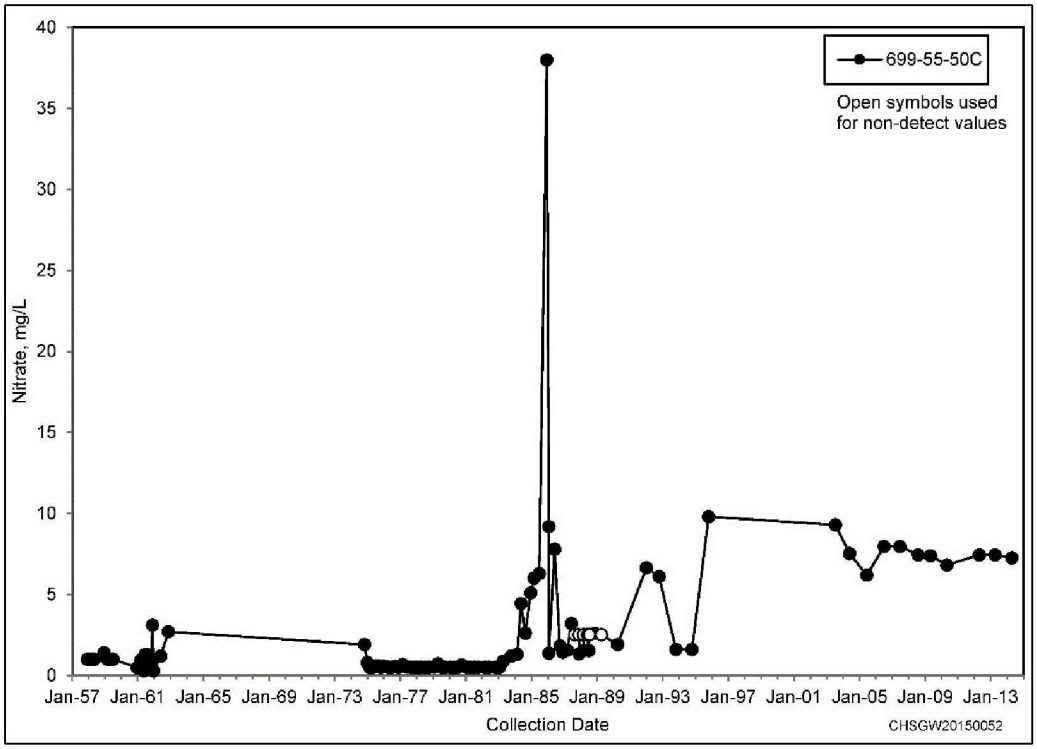

Figure 4-35. Nitrate Concentrations in Wells 699-55-50C

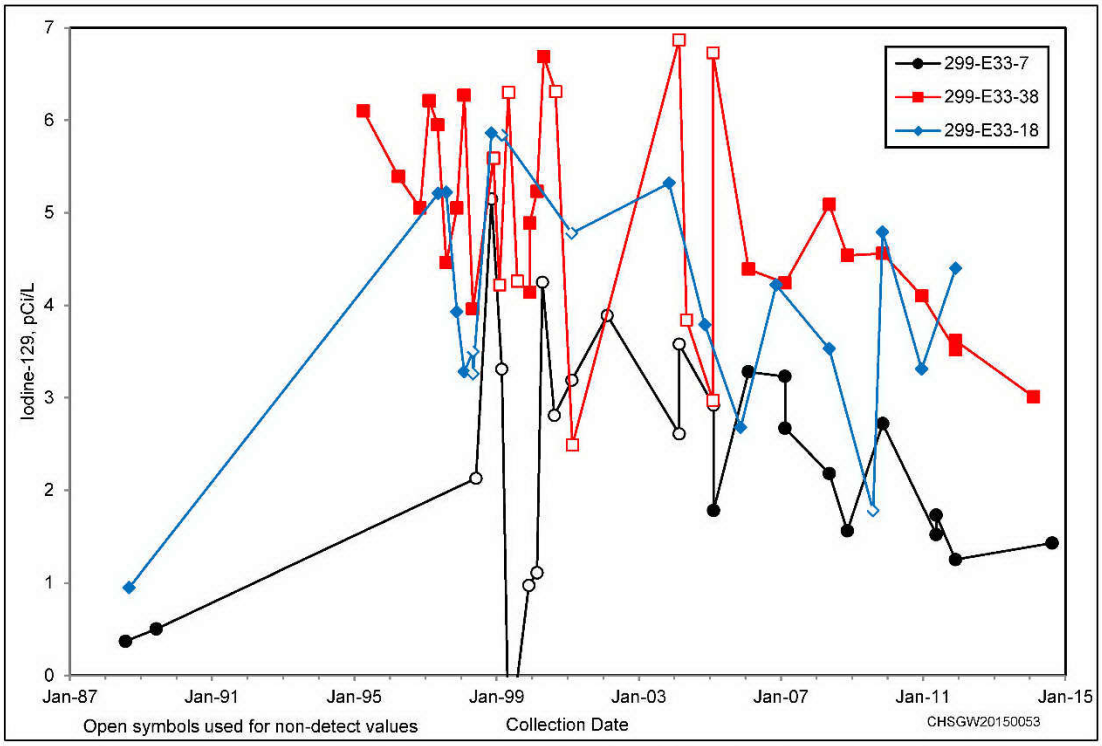

Figure 4-36. Iodine-129 Activity at Wells 299-E33-7, 299-E33-38, and 299-E33-18

4.4.3.2 Waste Management Area C

High activity iodine-129 releases at WMA C have occurred and are associated with UPRs. The average activities associated with these releases were two orders of magnitude greater than those at the B Complex (4,000 to 700,000 pCi/L) (RPP-26744). However, iodine-129 activity in groundwater has been relatively unchanged at the WMA C monitoring wells since the early 1990s (Figure 4-37). An alternative source of the high iodine-129 activity in WMA C monitoring wells appears to be from sources to the west and southwest, as described below.

Elevated iodine-129 activity has been present in the original upgradient WMA C Wells 299-E27-7 and 299-E27-14 since groundwater sampling began. However, consistently higher iodine-129 activity has been present in wells to the southeast (299-E25-42 and 299-E25-46), which were considered upgradient wells in the mid- to late 1980s (Figure 4-38). A westerly groundwater flow direction in 1987 was interpreted in PNL-8356, *Estimation of the Release and Migration of Lead Through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground, Volume 1: Final Report*. PNL-8356 interpreted groundwater in the 200 East Area as flowing westerly from B Pond, then turning northwest toward the northwest corner of the 200 East Area, and continuing to and through the gap between Gable Butte and Gable Mountain (Gable Gap). Northwest groundwater contaminant movement from as far south as the PUREX Cribs toward Gable Gap was interpreted in WHC-EP-0260, *Operational Groundwater Monitoring at the Hanford Site–1988*.

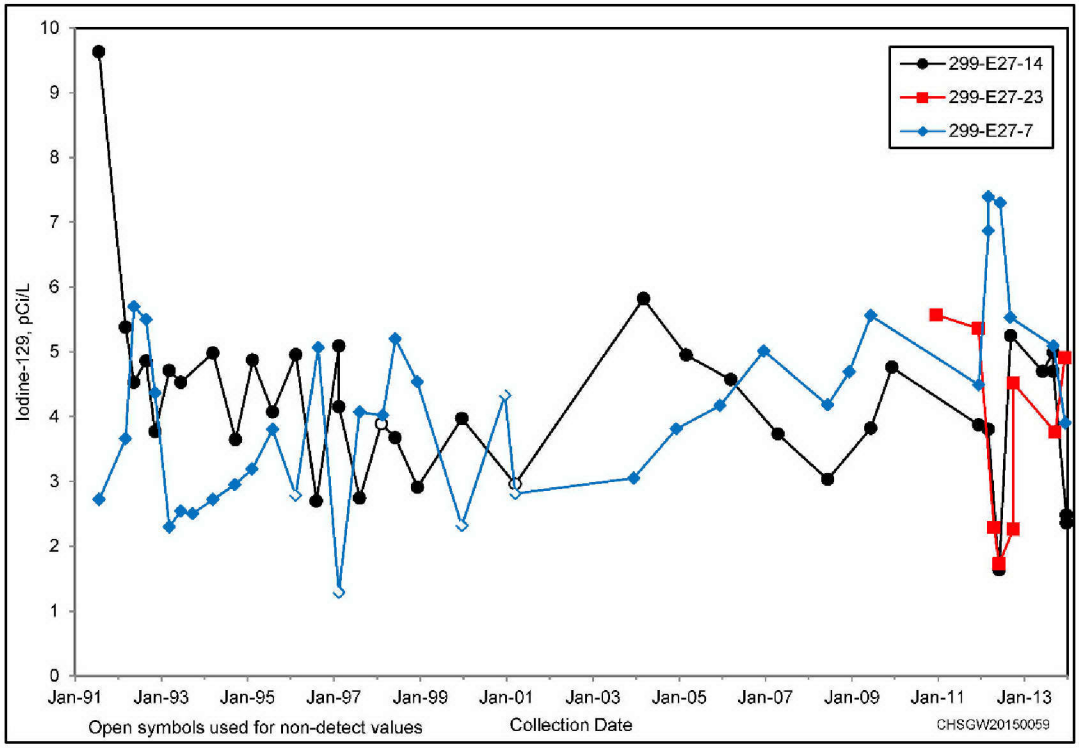

Figure 4-37. Iodine-129 Activity at Wells 299-E27-14, 299-E27-23, and 299-E27-7

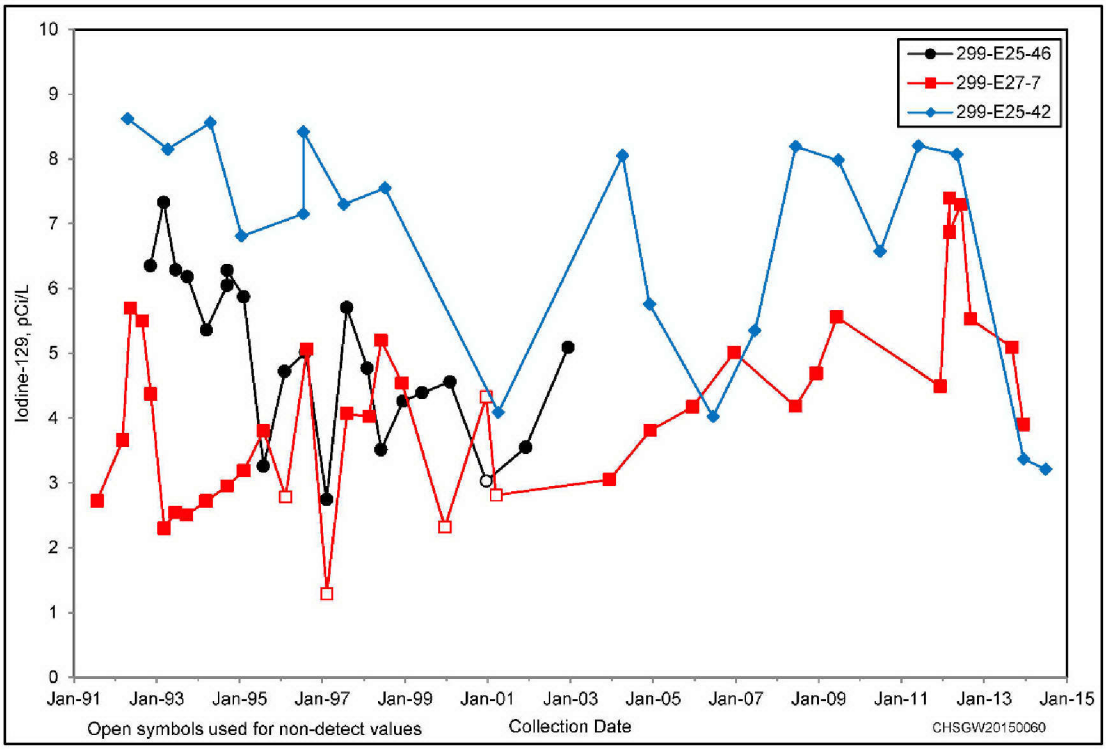

Figure 4-38. Iodine-129 Activity at Wells 299-E25-42, 299-E25-46, and 299-E27-7

The iodine-129 plume interpretation between 1988 and 1991, based on these groundwater flow interpretations, is shown in Figure 4-39 (WHC-SD-EN-TI-019). The reason for the change of flow to the northwest, as far as the southern portion of the 200 East Area, was attributed to deactivation of the Gable Mountain Pond and increased disposal to B Pond (Figure 4-40). Figure 4-41 provides the presumed flow direction, as depicted in PNL-8356. The distribution of iodine-129 above the 1 pCi/L DWS by 1995 is shown in Figure 4-42. Based on these observations, it appears likely that the elevated iodine-129 at WMA C (in the past and currently) was from historical migration of iodine-129 sources within the 200-PO-1 OU.

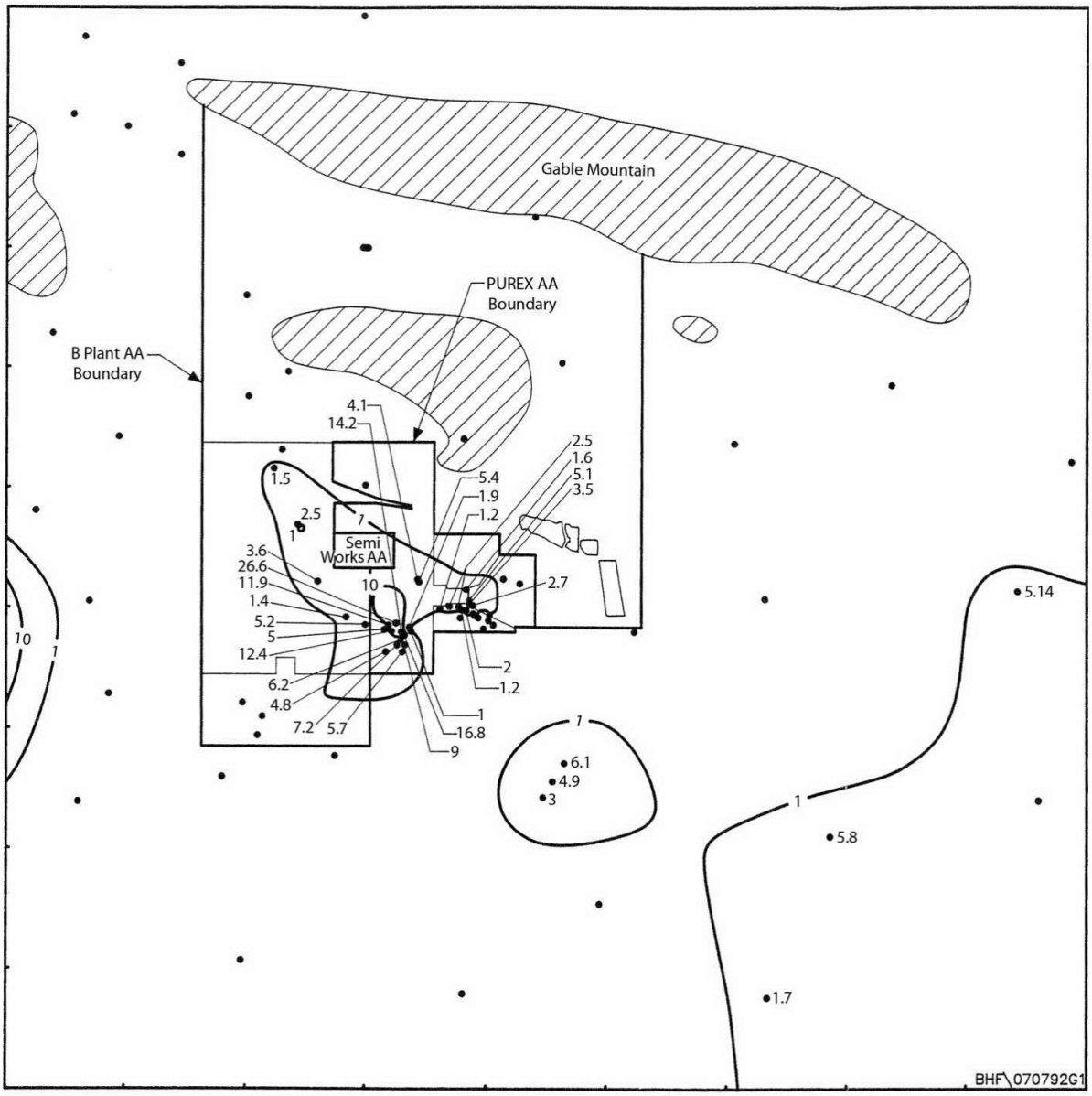

Figure 4-39. Distribution of Iodine-129 in the 200-BP-5 OU, 1988 to 1991

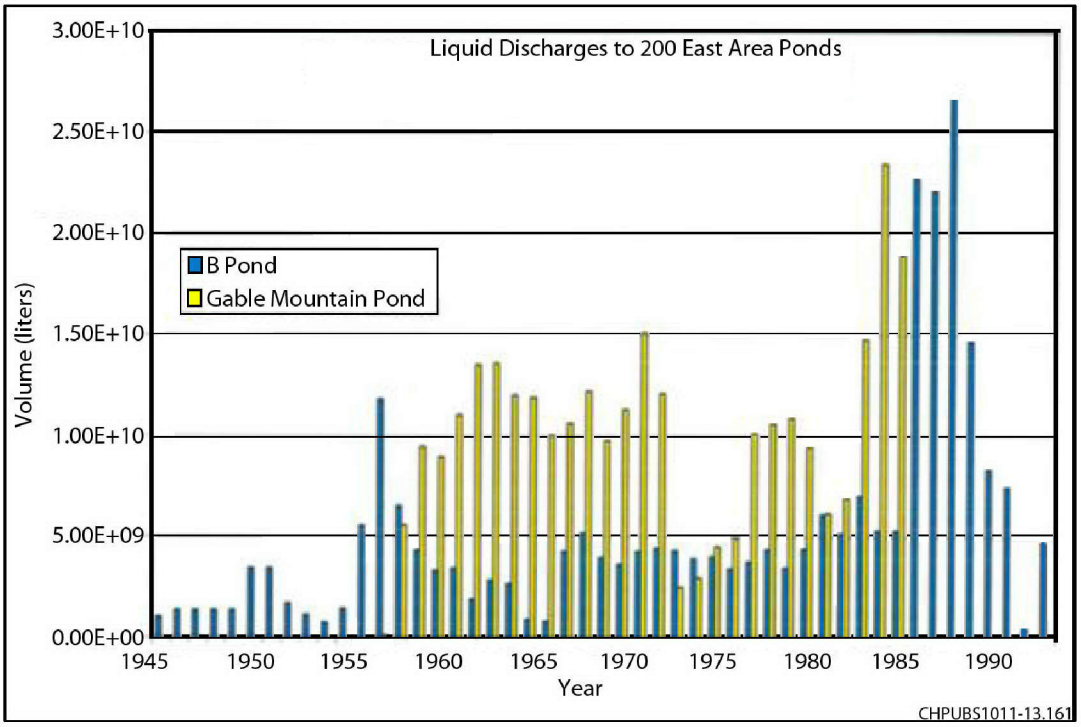

Figure 4-40. Volumes of Liquid Discharges to 200 East Area Ponds

4.4.3.3 B Pond

Liquid discharges with elevated activities of iodine-129 were not sent to B Pond according to the inventory developed for RPP-26744; however, iodine-129 is present in the groundwater beneath B Pond. Groundwater analyses for iodine-129 at B Pond began in 1994 at four wells: 699-42-42B, 699-43-41E, 699-43-43, and 699-45-42 (Figure 4-43). Five additional wells were sampled between 1996 and 2013 within and adjacent the 200-BP-5 OU boundary at B Pond: 699-42-40A, 699-43-40, 699-43-41F, 699-43-41G, and 699-44-39B. The highest and longest duration results for iodine-129 are associated with Wells 699-42-42B and 699-45-42, where iodine-129 levels have been slowly trending downward since 1994. The 2013 extent of iodine-129 exceeding the DWS is shown in Figure 1-3. The other wells monitored with lower iodine-129 levels also show generally declining levels; however, some of the wells have not been sampled recently because they became dry.

4.4.4 Uranium

Two source areas of uranium have been identified within the 200-BP-5 OU: 241-BX-102 UPR and 216-B-12 Crib. Although various quantities of uranium were released at several other sites overlying the OU, most waste site uranium inventories were more than three orders of magnitude lower than the 241-BX-102 UPR. The average derived uranium concentration in the waste released from 241-BX-102 was 29,000 mg/L. The following subsections discuss the characteristics associated with the releases, migration pathways, and extent of uranium in the groundwater from these sites.

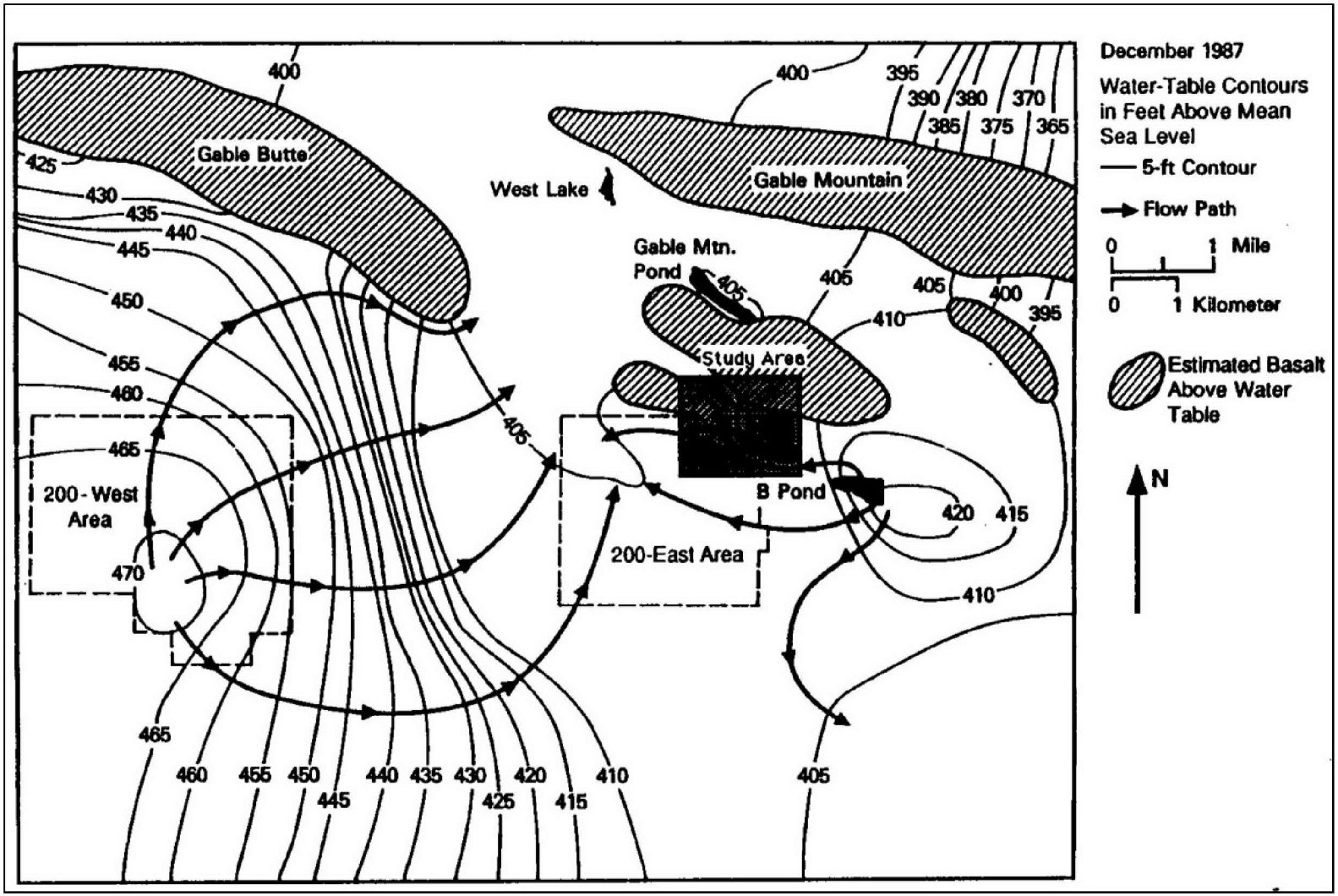

Figure 4-41. Water Table and Flow Directions in the Unconfined Aquifer beneath the Hanford Site 200 Areas, 1987

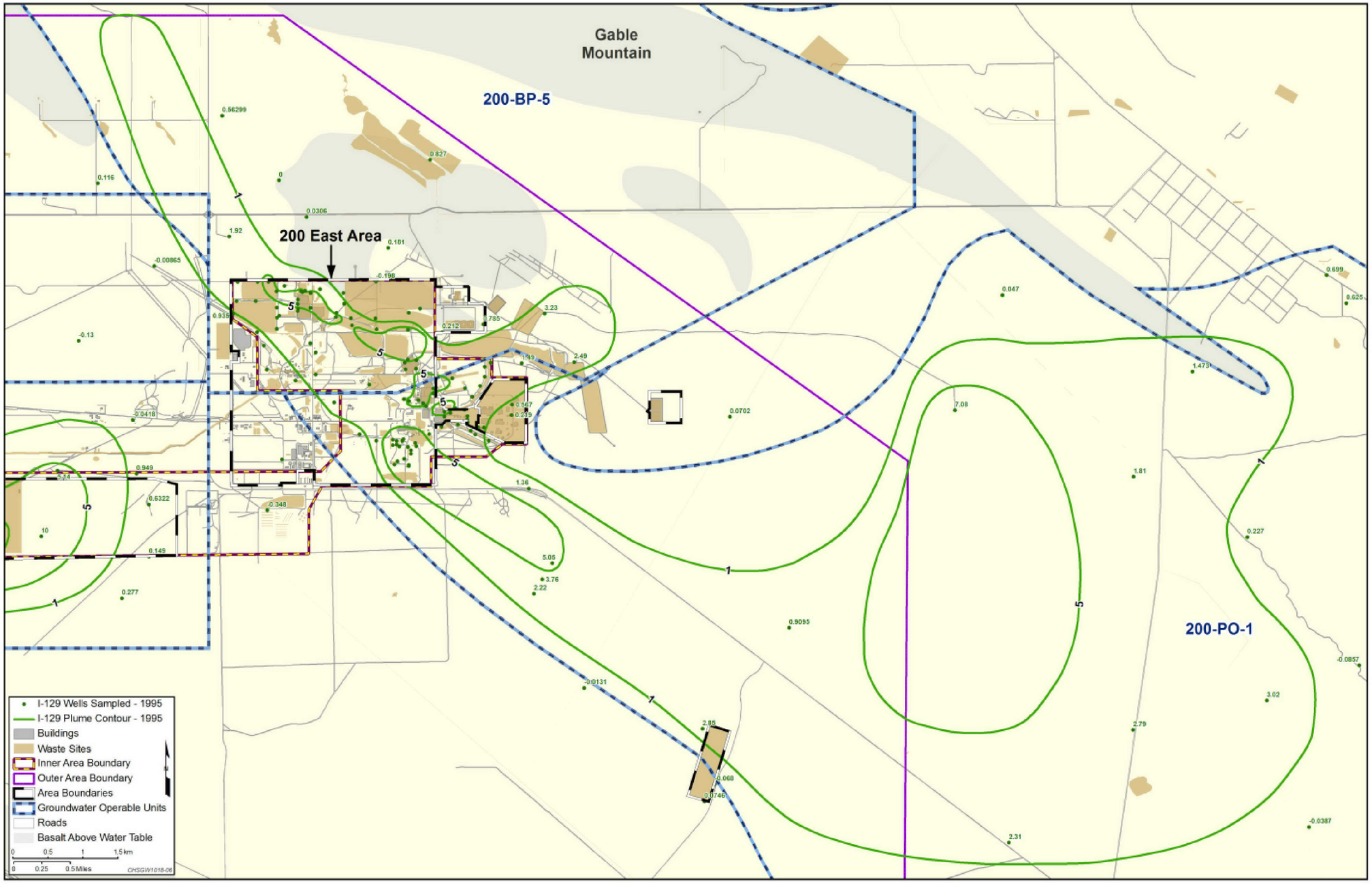

Figure 4-42. Distribution of Iodine-129 on the Central Plateau, 1995

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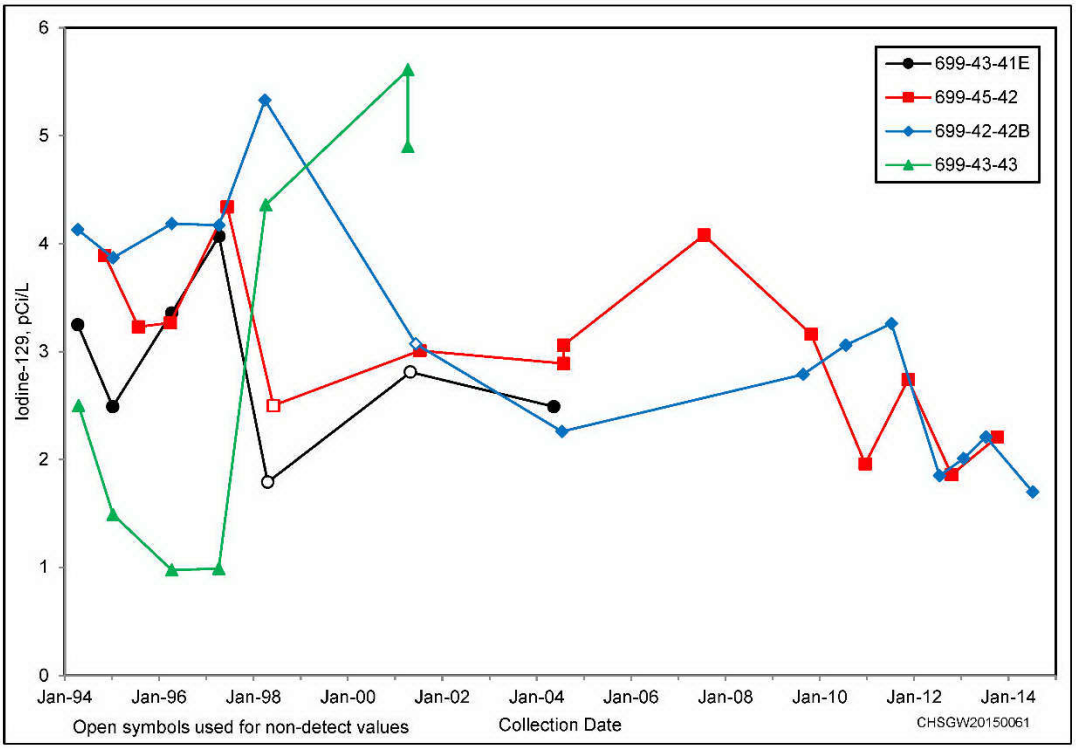

Figure 4-43. Iodine-129 Levels at Wells 699-43-41E, 699-45-42, and 699-42-42B

4.4.4.1 B Complex

The most significant uranium occurrence in groundwater for the 200-BP-5 OU is from the 241-BX-102 high-activity metal waste UPR. Uranium concentrations in groundwater associated with this release were measured as high as 5,550 µg/L in June 2009 from RI Well 299-E33-343 (Figure 4-4). Although the UPR occurred in 1951, evidence of uranium-contaminated pore water effects on the groundwater quality was not observed until 1992 (WMP-28945, Appendix D). From 1992 to 2005, uranium concentrations in the groundwater continued to increase; however, evidence to determine the source was lacking. Through the DQO process (WMP-28945) and the 200-BP-5 RI/FS work plan (DOE/RL-2007-18), activities were planned to provide defensible data to support a CSM for uranium source, migration, and extent related to the 241-BX-102 UPR. The following includes the findings associated with those activities.

The location and sampling for Wells 299-E33-205, 299-E33-343, and 299-E33-345 (drilled for this RI) were established through the 200-BP-5 OU DQO process (WMP-28945). Vadose zone uranium results from samples collected during drilling of these wells and additional Well 299-E33-344 were compiled with existing vadose zone data to derive an estimated amount of water-leachable uranium in the deep vadose zone in this area. The result was approximately 1,520 to 1,600 kg (PNNL-19277).

Since the initial high groundwater uranium results were collected beneath the 241-BX-102 UPR, concentrations decreased steadily from February 2010 to January 2012 at Well 299-E33-343 (Figure 4-44). The decreasing trend represents migration and decreased infiltration from the vadose zone. Although the water table gradient was extremely low in this area and gradients could not be reliably calculated, the flow direction was north-northwest in 2009 based on plume migration interpretations. Shortly after the flow direction change from the northwest to the southeast in mid-2011, the uranium concentrations at Well 299-E33-38 (north of Well 299-E33-343) began to decrease (Figure 4-44). This is consistent with the south-southeast flow direction change; however, uranium concentrations began to increase significantly at Well 299-E33-18, located to the east of Well 299-E33-343 (Figure 4-44).

The increased uranium concentrations at Well 299-E33-18 indicate that the center of mass from earlier infiltration near Well 299-E33-343 was migrating into the area near Well 299-E33-18. The uranium concentration at Well 299-E33-18 peaked at 4,470 µg/L in May 2012, which was approximately 1,100 µg/L lower than observed at Well 299-E33-343 in 2009.

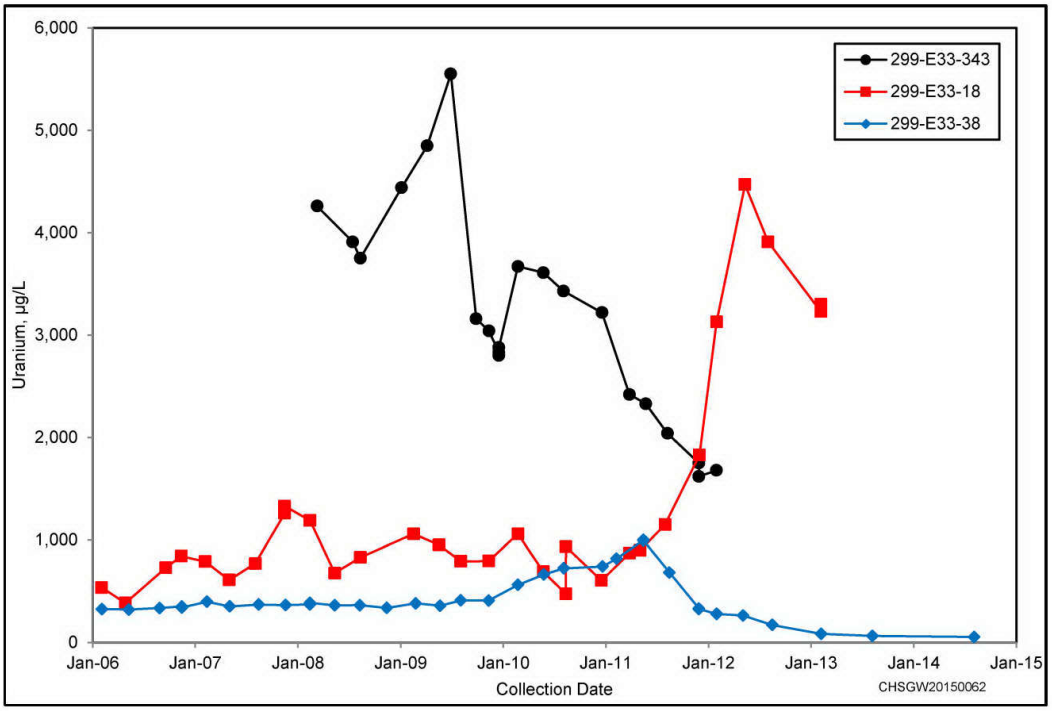

Figure 4-44. Uranium Concentrations at Wells 299-E33-343, 299-E33-18, and 299-E33-38

Figure 4-1 depicts the extent of uranium migration to the southeast in 2013. Uranium concentrations decrease in the direction of groundwater flow, primarily due to dispersion and dilution in the aquifer. Since the flow direction change from the northwest to the southeast, the increased aquifer thickness to the southeast and faster migration of groundwater beneath the source area are contributing to the dispersion and dilution of uranium. As a result, less mass of vadose zone contaminant infiltration per unit volume of groundwater is attributed to the decreasing groundwater uranium concentrations beneath the source site. The dispersion is related to aquifer thickness, which is approximately 2 m (6 ft) thick near Wells 299-E33-343 and 299-E33-18 but increases to 4 m (13 ft) on the southeast side of the B Tank Farm at Well 299-E33-338. The aquifer is even thicker on the south side of the B Tank Farm at Well 299-E33-337 (5.8 m [19 ft]). The decreasing uranium concentrations also correlate with decreasing technetium-99 and nitrate plumes migrating to the south.

Concentrations on the periphery of the uranium plume are changing, reflecting position to the source. For example, decreasing concentrations at wells that were upgradient of the infiltration source are occurring since the change in groundwater flow direction. Specifically, Well 299-E33-38 (Figure 4-44) decreased from 1,000 µg/L in May 2011 to 65 µg/L by August 2013. As flow continues to the southeast, concentrations in Well 299-E33-337 or 299-E33-338 are expected to increase. In 2013, these wells had uranium concentrations of 78 and 54 µg/L, respectively (Figure 4-45); however, the concentrations should continue to increase as the center of mass migrates through this area.

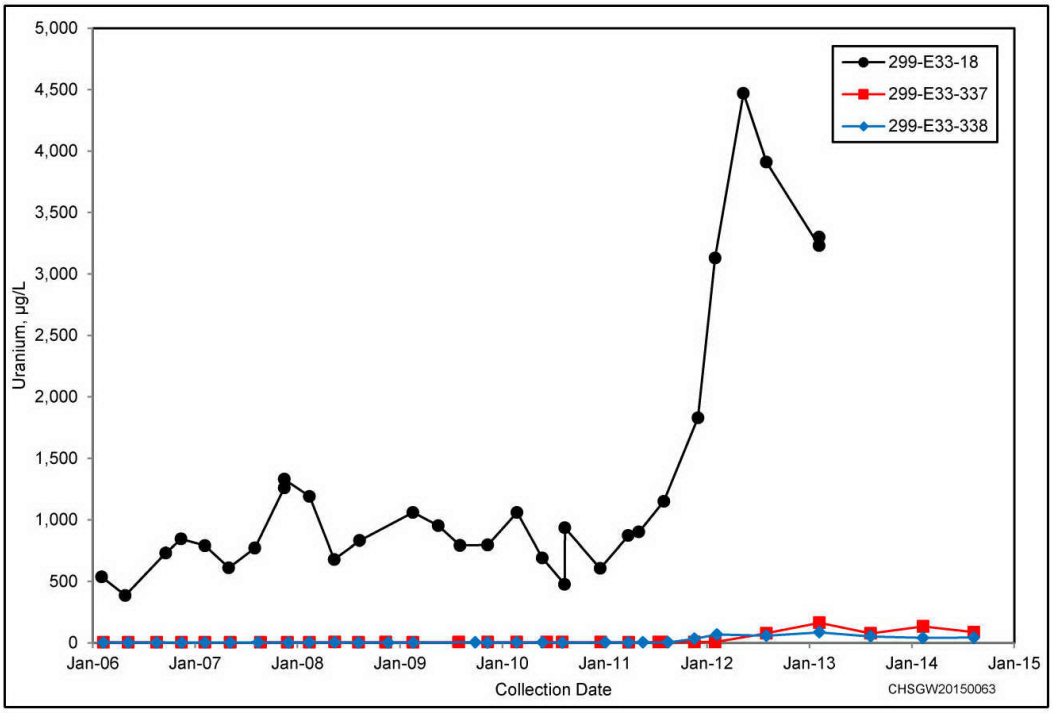

Figure 4-45. Uranium Concentrations at Wells 299-E33-18, 299-E33-337, and 299-E33-338

4.4.4.2 B Plant

RPP-26744 reported that the average mean uranium inventory disposed to the 216-B-12 Crib was approximately 15,000 kg, which is a much larger inventory than any of the adjacent waste sites in the B Plant area. In addition, elevated uranium in the deep vadose zone southeast of this crib was observed during geophysical logging in Well 299-E28-16 (before it was decommissioned in 2004). The elevated uranium was reported between 47 and 50 m (154 and 164 ft) bgs. Based on RHO-RE-SR-87-24P, *Results of the Separations Area Ground-Water Monitoring Network for 1986*, uranium detected at Well 299-E28-18 was associated with the inactive 216-B-12 Crib rather than the 216-B-62 Crib, and a depth-discrete groundwater investigation associated with RI Well 299-E28-30 was conducted. The following discussion includes the additional findings associated with the DQO process (WMP-28945) and results of the 200-BP-5 RI/FS work plan (DOE/RL-2007-18) activities completed in the RI to define the 216-B-12 Crib liquid uranium migration and extent.

Elevated uranium was first detected in the mid-1980s at Wells 299-E28-18 and 299-E28-21. Concentrations were detected as high as 423 µg/L in 1985 at Well 299-E28-18 (Figure 4-46). During this timeframe, significant steam condensate discharges (averaging 46.6 million L/yr [12.3 million gal/yr] from 1977 to 1984) were sent to the 216-B-55 Crib, apparently contributing to a northerly flow direction. Since the 1980s, the uranium has migrated to the north boundary of LLWMA-1 while also dispersing laterally. Concentrations of uranium as of 2013 were 11.3 µg/L at Well 299-E28-18 and did not exceed 15 µg/L at any of the wells existing between Wells 299-E28-18 and 299-E32-8 (located in the northwest corner of LLWMA-1).

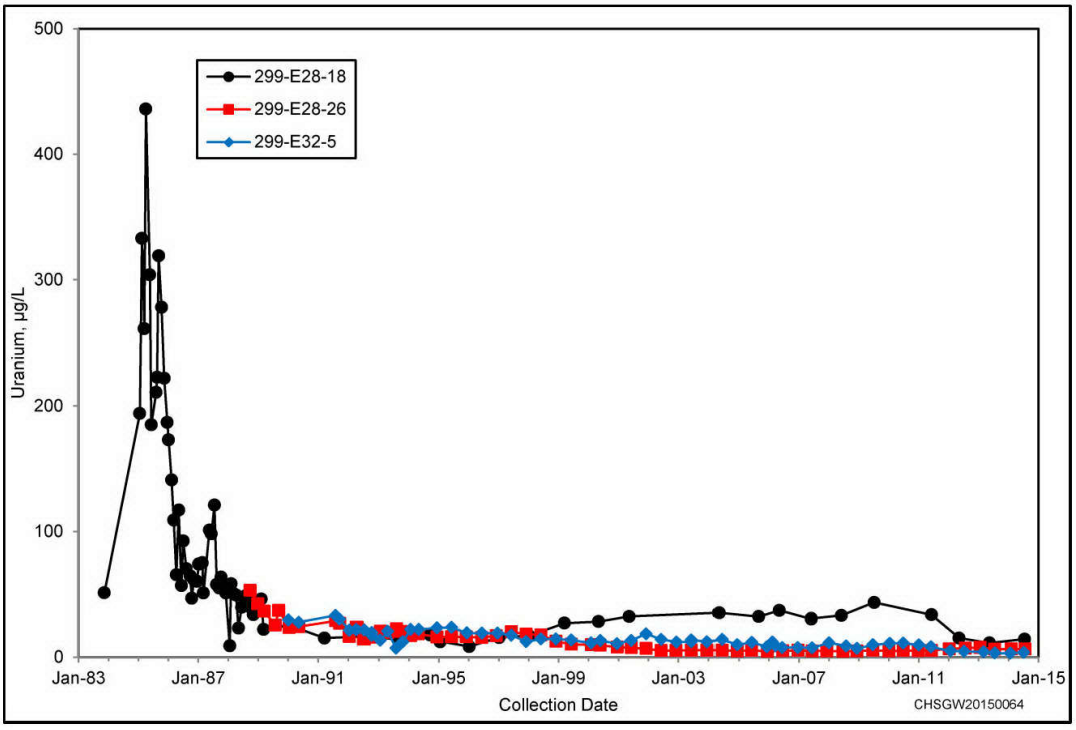

Figure 4-46. Uranium Concentrations at Wells 299-E28-18, 299-E28-26, and 299-E32-5

During drilling of RI Well 299-E28-30 in 2010, located just south of the 216-B-12 Crib, depth-discrete groundwater samples from approximately 7.6 m (25 ft) below the water table revealed uranium concentrations of 35 µg/L, exceeding the DWS of 30 µg/L. Further east, at RI Well 299-E29-54, drilled in 2010, initial uranium concentrations were less than the DWS. However, a recent groundwater flow direction change in 2011 appears to have caused uranium concentrations at Well 299-E29-54 to increase, with a maximum 2013 concentration of 47.3 µg/L (Figure 4-47). Elevated uranium has also been present further east at Well 299-E28-6 since it was first sampled in 1994 (Figure 4-47) and has recently increased at Well 299-E28-24 in 2013 (Figure 4-47). The inferred uranium extent exceeding the DWS is shown in Figure 4-1.

4.4.5 Tritium

High tritium activities were released at several areas overlying the 200-BP-5 OU (RPP-26744). Historically, large-volume discharges containing substantial tritium activity occurred in three areas (B Complex, 216-B-12 Crib, and B Pond) where tritium has been detected at concentrations near the DWS of 20,000 pCi/L since 2013. The three following subsections discuss the characteristics associated with the releases, migration pathways, and extent of tritium in the groundwater from these sites.

4.4.5.1 B Complex

Within the B Complex, the 216-B-50 and 216-B-57 Cribs had the largest inventory of tritium (126.3 and 194.6 Ci, respectively) (RPP-26744). These two cribs are located within and southeast of the BY Cribs, respectively. One other site contributing to activity levels above the tritium DWS in 2013 was the UPR at the 241-BX-102 Tank.

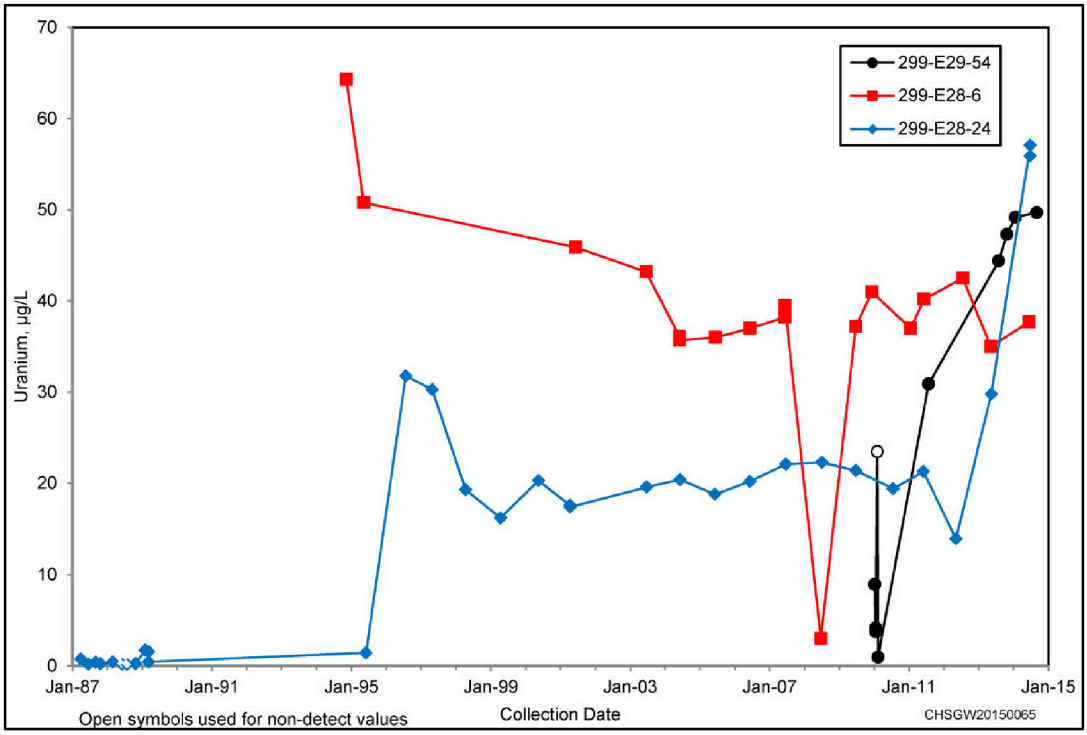

Figure 4-47. Uranium Concentrations at Wells 299-E29-54, 299-E28-6, and 299-E28-24

Prior to the late 1980s, only a few samples for tritium were collected near the BY Cribs. Activities in Well 299-E33-3 from 1966 (which was one year after the startup of active liquid disposal at the 216-B-50 Crib) were as high as 1,700,000 pCi/L. In the latter 1960s and early 1970s, elevated tritium activity was periodically detected at Well 699-49-57A (Figure 4-48). Tritium near Well 699-50-53A was lower than at Well 699-49-57A, likely due to the influence of Gable Mountain Pond. Tritium at Well 699-49-57A increased substantially in 1975, apparently due to reduced cooling water disposal at Gable Mountain Pond starting in 1973 and deactivation of the 116-K-2 Trench in 1971 (Figure 4-48).

During the RI, tritium levels near the 216-B-50 and 216-B-57 Cribs were higher in Well 299-E33-7 than in the wells to the south or east (Figure 4-49). The large tritium increases reflect slower groundwater flow velocity, northward migration, and possible variability in vadose zone infiltration. The variability in vadose zone infiltration is based on the large variability of groundwater tritium activity between November 2007 and May 2011, when groundwater flow rates were nearly stagnant and nitrate concentration in Well 299-E33-7 showed more consistent increases (Figure 4-50). As the flow direction changed to the southeast in mid-2011, activity levels quickly dropped at Well 299-E33-7 and increased briefly to the DWS beneath and east of the BY Cribs (Figure 4-49) at Wells 299-E33-3 and 299-E33-38. The 2013 extent of tritium is shown in Figure 4-1.

Further to the south near the 241-BX-102 UPR site, tritium has recently been detected at 28,000 pCi/L in the unconfined aquifer at Well 299-E33-18 (Figure 4-51). It appears that the tritium may have been associated with uranium in this area. The 2013 extent of tritium in this area is shown in Figure 4-1.

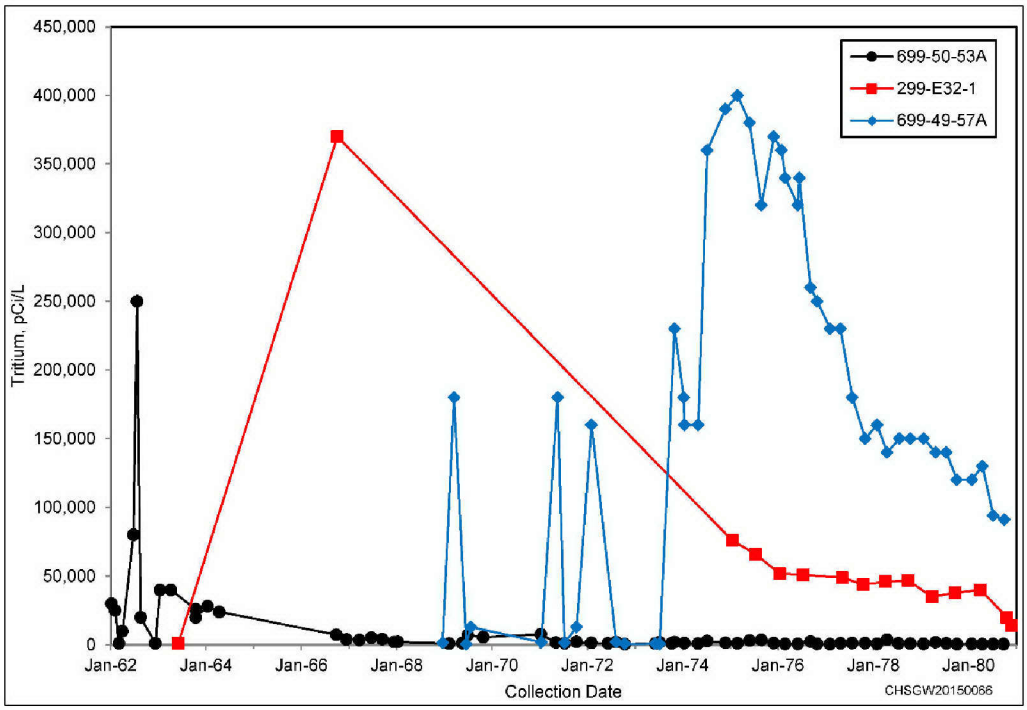

Figure 4-48. Tritium Concentrations in Wells 299-E32-1, 699-49-57A, and 699-50-53A

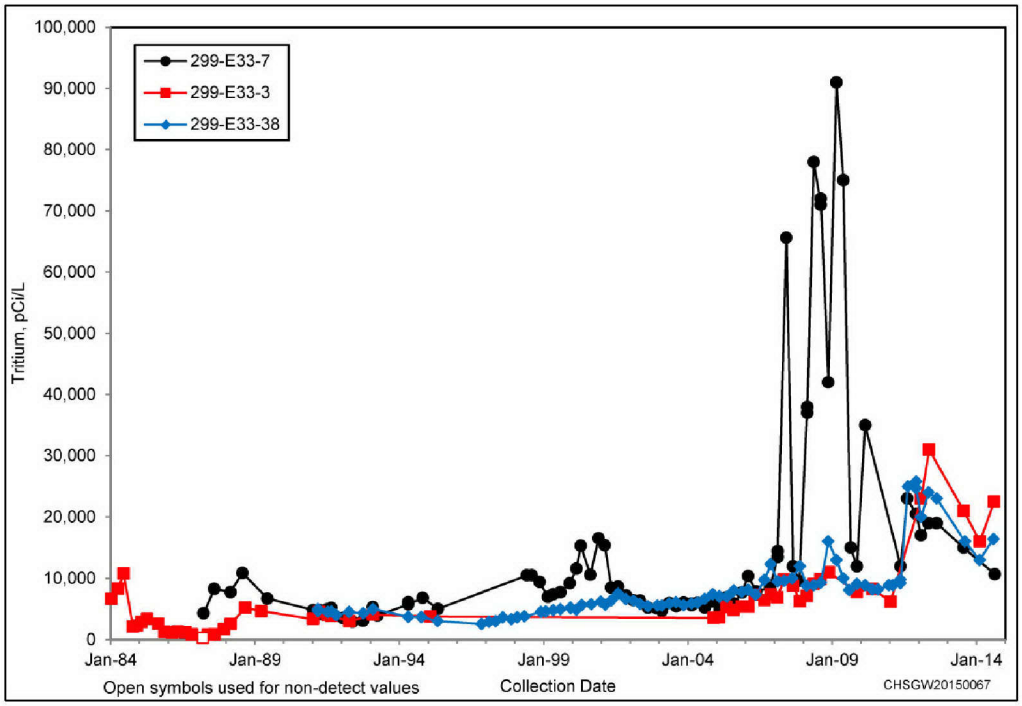

Figure 4-49. Tritium Activity Levels at Wells 299-E33-7, 299-E33-3, and 299-E33-38

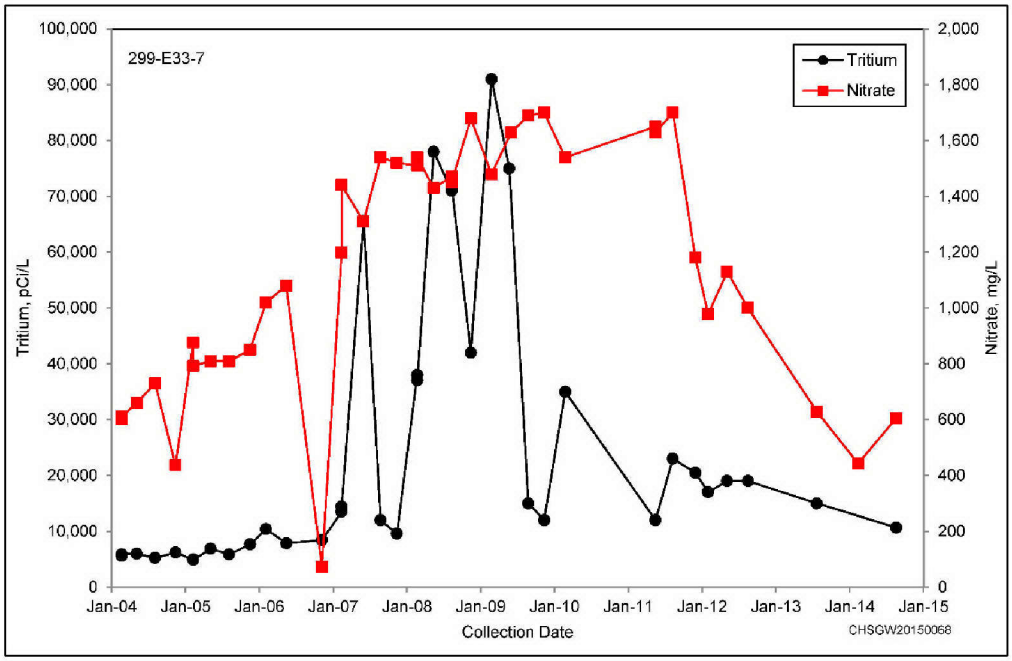

Figure 4-50. Tritium versus Nitrate Levels at Well 299-E33-7

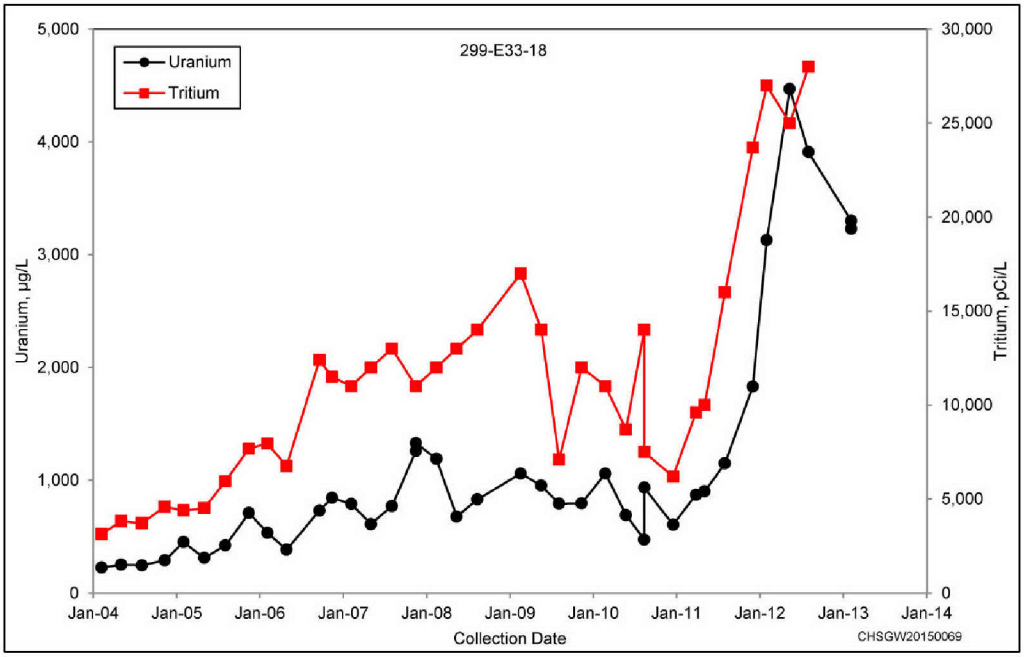

Figure 4-51. Tritium versus Uranium Levels at Well 299-E33-18

4.4.5.2 B Plant

Another apparent tritium source within the 200-BP-5 OU is the 216-B-12 Crib, which received 2,340 Ci of tritium during active disposal. Comparatively, all of the other sites in this area received less than 1 Ci collectively (RPP-26744).

Tritium levels as high as 470,000 pCi/L were reported in the mid-1960s at Well 299-E28-9, northwest of the 216-B-12 Crib (Figure 4-52). No discharges to the 216-B-12 Crib occurred from 1958 to 1967, and discharges to the crib resumed in 1967. The crib was deactivated in 1973, at which time the tritium levels averaged approximately 135,000 pCi/L in Well 299-E28-9 (Figure 4-52).

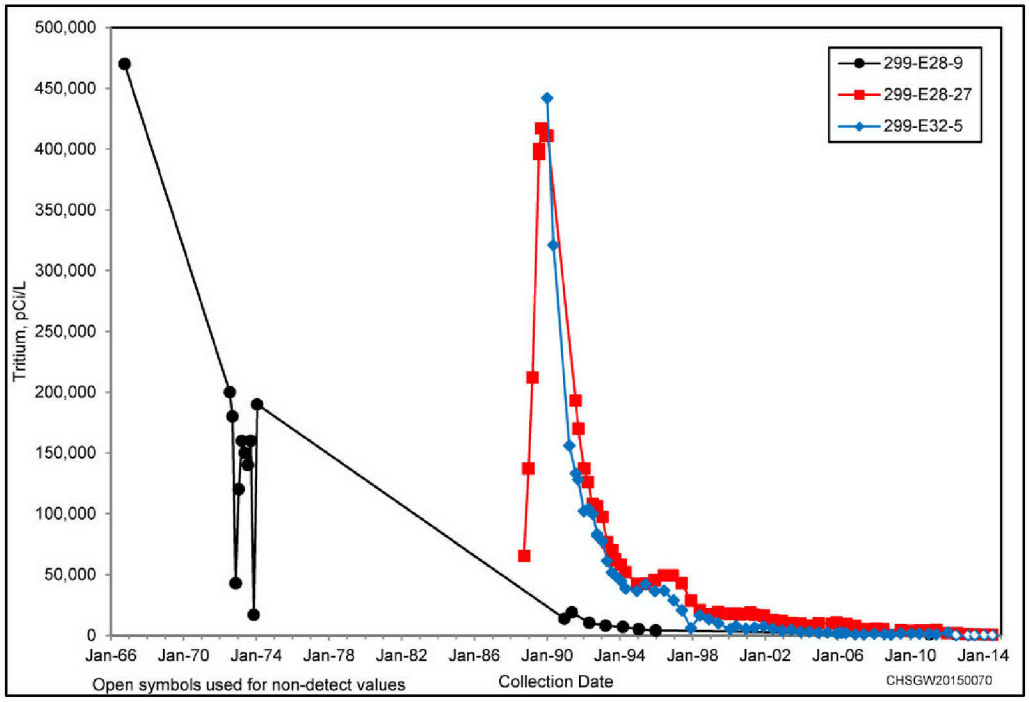

Figure 4-52. Tritium Levels at Wells 299-E28-9, 299-E28-27, and 299-E32-5

During the mid-1980s, the former Gable Mountain Pond was deactivated, and liquid cooling wastewater was routed to B Pond. The additional water discharged to B Pond resulted in changes to water table elevations, and a hydraulic gradient to the northwest across the 200 East Area was established. Flow from as far south as the PUREX Cribs was influenced by the head reduction in Gable Gap, resulting in a northwest flow direction. The migrating groundwater carried substantial levels of tritium, as shown at Wells 299-E28-27 and 299-E32-5 (Figure 4-52).

During depth-discrete sampling at Wells 299-E28-30 and 299-E29-54, elevated levels of tritium were detected at various depths. Tritium activity as high as 93,000 pCi/L was observed at Well 299-E28-30 at approximately 7.6 m (25 ft) below the water table (Figure 4-53). A higher tritium activity level (150,000 pCi/L) was observed near the bottom of the aquifer at Well 299-E29-54 (Figure 4-53). Tritium levels in the upper unconfined aquifer have not exceeded 9,000 pCi/L at any of the wells in this area since 2006.

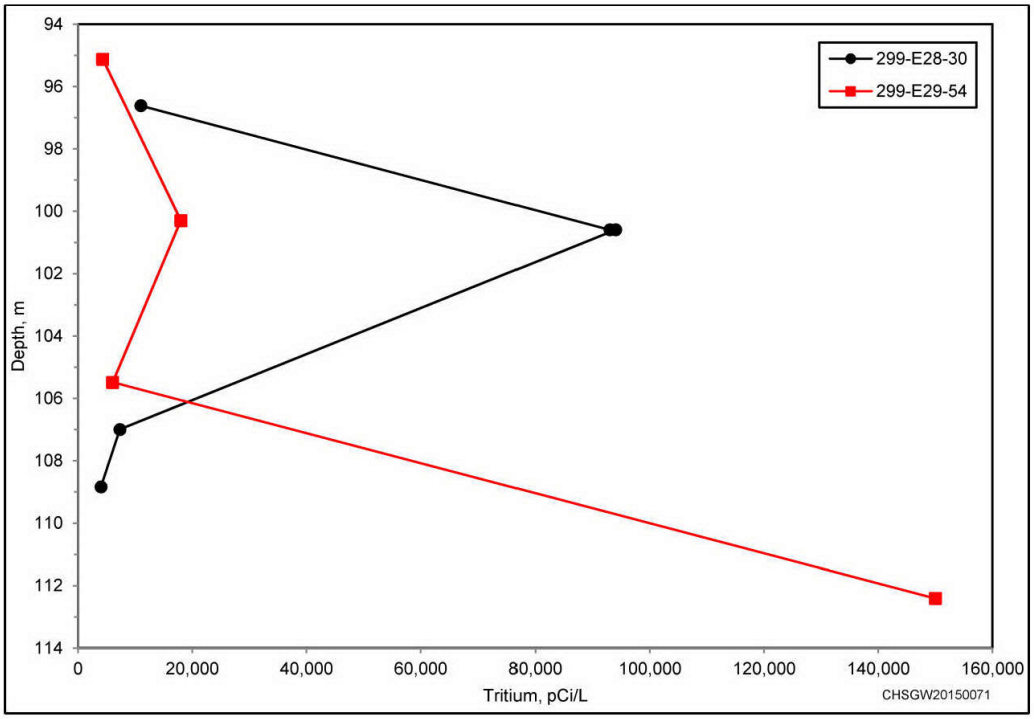

Figure 4-53. Depth-Discrete Tritium Levels at Wells 299-E28-30 and 299-E29-54 in 2010

4.4.5.3 B Pond

Elevated discharges of tritium were sent to B Pond overlying the 200-BP-5 OU during 1965 to 1974 and again from 1995 to 1997 (RPP-26744). Monitoring at B Pond began in early 1962 at Well 699-45-42, which is located just east of the contingency pond (north of the main pond). Activity levels were initially 140,000 pCi/L but increased until March 1969, reaching 960,000 pCi/L (Figure 4-54). Since 1969, tritium levels have decreased across the B Pond area (Figure 4-54). For example, Well 699-43-42 (located just east of the main pond) historically has had tritium activity levels consistent with those of Well 699-45-42 starting in 1975. The deeper semiconfined Ringold aquifer beneath the Ringold mud (Well 699-43-41G, located just north of the expansion 3B lobe and east of the main pond) has had tritium levels similar to those observed in the unconfined aquifer.

In 2013, the highest tritium activity was observed at Well 699-42-40A (42,000 pCi/L), located southeast of Well 699-43-41G. This well is screened in the deeper semiconfined Ringold aquifer beneath the Ringold mud, where tritium levels have ranged between 28,000 and 46,000 pCi/L since 2007. The plume is interpreted to extend to the southeast (Figure 1-3).

4.4.6 Cyanide

Elevated groundwater cyanide concentrations in 2013 were found in only one area, B Complex, within the 200-BP-5 OU; however, cyanide groundwater concentrations near the end of 2013 were decreasing. Cyanide (as a component of the metal ferrocyanide scavenging process) was used mainly to precipitate cesium-137 from the early high-activity metal waste after it was sent to the Uranium Recovery Plant. Within the B Complex, ferrocyanide-containing tank supernatant was discharged to the BY Cribs. In addition, a small release in the B Tank Farm (near the 241-B-105 and 241-B-106 Tanks) was identified in RPP-RPT-49089, *Hanford B-Farm Leak Inventory Assessments Report*.

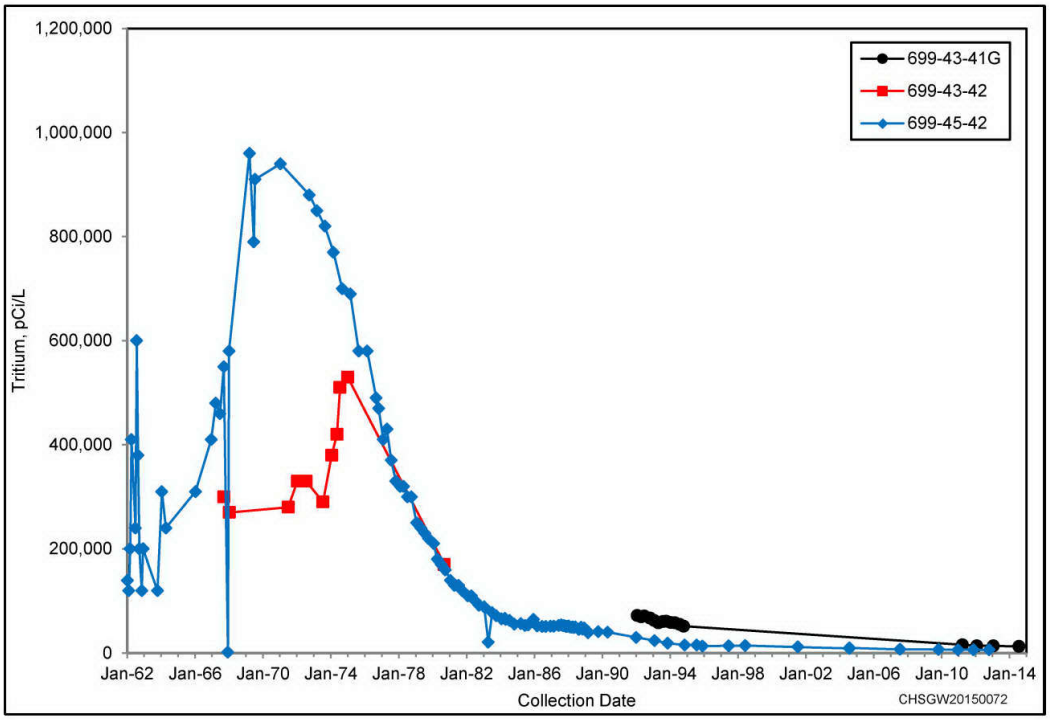

Figure 4-54. Tritium Levels at Wells 699-43-41G, 699-43-42, and 699-45-42

Cyanide was first released into the environment in the 1950s at the BY Cribs. The contamination migrated with nitrate and technetium-99 to the north and is present at concentrations of about one-half of the DWS in Gable Gap near Well 699-53-55C (Figure 4-55). The concentrations at this well have decreased since 2010, after the groundwater flow reversed in the northwest part of the 200 East Area from northwest to southeast. It is uncertain if higher concentrations may exist to the south of this well, as cyanide concentrations in the late 1980s at Well 699-50-53A were observed as high as 1,690 µg/L (Figure 4-55), which occurred within the thin aquifer near this well. Cyanide contamination continued to migrate toward Well 699-53-55C for more than two decades, as defined by the continued contaminant increase until 2010. Note that as the contamination moved from the thin aquifer near Well 699-50-53A into the Gable Gap area at Well 699-53-55C, the aquifer thickness increased by about 20 times. This transition in aquifer thickness contributes to the lower cyanide concentrations most likely due to dilution and dispersion. The deeper Well 699-53-55B (located near Well 699-53-55C) has similar detected concentrations of cyanide, although it appears to collect water at 14 to 23.8 m (46 to 78 ft) below the water table (Figure 4-55). Well 699-53-55C is screened from 4.6 to 7.6 m (15 to 25 ft) below the water table.

Cyanide concentrations have also recently decreased substantially beneath the BY Cribs. The high cyanide concentrations observed during 2009 are inferred to have been associated with continued contaminant infiltration from the vadose zone beneath the cribs and a prolonged period of nearly stagnant groundwater flow conditions preceding the groundwater flow direction change. During the period of nearly stagnant flow conditions, cyanide concentrations increased at Well 299-E33-7 to 1,730 µg/L (Figure 4-56). However, as the groundwater flow rate has recently increased, the cyanide concentrations beneath the BY Cribs decreased to below 500 µg/L in October 2013. The current extent of cyanide contamination exceeding the DWS is shown in Figure 4-1.

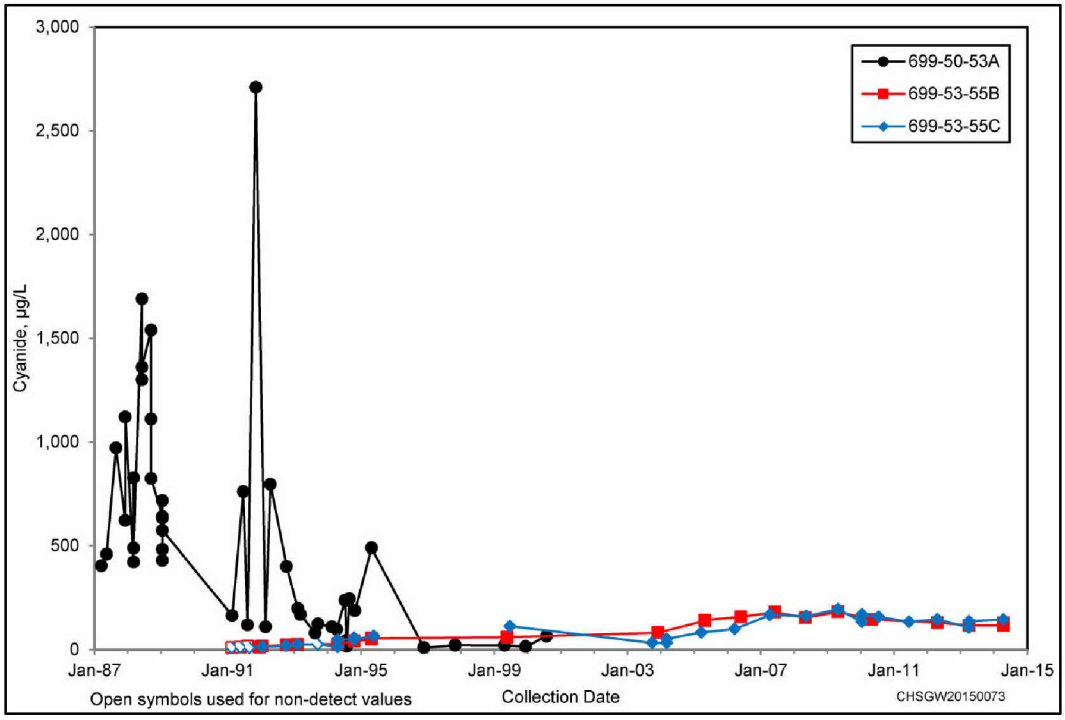

Figure 4-55. Cyanide Levels at Wells 699-50-53A, 699-53-55B, and 699-53-55C

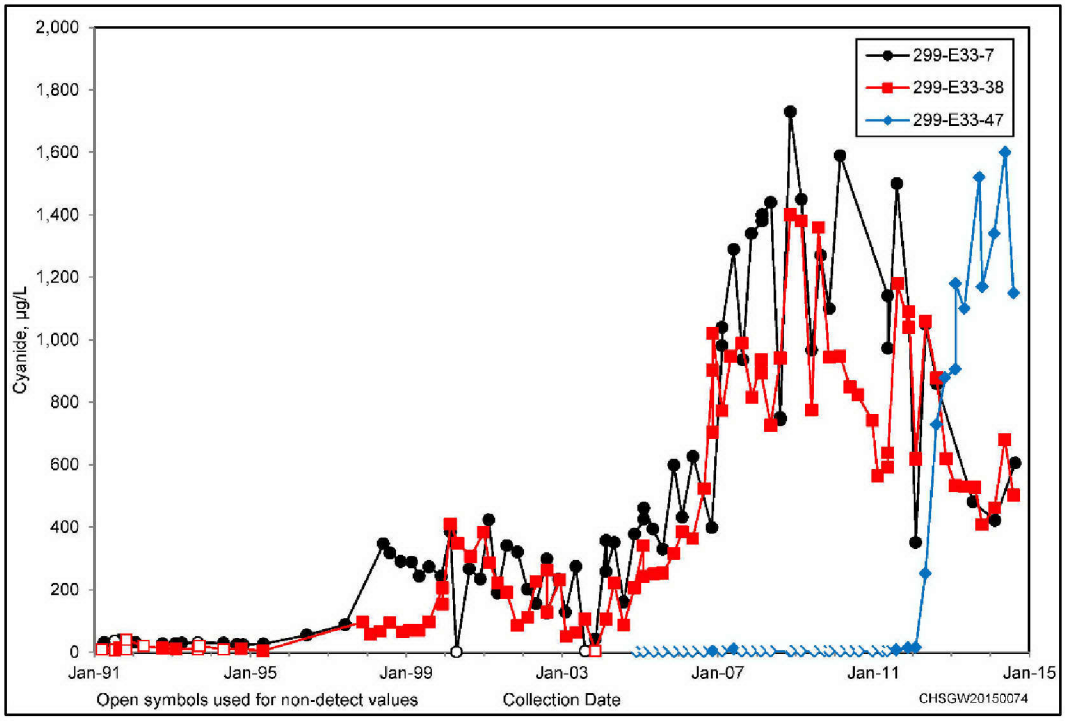

Figure 4-56. Cyanide Levels at Wells 299-E33-7, 299-E33-38, and 299-E33-47

A release near the B Tank Farm recently affected groundwater quality at Well 299-E33-47 (Figure 4-56). Although the aquifer is twice as thick in this area compared to the area beneath the BY Cribs, cyanide concentrations at Well 299-E33-47 peaked at nearly the same concentration as the BY Cribs, which is likely due to the prolonged and nearly stagnant flow conditions. While concentrations at both locations peaked at nearly the same level, the plume extent at the BY Cribs was much larger. Near the end of 2013, cyanide concentration began to decrease, likely associated with an increase in groundwater flow velocity in this area.

It appears that concentrations at both of the B Complex locations are influenced by flow rate. At higher flow velocities, groundwater concentrations are lower than at lower groundwater flow velocities. If the current flow velocity remains similar to the 2013 velocity, the concentrations of cyanide are expected to continue to decrease.

4.4.7 Strontium-90

Strontium-90 is found in only two locations in the 200-BP-5 OU: beneath the former Gable Mountain Pond (deactivated in the mid-1980s), and at the 216-B-5 Injection Well. Stronitum-90 tends to bind to vadose zone sediments; therefore, it only reached the groundwater at locations where the vadose zone is relatively thin in the OU. The vadose zone thickness at the former Gable Mountain Pond is less than 12 m (39 ft) thick, and the 216-B-5 Injection Well was screened within the unconfined aquifer.

4.4.7.1 Gable Mountain Pond

In 1984, groundwater beneath Gable Mountain Pond, north of the 200 East Area (Figure 4-3), was found to have been impacted by strontium-90 (RHO-RE-SR-87-24P). The source was a June 1964 leak from the cooling coil of the first-cycle acid waste storage tank (F-15) in the PUREX Plant, which was ultimately discharged to Gable Mountain Pond in a cooling water/steam condensate stream from the plant. The release contained 10,000 Ci of mixed fission products. Most of the radionuclides were short-lived, except for cesium-137 and strontium-90. Well 699-53-47A was installed in 1966 to evaluate groundwater near the pond outfall pipe. Gross beta has been detected in the well since sampling began in 1969. The well was not sampled for strontium-90 until 1980, and strontium-90 has been detected in the well in every sampling event since that time.

An investigation of Gable Mountain Pond was completed in 1984, and five additional wells were installed adjacent to the pond. Strontium-90 levels were initially the highest at Well 699-53-48B (Figure 4-57). Downgradient Wells 699-55-50A, 699-55-50C, and 699-55-50D were generally found to have strontium-90 concentrations below detection, except for a couple of early samples at Well 699-55-50C (Figure 4-58). Strontium-90 levels have mostly remained lower than detection levels at Well 699-55-50C.

Current and historical strontium-90 levels decrease to the northwest as the aquifer thickness increases. The aquifer thickness beneath Gable Mountain Pond ranges from 2 to 13 m (6 to 45 ft), with the thinnest portion of the aquifer near the abandoned outfall pipe and the deepest portion to the northwest. All of the wells are screened in the upper 4 m (13 ft) of the aquifer. Stronitum-90 levels at Well 699-53-47B (near the outfall pipe) were 220 pCi/L in 2013. Stronitum-90 levels at Well 699-54-49 were 170 pCi/L and at Well 699-55-50C were below detection limits.

The migration rate of strontium-90 within the aquifer has been calculated at approximately 1 m/yr (3.3 ft/yr). Based on the significant decreases over the past two decades, it appears that this plume is attenuating more quickly than the anticipated 197 years estimated in RHO-RE-SR-87-24P. The 2013 plume extent is shown in Figure 1-3.

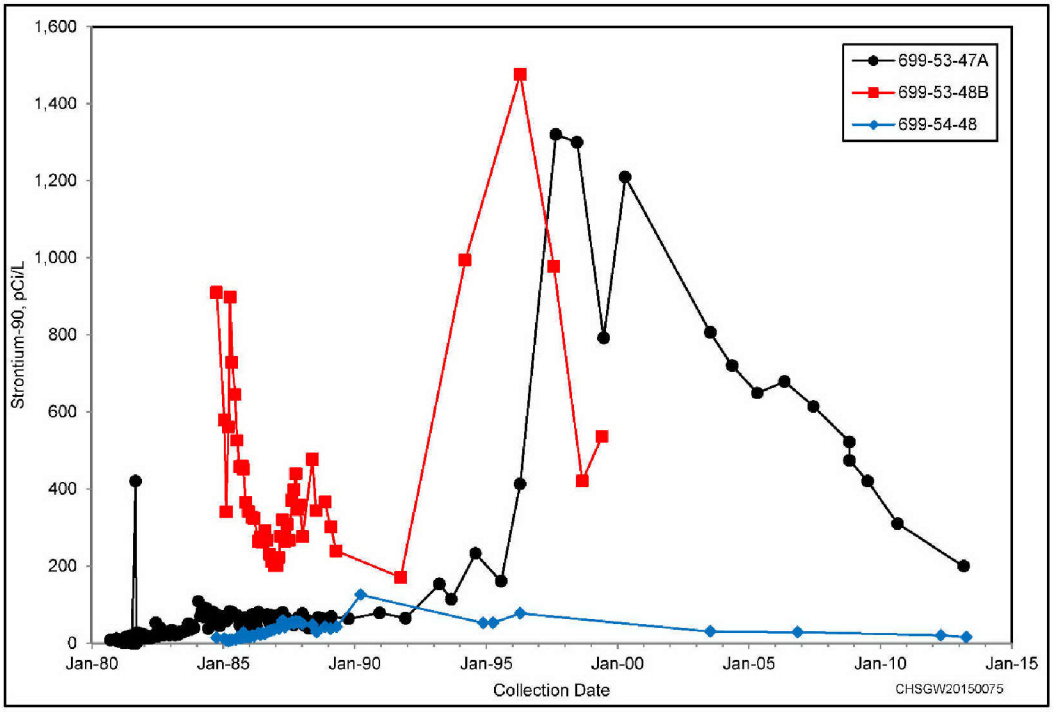

Figure 4-57. Strontium-90 Levels at Wells 699-53-47A, 699-53-48B, and 699-54-48

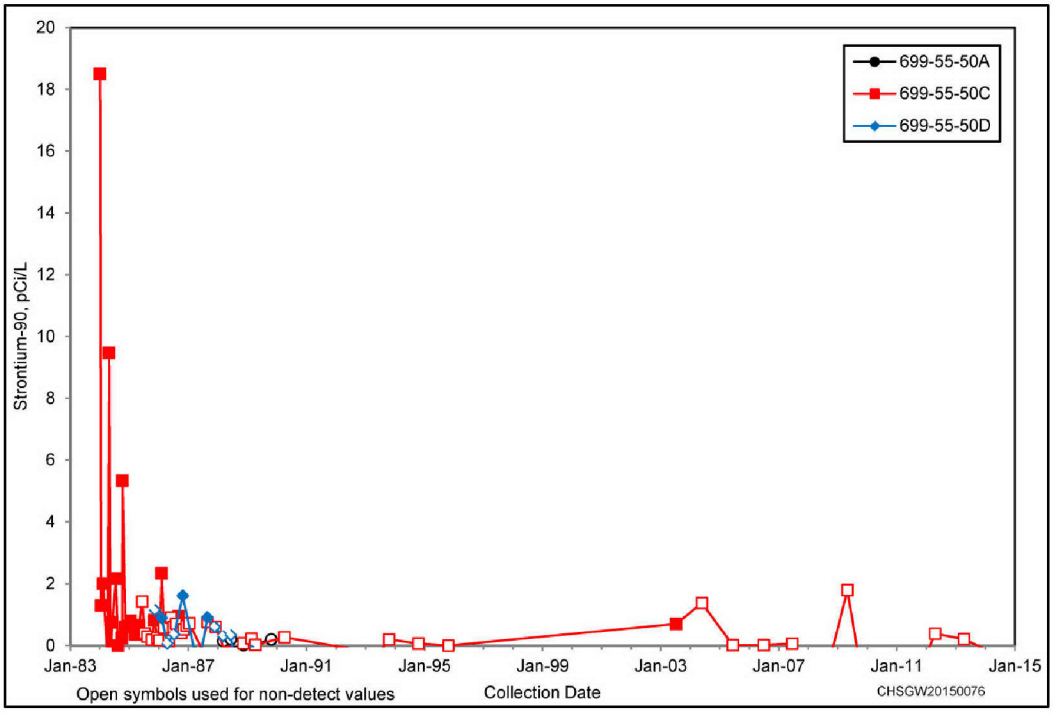

Figure 4-58. Strontium-90 Levels at Wells 699-55-50A, 699-55-50C, and 699-55-50D

4.4.7.2 216-B-5 Reverse Well

The 216-B-5 Reverse Well, located south of WMA B-BX-BY (Figures 4-1 and 4-3), impacted groundwater in 1945. This site received early 224-B Building lanthanum fluoride/bismuth phosphate cross-over waste from cell drainage (WMP-28945). The site also received waste containing activity from Cell 5-6 of the 221-B Building (HW-10475). Eleven wells were installed around this site for monitoring, and early gross beta monitoring results indicated that ruthenium (as monitored by gross beta analysis) preferentially migrated south-southeast from the reverse well. More recent sampling results indicate that strontium-90 is fairly localized near the reverse well. Strontium-90 has not migrated large distances away from the 216-B-5 Reverse Well site due to absorption to soil sediments.

The plume exceeding the DWS expanded to the northwest from the mid-1990s to 2012 (as shown by the differences between Figure 1.4 in DOE/RL-95-59 and Figure 3.4-19 in DOE/RL-2011-118). The migration was associated with deactivation of discharges to Gable Mountain Pond and increased discharges to B Pond, which caused changes in groundwater flow direction to the northwest. Since 2011, groundwater flow direction has changed from the northwest to the southeast, resulting in increasing activities in wells to the southeast of the 216-B-5 Reverse Well and decreasing activities in wells to the northwest. The 2013 extent of strontium-90 exceeding the DWS is presented in Figure 4-1.

4.4.8 Chromium

Elevated groundwater chromium concentrations in 2013 were found only in one area (B Complex) within the 200-BP-5 OU. Groundwater chromium concentrations have consistently been the highest beneath the 216-B-8 Crib, as measured at Well 299-E33-16 (Figure 4-4) since chromium monitoring began at this well in the 1990s (Figure 4-59). Figure 4-59 shows a comparison of the chromium trends at Wells 299-E33-18 and 299-E33-44, located to the south and west of the 216-B-8 Crib (Figure 4-4). Based on these comparisons and the evaluations completed for the conceptual model report (PNNL-19277), the 216-B-8 Crib is the most likely source of Cr(VI) in groundwater at the B Complex.

Chromium sent to the 216-B-8 Crib was in the form of Cr(VI) (Appendix A of WMP-28945). Cr(VI) was part of the sodium dichromate process used to oxidize plutonium during the early separation processes at B Plant. The waste stream sent to the 216-B-8 Crib was part of the second-cycle decontamination process. Average derived discharge concentrations of chromium to this crib ranged between 21 and 261 mg/L (RPP-26744). As shown in Figure 4-59, groundwater concentrations have ranged between 26 and 182 µg/L.

Fluctuations in groundwater chromium results for Well 299-E33-16 appear to be associated with groundwater flow rates (PNNL-19277). As the flow velocity increases, the concentrations in the groundwater decrease; as the flow velocity decreases, concentrations increase.

Chromium concentrations have decreased greatly since the mid-2011 flow direction change from the northwest to the southeast (Figure 4-59). It appears that if the flow rate to the southeast is maintained, chromium concentrations will continue to decrease; however, if the flow velocity decreases, concentrations of chromium may increase.

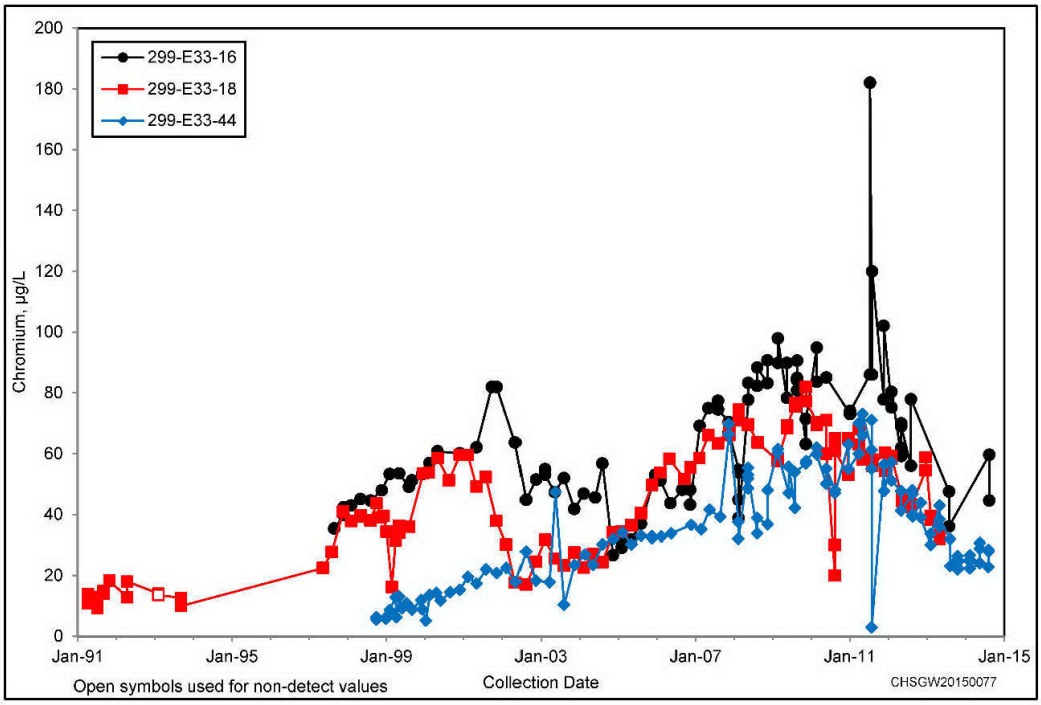

Figure 4-59. Chromium Concentrations at Wells 299-E33-16, 299-E33-18, and 299-E33-44

4.4.9 Cesium-137

Cesium-137 is associated with the 216-B-5 Reverse Well (Figure 4-3). Cesium-137 has not migrated large distances from the reverse well due to absorption to the soil sediments.

The area exceeding the DWS has maintained a similar configuration since mid-1990. Figure 4-60 shows the cesium-137 levels for Wells 299-E28-24 and 299-E28-25, located to the southeast and northwest of the 216-B-5 Reverse Well, respectively. The wells are located approximately 5 m (16 ft) to the southeast and 7 m (23 ft) to the northwest of the 216-B-5 Reverse Well. Cesium-137 activity at Well 299-E28-24 has ranged from 35.5 to 122 pCi/L; at Well 299-E28-25, activity has ranged from 34.5 to 114 pCi/L, besides the outlier of 238 pCi/L in 2004.

4.4.10 Plutonium-239/240

Plutonium-239/240 is associated with the 216-B-5 Reverse Well (Figure 4-3). Plutonium-239/240 has not migrated large distances from the reverse well due to absorption to soil sediments. Gross-alpha results exceeding the DWS in this area are mostly due to the elevated plutonium-239/240 and uranium.

The plutonium-239/240 plume exceeding the DWS has been relatively stable in a small area near the 216-B-5 Reverse Well since the mid-1990s. Figure 4-61 shows the plutonium-239/240 levels for Wells 299-E28-24 and 299-E28-25. The wells are located approximately 5 m (16 ft) to the southeast and 7 m (23 ft) to the northwest of the 216-B-5 Reverse Well, respectively. Plutonium-239/240 levels at Well 299-E28-24 have ranged from 0.04 to 16 pCi/L; at Well 299-E28-25, levels have ranged from 0 to 2.2 pCi/L.

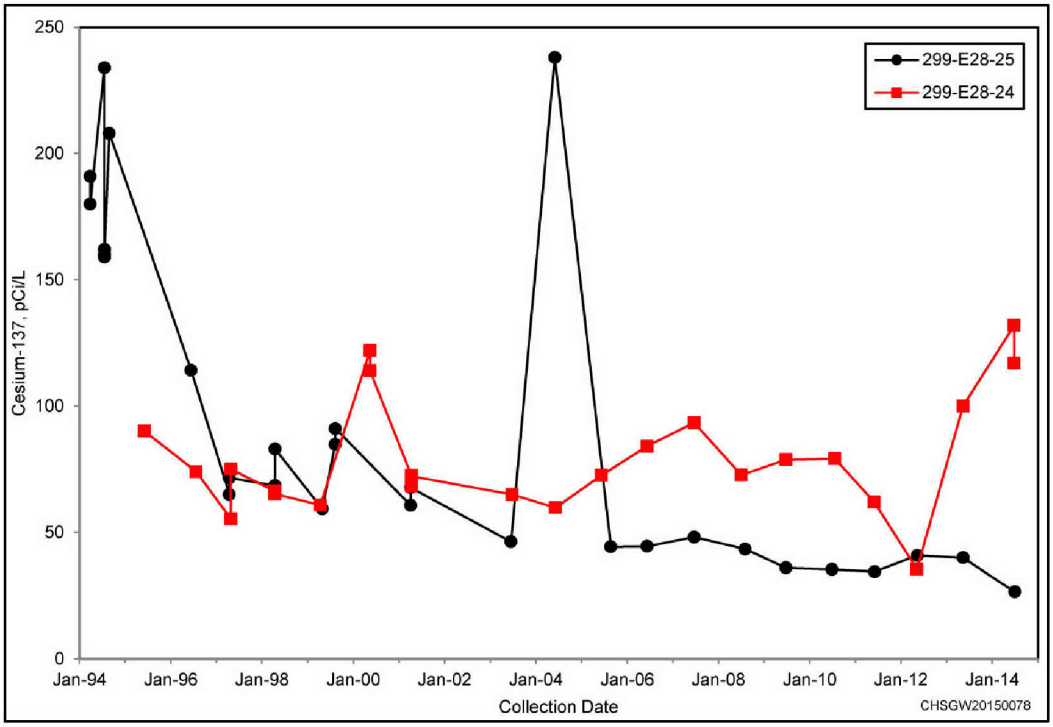

Figure 4-60. Cesium-137 Activity at Wells 299-E28-24 and 299-E28-25

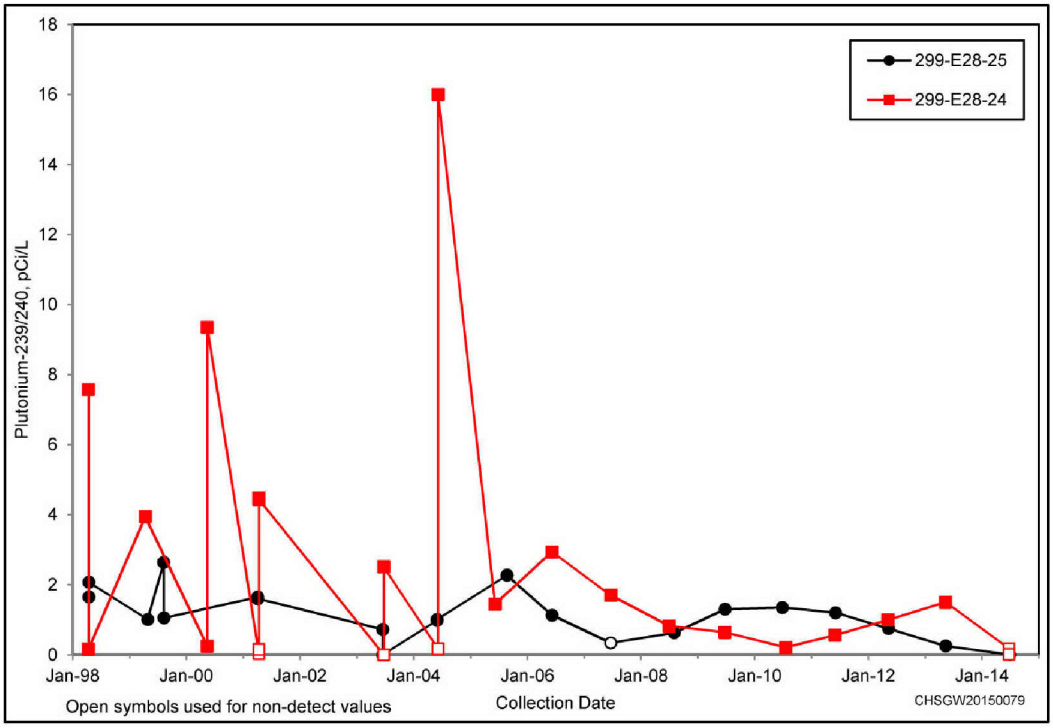

Figure 4-61. Plutonium-239/240 Activity at Wells 299-E28-24 and 299-E28-25

4.4.11 Fluoride

Elevated concentrations of fluoride remain at one well (299-E28-24) near the 216-B-5 Reverse Well. All of the remaining wells within the strontium-90 plume (a co-contaminant with fluoride from the 216-B-5 Reverse Well waste discharges) are considered to be within Hanford Site background limits for fluoride.

The 216-B-5 Reverse Well, located south of WMA B-BX-BY (Figure 4-3), impacted groundwater in 1945. This site received early 224-B Building lanthanum fluoride/bismuth phosphate cross-over waste from cell drainage (WMP-28945). The average derived fluoride concentration in the waste stream was nearly 2,400 mg/L (RPP-26744). Due to the high calcium concentrations in groundwater, the dissolved fluoride concentration within the groundwater was solubility limited. Studies have indicated that concentrations of fluoride generally do not exceed 3.1 mg/L.

It is hypothesized that the liquid fluoride was initially absorbed and possibly replaced hydroxide ions associated with sediments within the aquifer. Over time, desorption/absorption transport likely occurred until most of the fluoride reached equilibrium. Evidence of equilibrium is noted in fluoride sample results at Well 299-E28-7, located approximately 12 m (39 ft) southeast of Well 299-E28-24 (Figure 4-62). The results from this well were 500 to 600 µg/L prior to the August 1994 treatability test at the 200-BP-5 OU. Likewise, fluoride sample results at Well 299-E28-25, located approximately 12 m (39 ft) northwest of Well 299-E28-24, were 500 to 600 µg/L prior to the August 1994 treatability test (Figure 4-62). These results are about one-half of the Hanford Site groundwater background level of approximately 1,200 µg/L, as derived by the 95th percentile.

One possible reason for the fluoride concentrations exceeding the DWS at Well 299-E28-24 is the location of the well screen, between 7.6 and 9.1 m (25 to 30 ft) below the water table. It appears that the screen may be within less permeable Ringold sediments that have not established equilibrium conditions yet, and fluoride may still be desorbing from soil sediments into groundwater.

4.4.12 Arsenic

Arsenic has been detected at Well 299-E33-16 at elevated concentrations in the aquifer since sampling for arsenic began in 1997. The elevated concentrations are localized to this well. Nearby wells to the east, west, north, and south have arsenic concentrations well below the background level. Well 299-E33-16 was installed to monitor the 216-B-8 Crib. Due to the accidental addition of bismuth phosphate solids in 1948, crib drainage was compromised. Hydrochloric acid and acetic acid were added to the crib to increase the permeability or drainage at the crib; the amount of acid added to this crib is uncertain. It appears that the elevated arsenic results in Well 299-E33-16 are the result of mobilized natural arsenic from the acidified soil column.

4.4.13 Gross Alpha

Gross-alpha measurements in excess of the 15 pCi/L maximum contaminant level (MCL) were noted at the 216-B-62 Crib (22 pCi/L) and the 216-B-5 Reverse Well (22 pCi/L). Gross-alpha measurements near WMA B-BX-BY were also measured as high as 2,000 pCi/L. Gross alpha is considered an indicator for uranium and plutonium in the 200-BP-5 OU. Because it is only an indicator parameter, additional analyses are needed to define whether groundwater has been significantly affected. Thus, process knowledge and past groundwater results for uranium and plutonium have been relied upon more recently.

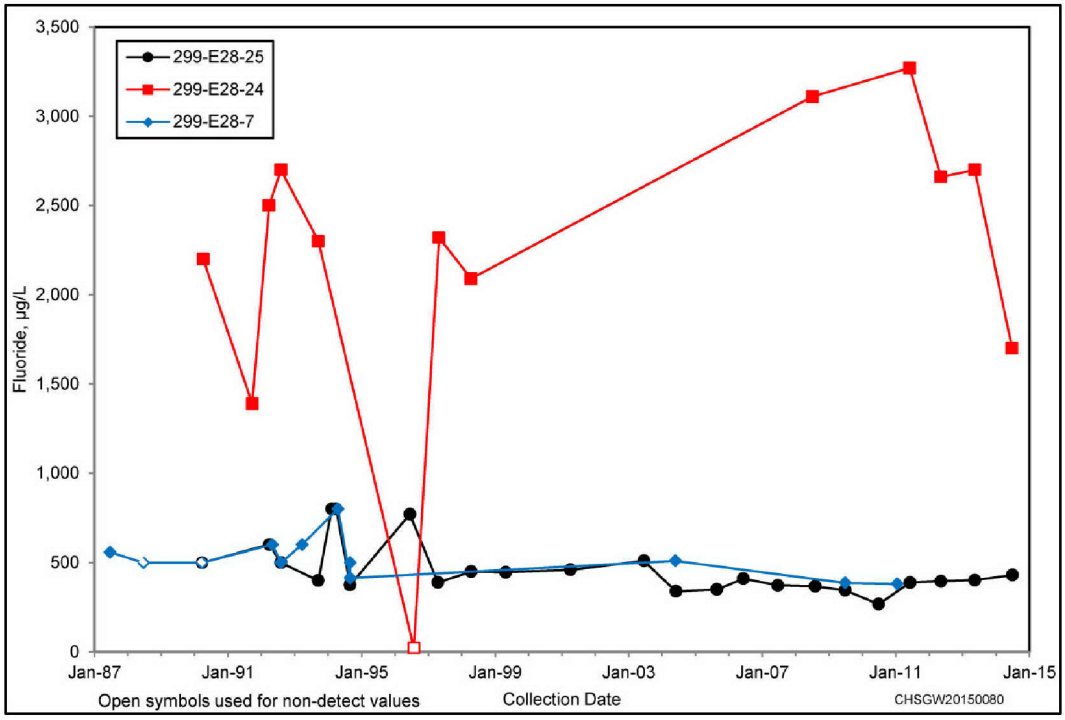

Figure 4-62. Fluoride Concentrations at Wells 299-E28-24, 299-E28-7, and 299-E28-25

4.4.14 Cobalt-60

Cobalt-60 has been detected in two wells, 299-E33-4 and 299-E33-7, near the BY Cribs. The BY Cribs received scavenged waste (Appendix B of WMP-28945) and are located north of the B-BX-BY Tank Farms (Figures 4-2 and 4-4). At the time of discharge, all of the transport properties of the various waste components were not known, and cribbing requirements were targeted at the mobility of cesium-137 and strontium-90. Because the transport properties of cobalt-60 in this waste stream were unknown at the time and the content of the waste stream was poorly understood, cobalt-60 was not considered in the cribbing criteria. It was later discovered that cobalt-60 was complexed by cyanide, allowing it to be transported through 82.3 m (270 ft) of the vadose zone and into the groundwater. In Well 299-E33-4, cobalt-60 was detected above 100 pCi/L from 1956 to 1963; the well was not sampled from 1964 to 1991. From 1991 to 1993, cobalt-60 was detected below 100 pCi/L; in samples collected from 2004 to 2008, it was detected above 100 pCi/L. The well has not been sampled since 2008, when it became sample dry. In Well 299-E33-7, cobalt-60 was detected above 100 pCi/L from 1960 to 1986, in one sample from 2007, and in two samples from 2008. Since 2008, cobalt-60 in this well has been detected at concentrations below 100 pCi/L. Cobalt-60 is no longer considered to be above the DWS, but it is monitored beneath the BY Cribs for possible changes due to flow changes or vadose zone infiltration variability.

4.4.15 Sulfate

Sulfate analyses are completed at more than 120 wells across the 200-BP-5 OU. The distribution of sulfate above the secondary DWS (250 mg/L) is limited to three locations within the OU: the BY Cribs, the east side of WMA C, and the southeast corner of LLWMA-2. High sulfate concentrations beneath the BY Cribs are not unexpected based on the large inventories of sulfate added in the initial phase of the bismuth phosphate process during B Plant operations. Portions of this waste stream were eventually sent to the BY Cribs after further separation of various fission and metal products. Although sulfate is a co-contaminant with nitrate, the extent of sulfate exceeding the secondary DWS is much less than nitrate and local to the sources contributing to the elevated concentrations.

Elevated sulfate concentrations at WMA C are limited to Wells 299-E27-14 and 299-E27-24 (southeast side of WMA C) since 2007. Concentrations vary but have not exceeded 310 mg/L.

Sulfate concentration in Well 299-E27-10 (on the southeast corner of LLWMA-2 and north of WMA C) has been detected above the secondary DWS of 250 mg/L since 2006. The highest concentration detected in this well was 361 mg/L from a depth-discrete sample located in the bottom portion of the screened interval. The elevated sulfate concentration in this well could be associated with migration of prior UPRs associated with the 216-B-2-1 and 216-B-2-2 Ditches. However, sulfate was not a substantial part of the later strontium-90 fractionation solutions. Alternatively, the elevated concentrations may be associated with dissolution of gypsum (a common arid environment evaporite mineral [$CaSO_4 \cdot 2H_2O$]) produces Ca^{2+} and SO_4^{2-}). This plume extends southward, with the south boundary near Well 299-E27-25 (located east of WMA C).

4.4.16 Other Elevated Constituents

During the investigation, certain constituents were found at elevated concentrations that do not result from contaminant discharges. For example, elevated concentrations of nickel, iron, cobalt, and chromium at Wells 299-E33-337 and 299-E33-339 were observed in 2011 and 2012 (Figure 4-63). These constituents were determined to be associated with casing corrosion based on video surveys and sample results of amorphous material from the well screen. Other wells have also been video surveyed and found to have minor well screen corrosion occurring (i.e., 299-E27-10 and 699-54-45A). One other well (699-52-55), although not video surveyed, has been identified with corrosion constituents based upon review of the drilling, installation, development, and sampling issues with this well. Thus, nickel, iron, cobalt, and chromium (except chromium associated with the 216-B-8 Crib) are not considered to be associated with contamination from a waste site or release, but rather from casing corrosion.

Likewise, manganese and zinc have been elevated in Well 299-E33-20 since 2000. An assessment of the pump and tubing materials for this well found a well maintenance order requiring replacement of existing tubing material with new tubing in the well. The new well tubing material included a 72.9 m (239.3 ft) length of galvanized tubing. Literature studies identify galvanized steel risers as a poor material for wells due to galvanic corrosion (PNNL-13690, *Selection of Sampling Pumps Used for Groundwater Monitoring at the Hanford Site*). PNNL-13690 states that "…common corrosion products associated with galvanized steel risers at Hanford include manganese and zinc." Thus, manganese and zinc are not considered to be associated with liquid waste discharges but are instead associated with galvanized pipe corrosion within the well. One other well (699-73-62) has been identified with a galvanized screen resulting in elevated zinc results, which is not considered representative of aquifer conditions.

At Well 699-50-56, cobalt concentrations just above the DWS were identified in 3 of 11 filtered samples. Cobalt is not detected in nearby wells, including wells that are upgradient of this well and downgradient of the nearest waste sites. Therefore, it appears that the detected cobalt concentrations are isolated to this well and are only detected intermittently. No source of cobalt near this well has been identified. The positive results are considered not to be representative of the aquifer, but are instead false-positive laboratory results.

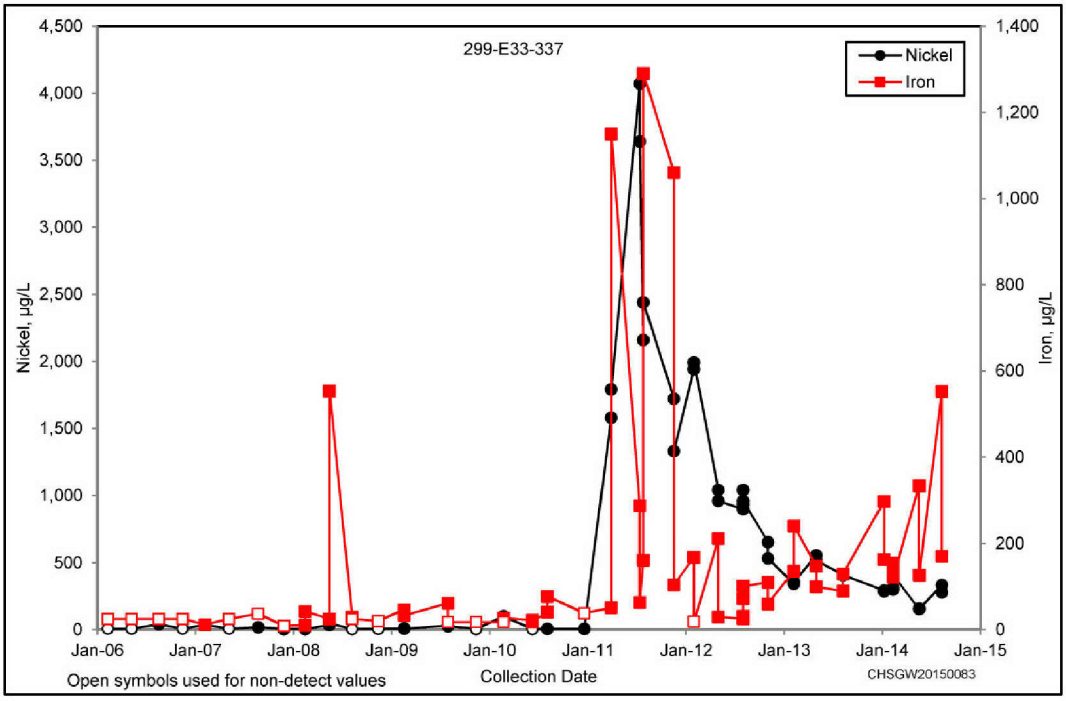

Figure 4-63. Nickel and Iron Concentrations at Well 299-E33-337

4.4.16.1 Confined Aquifer

Two locations within the 200-BP-5 OU confined aquifer have been impacted by Hanford Site operations (WHC-SD-EN-TI-019): east of the 200 East Area, and near WMA B-BX-BY. Well 699-45-42 is completed in the confined Ringold Formation (beneath the lower mud unit) east of the 200 East Area (Figure 2-3). Tritium was detected above 20,000 pCi/L in this well from 1962 to 1993. Tritium concentrations in the well have decreased from a peak concentration of 960,000 pCi/L in 1969 to less than 20,000 pCi/L staring in late 1993. Iodine-129 has been detected above 1 pCi/L in the well since sampling for this constituent began in 1994.

Well 299-E33-12 is completed in the Rattlesnake Ridge interbed near WMA B-BX-BY (Figure 4-4). Technetium-99 at concentrations greater than 900 pCi/L has been detected in the well since 1991. Because this well was installed in the 1950s and did not seal the unconfined aquifer from the confined aquifer, two additional wells (299-E33-50 and 299-E33-340) were installed during the RI to evaluate the aquifer in this area. Well 299-E33-50 was installed 33 m (108 ft) to the south to evaluate the upgradient groundwater quality and to evaluate whether contamination was associated with an upgradient source or from the lack of a well seal initially in Well 299-E33-12. Groundwater results from this well were nondetects or below background concentrations for all constituents. Well 299-E33-340 was installed 132 m (433 ft) to the north to evaluate the potential impact from groundwater downgradient of Well 299-E33-12. Some elevated concentrations of cyanide, iodine-129, nitrate, and technetium-99 were initially detected in the new well; however, the results were associated with samples collected during drilling and were determined to represent contamination from the unconfined aquifer mixed with the confined aquifer during drilling. The aquifer was purged substantially during development, and subsequent results have revealed much lower concentrations of cyanide, iodine-129, nitrate, and technetium-99. After well development and sampling, concentrations of cyanide, nitrate, and technetium-99 were approximately two orders of magnitude less than previous sampling, and iodine-129 was not detected in samples. Therefore, technetium-99 and other elevated constituents in the confined

aquifer appear to be very localized near Well 299-E33-12 and likely resulted from leakage along the poorly sealed well (see Section 4.4.2.1).

4.4.17 Surface Water and Sediments

Surface water and sediments are not applicable. This RI report is focused on groundwater and is not intended to address contamination in surface water or sediments.

4.4.18 Biota

Biota are not applicable. This RI report is focused on groundwater and is not intended to address contamination in biota.

4.4.19 Air

Air is not applicable. This RI report is focused on groundwater and is not intended to address contamination in the air.

4.5 Evaluation of Measured Groundwater Concentrations

This section presents a comprehensive interpretation of the sampling results used to identify analyte concentrations that are greater than action levels. Action levels are defined as screening levels derived from chemical-specific DWSs, ambient water quality criteria (AWQC), state surface water quality standards, and/or risk-based concentrations using default exposure assumptions. It is important to note that some of the exposure pathways in these screening levels are incomplete. The results of this evaluation will be used to support the COPC identification process that is provided in the groundwater BRA, which is presented in Chapter 6. The groundwater BRA provides a comprehensive evaluation of cumulative cancer risks and noncancer hazards.

A total of 161 monitoring and compliance wells were identified for inclusion in this evaluation, which is consistent with the data set used in the BRA. A total of 145 monitoring wells were screened in the unconfined aquifer, and 16 of the monitoring wells were screened in the basalt-confined aquifer. The groundwater evaluation was based on samples collected between January 2008 and December 2013, which were considered representative of current groundwater conditions. A list of the wells included in this evaluation is provided in Table 4-5, and well locations within the 200-BP-5 OU are shown in Figures E-1 through E-4 of Appendix E.

As described in Section 1.2.2, the 200-BP-5 OU underlies 71 CERCLA effluent waste sites and 6 RCRA facilities. As a result, the groundwater data set used in this evaluation was collected to fulfill monitoring requirements under RCRA, CERCLA, and the AEA. Because these data are collected for different purposes, wells within this OU are monitored for different target analytes, sampling frequencies, and required method detection limits (MDLs).

The boundaries of the 200-BP-5 OU encompass an area of approximately 84.5 km^2 (32.6 mi^2). At its northernmost extent, the OU borders the Columbia River, downgradient of the 100-BC-5 OU and upgradient of the 100-KR-4 OU. For the purpose of this evaluation, monitoring wells were spatially separated into 12 different areas to aid in the interpretation of the results. Table 4-5 provides a list of the 200-BP-5 OU monitoring wells by exposure area.

Table 4-5. 200-BP-5 OU Monitoring Wells by Exposure Area

LLWMA-1				
299-E28-26	299-E28-27	299-E28-28	299-E32-10	299-E32-2
299-E32-3	299-E32-4	299-E32-5	299-E32-6	299-E32-7
299-E32-8	299-E32-9	299-E33-265	299-E33-266	299-E33-28
299-E33-29	299-E33-30	299-E33-34	299-E33-35	
LLWMA-2 and 216-B-63 Trench				
299-E27-10	299-E27-11	299-E27-16	299-E27-17	299-E27-18
299-E27-19	299-E27-8	299-E27-9	299-E33-33	299-E33-36
299-E33-37	299-E34-10	299-E34-12	299-E34-2	299-E34-5[b]
299-E34-7[c]	299-E34-8	299-E34-9		
WMA B-BX-BY Tank Farm				
299-E28-8	299-E33-13	299-E33-14	299-E33-15	299-E33-16
299-E33-17	299-E33-18	299-E33-1A	299-E33-2	299-E33-20
299-E33-205	299-E33-21	299-E33-25[a]	299-E33-26	299-E33-3
299-E33-31	299-E33-32	299-E33-334	299-E33-335	299-E33-337
299-E33-338	299-E33-339	299-E33-341	299-E33-342	299-E33-343
299-E33-345	299-E33-38	299-E33-39	299-E33-4	299-E33-41
299-E33-42	299-E33-43	299-E33-44	299-E33-47	299-E33-48
299-E33-49	299-E33-5	299-E33-7	299-E33-9	
WMA C Tank Farm				
299-E27-12	299-E27-13	299-E27-14	299-E27-15	299-E27-155
299-E27-21	299-E27-22	299-E27-23	299-E27-24	299-E27-25
299-E27-4	299-E27-7			
B Plant				
299-E24-25	299-E28-13	299-E28-17	299-E28-18	299-E28-2
299-E28-21	299-E28-23	299-E28-24	299-E28-25	299-E28-30
299-E28-5	299-E28-6	299-E28-7	299-E29-54	
Semiworks				
299-E24-25	299-E24-8			

Table 4-5. 200-BP-5 OU Monitoring Wells by Exposure Area

Liquid Effluent Retention Basin				
299-E26-10	299-E26-11	299-E26-77	299-E26-79	
Gable Mountain Pond				
699-53-47A	699-53-47B	699-53-48A	699-54-48	699-54-49
699-55-50C				
200-BP-5 West				
699-47-60	699-48-50B	699-49-55A	699-49-57A	699-50-28B
699-50-56	699-50-59	699-52-55	699-53-55A	699-53-55B
699-53-55C	699-54-45A	699-55-57	699-55-60A	699-57-59
699-59-58	699-60-60			
Far-Field Area (North of Gable Gap)				
699-61-62	699-61-66	699-62-43F	699-63-55	699-64-62
699-65-50	699-66-58	699-67-51		
Near-River Area				
199-K-31	699-52-19	699-65-72	699-66-64	699-70-68
699-72-73	699-73-61			
200-BP-5 Confined				
299-E26-8	299-E33-12	299-E33-340	299-E33-40	299-E33-50
699-42-40C	699-49-55B	699-49-57B	699-50-53B	699-52-46A
699-52-55B	699-54-34	699-54-45B	699-56-43	699-56-53

Notes: Well 299-E33-25 is screened in the unconfined aquifer; however, the last sample collected was December 4, 2007.
Well 299-E34-5 is screened in the unconfined aquifer; however, the last sample collected was April 11, 2005.
Well 299-E34-7 is screened in the unconfined aquifer; however, the last sample collected was August 11, 2005.
LLWMA = low-level waste management area
WMA = waste management area

Monitoring wells located within the near-field area of the 200-BP-5 OU and screened in the unconfined aquifer were separated into nine exposure areas:

- LLWMA-1 (218-E-10 Landfill)
- LLWMA-2 (218-E-12B Landfill) and the 216-B-63 Trench
- WMA B-BX-BY Tank Farms (B-BX-BY Tank Farms)
- WMA C Tank Farm (C Tank Farm)

- B Plant
- Semiworks
- LERF
- Gable Mountain Pond
- 200-BP-5 west

Monitoring wells located within the far-field area of the 200-BP-5 OU and screened in the unconfined aquifer were separated into two exposure areas:

- Far-field area (north of Gable Gap)
- Near-river area

Monitoring wells screened in the basalt-confined aquifer were grouped into a single exposure area, 200-BP-5 confined.

4.5.1.1 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, and/or risk-based concentrations using default exposure assumptions. It should be noted that exposure pathways for some of the screening levels are incomplete. The comparisons discussed further in this section identify the screening levels that are relevant for the exposure area.

The sources of action levels from federal regulations are as follows:

- 40 CFR 141, "National Primary Drinking Water Regulations"; MCLs; secondary MCLs; and nonzero maximum contaminant level goals (MCLGs) 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)
- 40 CFR 131, "Water Quality Standards," for states not complying with Section 304 of the CWA

The sources of action levels from Washington State regulations are as follows:

- WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"
- WAC 173-340-720, MTCA "Groundwater Cleanup Standards," 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 and AWQC standards are considered when identifying action levels, it must be noted that these standards only apply for groundwater where it enters the Columbia River (i.e., the near-river exposure area). 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. A summary of the action levels used for comparison of groundwater that could potentially discharge into the Columbia River is provided in Table 4-6. For the upland portions of groundwater, only DWSs are applicable. A summary of the action levels used for comparison of upland groundwater is provided in Table 4-7.

Table 4-6. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 200-BP-5 OU

			Groundwater					Surface Water					Action Level Value	
			40 CFR 141		WAC 246-290-310	WAC 173-340-720		CWA National Recommended Water Quality Criteria		WAC 173-201A	40 CFR 131			
CAS Number	Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
7429-90-5	Aluminum	µg/L	—	—	—	—	16,000	750	87	—	—	—	87	CWA – freshwater CCC
14596-10-2	Americium-241	pCi/L	15	—	—	—	—	—	—	—	—	—	15	40 CFR 141 – federal MCL
7440-38-2	Arsenic	µg/L	10	—	10	—	0.058	340	150	360	190	190	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-39-3	Barium	µg/L	2,000	2,000	2,000	—	3,200	—	—	—	—	—	2,000	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)
7440-43-9	Cadmium	µg/L	5	5	5	—	8	2	0.25	3.7	1	0.91	0.25	CWA – freshwater CCC
14762-75-5	Carbon-14	pCi/L	2,000	—	--	—	—	—	—	—	—	—	2,000	40 CFR 141 – federal MCL
16887-00-6	Chloride	µg/L	250,000	—	250,000	—	—	—	—	—	—	—	250,000	40 CFR 141 – secondary federal MCL
67-66-3	Chloroform	µg/L	70	—	70	—	1.4	—	—	—	—	—	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-47-3	Chromium	µg/L	100	100	100	—	24,000	570	64.878	550	180	156	65	CWA – freshwater CCC
7440-48-4	Cobalt	µg/L	—	—	—	—	4.8	—	—	—	—	—	4.8	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-50-8	Copper	µg/L	1,300	1,300	—	—	640	—	9	17	11	—	9	CWA – freshwater CCC
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	mrem/yr	4[a]	—	—	—	—	—	—	—	—	—	4	40 CFR 141 – federal MCL
18540-29-9	Cr(VI)	µg/L	—	—	—	—	48	16	11	15	10	10	10	WAC 173-201A
150-46-84-1	Iodine-129	pCi/L	1	—	—	—	—	—	—	—	—	—	1.0	40 CFR 141 – federal MCL
7439-89-6	Iron	µg/L	—	—	—	—	11,200	—	1,000	—	—	—	1,000	CWA – freshwater CCC
7439-92-1	Lead	µg/L	15	—	—	15	--	65	2.5	65	2.5	2.1	2.1	WAC 173-201A
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)
7439-98-7	Molybdenum	µg/L	—	—	—	—	80	—	—	—	—	—	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-02-0	Nickel	µg/L	—	100	—	—	320	470	52	1400	160	137	52	CWA – freshwater CCC
14797-55-8	Nitrate	µg/L	45,000	45,000	—	—	113,600	—	—	—	—	—	45,000	40 CFR 141 – federal MCL

Table 4-6. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 200-BP-5 OU

			Groundwater					Surface Water					Action Level Value	
			40 CFR 141		WAC 246-290-310	WAC 173-340-720		CWA National Recommended Water Quality Criteria		WAC 173-201A	40 CFR 131			
CAS Number	Analyte Name	Units	Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Acute Freshwater CMC	Freshwater CCC	Freshwater CCC	Freshwater CMC	Freshwater CCC	Action Level	Action Level Basis
14797-65-0	Nitrite	µg/L	3,300	3,300	—	—	4,800	—	—	—	—	—	3,300	40 CFR 141 – federal MCL
7782-49-2	Selenium	µg/L	—	—	—	—	80	—	5	20	5	5	5	CWA – freshwater CCC
7440-24-6	Strontium	µg/L	—	—	—	—	9,600	—	—	—	—	—	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
14808-79-8	Sulfate	µg/L	250,000	—	250,000	—	—	—	—	—	—	—	250,000	40 CFR 141 – secondary federal MCL
14133-76-7	Technetium-99	pCi/L	900	—	—	—	—	—	—	—	—	—	900	40 CFR 141 – federal MCL
7440-28-0	Thallium	µg/L	2	0.5	—	—	—	—	—	—	—	—	0.50	--
7440-31-5	Tin	µg/L	—	—	—	—	9,600	—	—	—	—	—	9,600	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
79-01-6	Trichloroethene	µg/L	5	—	—	—	0.54	—	—	—	—	—	0.54	CLARC guidance[b]
10028-17-8	Tritium	pCi/L	20,000	—	—	—	—	—	—	—	—	—	20,000	40 CFR 141 – federal MCL
7440-61-1	Uranium	µg/L	30	—	—	—	48	—	—	—	—	—	30	40 CFR 141 – federal MCL
7440-62-2	Vanadium	µg/L	—	—	—	—	80	—	—	—	—	—	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-66-6	Zinc	µg/L	5,000	—	5,000	—	4,800	120	120	110	100	91	91	WAC 173-201A

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.

a. The DWS listed for gross beta represents the annual cumulative dose equivalent of 4 mrem to the total body or internal organ from exposure to beta and photon emitters.

b. CLARC guidance from CLARC 2014 data tables ("Groundwater – Method B, Method A, and ARARs, Trichloroethylene").

Sources:

40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

Ecology Publication 94-06, *Model Toxics Control Act Cleanup Regulation and Statute*.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720(4)(b)(ii)(A) and (B), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

CAS = Chemical Abstract Services
CCC = criteria continuous concentration
CLARC = Cleanup Levels and Risk Calculations (database)
CMC = criteria maximum concentration
Cr(VI) = hexavalent chromium
CWA = *Clean Water Act of 1977*
DWS = drinking water standard
MCL = maximum contaminant level
MCLG = maximum contaminant level goal

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Table 4-7. Summary of Federal and State DWSs Used as Human Health Action Levels for the 200-BP-5 OU

CAS Number	Analyte Name	Units	Groundwater					Human Health Action Level Value	
			40 CFR 141		WAC 246-290-310	WAC 173-340-720			
			Federal MCL	Federal MCLG	State MCL	Groundwater Method A Cleanup Levels	Groundwater Method B Unrestricted Land Use	Action Level	Action Level Basis
591-78-6	2-Hexanone	µg/L	—	—	—	—	40	40	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)
98-86-2	Acetophenone	µg/L	—	—	—	—	800	800	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)
14596-10-2	Americium-241	pCi/L	15	—	—	—	—	15	40 CFR 141 – federal MCL
7440-36-0	Antimony	µg/L	6	6	6	—	6.4	6	40 CFR 141 – federal MCL
7440-38-2	Arsenic	µg/L	10	—	10	—	0.058	0.058	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-39-3	Barium	µg/L	2,000	2,000	2,000	—	3,200	2,000	40 CFR 141 – federal MCL
71-43-2	Benzene	µg/L	5	—	—	—	0.8	0.8	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-41-7	Beryllium	µg/L	4	4	4	—	32	4	40 CFR 141 – federal MCL
117-81-7	Bis(2-ethylhexyl)phthalate	µg/L	6	—	—	—	6.3	6	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)
85-68-7	Butylbenzylphthalate	µg/L	—	—	—	—	46	46	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-43-9	Cadmium	µg/L	5	5	5	—	8	5	40 CFR 141 – federal MCL
14762-75-5	Carbon-14	pCi/L	2,000	—	—	—	—	2,000	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	—	—	—	0.625	0.625	WAC 173-340-720(4)(b)(iii)(A) and (B)
10045-97-3	Cesium-137	pCi/L	200	—	—	—	—	200	40 CFR 141 – federal MCL
16887-00-6	Chloride	µg/L	250,000	—	250,000	—	—	250,000	40 CFR 141 – secondary federal MCL
67-66-3	Chloroform	µg/L	70	—	70	—	1.4	1.4	WAC 173-340-720(4)(b)(iii)(A) and (B)
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	1,300	—	—	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)
15585-10-1	Europium-154	pCi/L	60	—	—	—	—	60	40 CFR 141 – federal MCL
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	mrem/yr	4*	—	—	—	—	4	40 CFR 141 – federal MCL
18540-29-9	Cr(VI)	µg/L	—	—	—	—	48	48	WAC 173-340-720(4)(b)(iii)(A) and (B)
150-46-84-1	Iodine-129	pCi/L	1	—	—	—	—	1	40 CFR 141 – federal MCL

Table 4-7. Summary of Federal and State DWSs Used as Human Health Action Levels for the 200-BP-5 OU

			Groundwater					Human Health Action Level Value	
			40 CFR 141		WAC 246-290-310	WAC 173-340-720			
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
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	—	—	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)
7487-94-7	Mercury	µg/L	2	2	2	—	4.8	2	40 CFR 141 – federal MCL
80-62-6	Methyl methacrylate	µg/L	—	—	—	—	11,200	11,200	WAC 173-340-720(4)(b)(iii)(A) and (B)
66-27-3	Methyl methanesulfonate	µg/L	—	—	—	—	0.88	0.88	WAC 173-340-720(4)(b)(iii)(A) and (B)
13994-20-2	Neptunium-237	pCi/L	15	—	—	—	—	15	40 CFR 141 – federal MCL
7440-02-0	Nickel	µg/L	—	100	—	—	320	100	40 CFR 141 – federal MCL
14797-55-8	Nitrate	µg/L	45,000	45,000	—	—	113,600	45,000	40 CFR 141 – federal MCL
14797-65-0	Nitrite	µg/L	3,300	3,300	—	—	4,800	3,300	40 CFR 141 – federal MCL
621-64-7	n-Nitrosodi-n-dipropylamine	µg/L	—	—	—	—	0.013	0.013	WAC 173-340-720(4)(b)(iii)(A) and (B)
39001-02-0	Octachlorodibenzofuran	µg/L	—	—	—	—	3.36E-09	3.36E-09	WAC 173-340-720(4)(b)(iii)(A) and (B)
OIL/GREASE	Oil and grease	µg/L	—	—	—	500	—	500	WAC 173-340-900 Tables, Table 720-1
108-95-2	Phenol	µg/L	—	—	—	—	2,400	2,400	WAC 173-340-720(4)(b)(iii)(A) and (B)
13981-16-3	Plutonium-238	pCi/L	15	—	—	—	—	15	40 CFR 141 – federal MCL
PU-239/240	Plutonium-239/240	pCi/L	15	—	—	—	—	15	40 CFR 141 – federal MCL
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	—	—	—	—	8	40 CFR 141 – federal MCL
14808-79-8	Sulfate	µg/L	250,000	—	250,000	—	—	250,000	40 CFR 141 – secondary federal MCL
14133-76-7	Technetium-99	pCi/L	900	—	—	—	—	900	40 CFR 141 – federal MCL
7440-28-0	Thallium	µg/L	2	—	—	—	—	2	40 CFR 141 – federal MCL
7440-31-5	Tin	µg/L	—	—	—	—	9,600	9,600	WAC 173-340-720(4)(b)(iii)(A) and (B)
108-88-3	Toluene	µg/L	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
126-73-8	Tributyl phosphate	µg/L	—	—	—	—	9.72	9.72	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	—	—	—	48	30	40 CFR 141 – federal MCL
7440-62-2	Vanadium	µg/L	—	—	—	—	80	80	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-66-6	Zinc	µg/L	5,000	—	5,000	—	4,800	4,800	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table 4-7. Summary of Federal and State DWSs Used as Human Health Action Levels for the 200-BP-5 OU

			Groundwater					Human Health Action Level Value	
			40 CFR 141		WAC 246-290-310	WAC 173-340-720			
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

Sources: 40 CFR 141, "National Primary Drinking Water Regulations."

Ecology Publication 94-06, *Model Toxics Control Act Cleanup Regulation and Statute*.

WAC 173-340-720(4)(b)(ii)(A) and (B), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."

* The DWS listed for gross beta represents the annual cumulative dose equivalent of 4 mrem to the total body or internal organ from exposure to beta and photon emitters.

CAS = Chemical Abstract Services
Cr(VI) = hexavalent chromium
DWS = drinking water standard
MCL = maximum contaminant level
MCLG = maximum contaminant level goal

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4.5.1.2 Comparison Results for the Unconfined Aquifer

As previously discussed, wells within the near-field area of the OU were separated into nine exposure areas, and wells within the far-field area of the OU were separated into two exposure areas. Groundwater data for each exposure area were compiled and statistically analyzed, and the results are presented in Appendix E, Tables E-1 through E-12. These tables present the summary statistics for each analyte detected within the exposure area, the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available, and the action level for each analyte. Data processing and reduction steps are described in Section 6.1.1.1 of this RI report.

Low-Level Waste Management Area 1

Nineteen wells are screened in the unconfined aquifer and monitor contaminants near LLWMA-1. Groundwater samples are collected to fulfill RCRA and AEA monitoring requirements. Groundwater samples within this exposure area were analyzed for the following classes of analytes: anions, cyanide, herbicides, metals, pesticides, phenols, polychlorinated biphenyls (PCBs), radionuclides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), dioxins/furans, total petroleum hydrocarbon (TPH)-diesel range organics, and TPH-gasoline range organics.

All sample results for phenols, SVOCs, pesticides, PCBs, herbicides, and TPH-gasoline were reported as nondetected and are not discussed further in this section. The analytes that were detected at least once are as follows:

- **Radionuclides:** As shown in Table E-1 of Appendix E, cobalt-60, gross alpha, gross beta, iodine-129, technetium-99, and tritium were detected in groundwater. Gross alpha, iodine-129, technetium-99, and tritium concentrations were greater than their respective DWSs. All wells in this exposure area were analyzed for iodine-129, technetium-99, and tritium; 11 wells were analyzed for gross alpha; and 10 wells were analyzed for gross beta. Radionuclides reported at concentrations above their respective DWSs are discussed below.

  - Gross alpha was detected in 13 of 16 groundwater samples (81 percent frequency), with concentrations ranging between 3.5 and 26 pCi/L. Well 299-E32-10 reported concentrations of 19 and 26 pCi/L, which are above the DWS of 15 pCi/L. Gross alpha is an indicator of uranium and is retained as a COPC.

  - Gross beta was detected in all of the 20 groundwater samples (100 percent frequency), with concentrations ranging between 17 and 4,200 pCi/L. The presence of gross beta is generally consistent with that of iodine-129, technetium-99, 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 6.4.4.

  - Iodine-129 was detected in 140 of 204 groundwater samples (69 percent frequency), with concentrations ranging between 0.17 and 5.2 pCi/L. Eleven of 19 wells reported concentrations greater than the DWS of 1 pCi/L. Wells that reported iodine-129 above the DWS include 299-E28-27, 299-E32-10, 299-E32-8, 299-E32-9, 299-E33-28, 299-E33-29, 299-E33-30, 299-E33-34, 299-E33-35, 299-E33-265, and 299-E33-266. Iodine-129 is retained as a COPC.

- Technetium-99 was detected in 204 of 205 groundwater samples (greater than 99 percent frequency), with concentrations ranging between 11 and 21,000 pCi/L. Seven of 19 wells reported concentrations greater than the DWS of 900 pCi/L. Wells that reported technetium-99 concentrations above the DWS include 299-E32-10, 299-E32-8, 299-E32-9, 299-E33-265, 299-E33-28, 299-E33-34, and 299-E33-35. Technetium-99 is retained as a COPC.

- Tritium was detected in 181 of 206 groundwater samples (88 percent frequency), with concentrations ranging between 210 and 26,000 pCi/L. Well 299-E33-34 reported concentrations (21,000 to 26,000 pCi/L) above the DWS of 20,000 pCi/L. Tritium is retained as a COPC.

- **VOCs:** As shown in Table E-1 of Appendix E, acetone and chloroform were each detected once in groundwater.

  - Acetone was detected in one of 24 groundwater samples (4.2 percent frequency), with the single detection reported at a concentration of 1 µg/L. All acetone results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 7,200 µg/L. Based on these results, acetone is not retained as a COPC.

  - Chloroform was detected in one of 24 groundwater samples (4.2 percent frequency), with the single detection reported at a concentration of 0.13 µg/L. All chloroform results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 1.4 µg/L. Based on these results, chloroform is not retained as a COPC.

- **TPH-diesel:** As shown in Table E-1 of Appendix E, TPH-diesel was detected in 2 of 22 groundwater samples (9.1 percent frequency) at a concentration of 140 µg/L. All TPH-diesel results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) Method A value of 500 µg/L. Based on these results, TPH-diesel is not retained as a COPC.

- **Dioxins/furans**: As shown in Table E-1 of Appendix E, octachlorodibenzofuran was detected in 4 of 22 groundwater samples (18 percent frequency), with concentrations ranging between 0.000001 and 0.0000017 µg/L. All of the results (detected results and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 0.0022 µg/L. Octachlorodibenzofuran is not retained as a COPC.

- **Anions:** As shown in Table E-1 of Appendix E, chloride, fluoride, nitrite, and sulfate were each detected in groundwater. All chloride, fluoride, nitrite, and sulfate results (detected concentrations and MDLs) were less than their respective action levels. Chloride, fluoride, nitrite, and sulfate are not retained as COPCs.

  - Nitrate was detected in each of the 227 groundwater samples, with concentrations ranging between 31,900 and 1,050,000 µg/L. Each of the 19 wells reported concentrations greater than the DWS of 45,000 µg/L. Nitrate is retained as a COPC.

- **Cyanide:** As shown in Table E-1 of Appendix E, cyanide was detected in 62 of 94 groundwater samples analyzed (66 percent frequency), with concentrations ranging between 4.1 and 558 µg/L. Each of the 19 wells reported concentrations greater than the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, cobalt, and uranium, all metals results (detected concentrations and MDLs) were less than their respective action levels.

- As shown in Table E-1 of Appendix E, antimony was detected in 3 of 23 unfiltered groundwater samples (13 percent frequency), with concentrations ranging between 46 and 50 µg/L. Antimony was analyzed in each of the 19 wells. All three detected concentrations were greater than the DWS of 6 µg/L, which was also analyzed using EPA Method 6010. Antimony results reported by Method 6010 are not accurate at concentrations at or near the DWS or the Hanford Site background concentration. Groundwater samples from Wells 299-E28-27 and 299-E33-30 were analyzed using Methods 6010 and 200.8 to identify the differences in analytical method sensitivity. Figures E-5 and E-6 in Appendix E provide time-series plots of antimony results for both analytical methods. All MDLs for Method 6010 are greater than the DWS, and many are greater than the Hanford Site background level of 55 µg/L, whereas MDLs for Method 200.8 are all less than the DWS (less than 1 µg/L). Results show that when groundwater samples are analyzed using Method 200.8, antimony concentrations are less than the DWS and Hanford Site background. Based on these results, antimony is not retained as a COPC.

- As shown in Table E-1 of Appendix E, arsenic was detected in all of the 33 unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 3.3 and 6.3 µg/L. Arsenic was analyzed in each of the 19 wells. All detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All arsenic concentrations in unfiltered samples are less than the 90th percentile Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

- As shown in Table E-1 of Appendix E, cobalt was detected in 19 of the 225 unfiltered groundwater samples (8.4 percent frequency), with concentrations ranging between 0.1 and 5.7 µg/L. Cobalt was analyzed in each of the 19 wells; 2 wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Wells that reported cobalt above the action level include 299-E28-27 and 299-E32-3. Cobalt concentrations in both wells are not associated with a trend. Cobalt was analyzed more than 10 times over the past 10 years at both wells. A single sporadic result was reported above the 2007 MTCA cleanup level at Well 299-E28-27 (4.9 µg/L) and Well 299-E32-3 (5.7 µg/L); both results were flagged by the laboratory with a "B" qualifier, indicating it is an estimated result. All remaining results were less than the 2007 MTCA cleanup level. Based on these results, cobalt is not retained as a COPC.

- As shown in Table E-1 of Appendix E, uranium was detected in 205 of 206 groundwater samples (greater than 99 percent frequency), with concentrations ranging between 2.3 and 159 µg/L. Uranium was analyzed in each of the 19 wells. Four of 19 wells (299-E28-27, 299-E32-10, 299-E33-34, and 299-E33-35) reported concentrations above the DWS of 30 µg/L. Uranium is retained as a COPC.

Low-Level Waste Management Area 2 and 216-B-63 Trench

Eighteen wells are screened in the unconfined aquifer and monitor contaminants near LLWMA-2 and the 216-B-63 Trench. However, two wells (299-E34-5 and 299-E34-7) did not have samples collected within the time frame of interest; therefore, 16 wells are evaluated in this exposure area. Groundwater samples are collected to fulfill CERCLA, RCRA, and AEA monitoring requirements. One or more groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, VOCs, phenols, SVOCs, PCBs, TPH-diesel range organics, and TPH-gasoline range organics.

All sample results for phenols, SVOCs, VOCs, PCBs, TPH-diesel, and TPH-gasoline were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-2 of Appendix E, gross alpha, gross beta, iodine-129, technetium-99, and tritium were detected in groundwater. Iodine-129 and technetium-99 concentrations were greater than their respective DWSs. Fifteen wells were analyzed for iodine-129, and 14 wells were analyzed for technetium-99. Radionuclides reported at concentrations above their respective DWSs are discussed below.

  - Gross beta was detected in 55 of 56 groundwater samples (98 percent frequency), with concentrations ranging between 4.2 and 1,400 pCi/L. The presence of gross beta is generally consistent with that of iodine-129 and technetium-99. 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 6.4.4.

  - Iodine-129 was detected in 95 of 122 groundwater samples (78 percent frequency), with concentrations ranging between 0.22 and 4.2 pCi/L. Twelve of 15 wells reported concentrations greater than the DWS of 1 pCi/L. Wells that reported iodine-129 above the DWS include 299-E27-10, 299-E27-11, 299-E27-17, 299-E27-18, 299-E27-19, 299-E27-8, 299-E27-9, 299-E33-33, 299-E33-36, 299-E33-37, 299-E34-12, and 299-E34-8. Iodine-129 is retained as a COPC.

  - Technetium-99 was detected in 66 of 133 groundwater samples (50 percent frequency), with concentrations ranging between 7.1 and 9,800 pCi/L. Three of 14 wells (299-E33-36, 299-E33-37, and 299-E34-9) reported concentrations greater than the DWS of 900 pCi/L. Technetium-99 is retained as a COPC.

- **Anions:** As shown in Table E-2 in Appendix E, chloride, fluoride, and nitrite were each detected in groundwater. All chloride, fluoride, and nitrite results (detected concentrations and MDLs) were less than their respective action levels. Chloride, fluoride, and nitrite are not retained as COPCs.

  - Nitrate was detected in all of the 172 groundwater samples, with concentrations ranging between 6,770 and 452,000 µg/L. Twelve of 16 wells reported concentrations greater than the DWS of 45,000 µg/L. Wells that reported concentrations above the DWS include 299-E27-10, 299-E27-16, 299-E27-18, 299-E27-19, 299-E27-9, 299-E33-33, 299-E33-36, 299-E33-37, 299-E34-10, 299-E34-12, 299-E34-8, and 299-E34-9. Nitrate is retained as a COPC.

  - Sulfate was detected in each of the 172 groundwater samples, with concentrations ranging between 53,000 and 361,000 µg/L. Two of 16 wells (299-E27-10 and 299-E27-9) reported concentrations greater than the secondary DWS of 250,000 µg/L. Sulfate is retained as a COPC.

- **Cyanide:** As shown in Table E-2 in Appendix E, cyanide was detected in 5 of 25 groundwater samples (20 percent frequency), with concentrations ranging between 6.2 and 411 µg/L. Four of seven wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Wells that reported concentrations above the action level include 299-E33-33, 299-E33-36, 299-E33-37, and 299-E34-9. All of these wells showed recent upward trends in cyanide concentrations. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, and nickel, all metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-2 in Appendix E, antimony was detected in 6 of 21 unfiltered groundwater samples (29 percent frequency), with concentrations ranging between 5.6 and 114 µg/L.

Antimony was analyzed in 14 of 16 wells. Five of six detected concentrations were greater than the DWS of 6 µg/L, and four of six were greater than the 90th percentile Hanford Site background level of 55 µg/L. As discussed previously, antimony results reported using Method 6010 are not accurate at concentrations at or near the DWS or the Hanford Site background concentration. Based on these results, antimony is not retained as a COPC.

- As shown in Table E-2 in Appendix E, arsenic was detected in each of the 19 unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 4.3 and 9.9 µg/L. Arsenic was analyzed in 8 of 16 wells. All detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All arsenic concentrations in unfiltered samples are within the range of Hanford Site background concentrations. Based on these results, arsenic is not retained as a COPC.

- As shown in Table E-2 in Appendix E, dissolved total chromium (evaluated as Cr(VI)) was detected in 63 of 153 filtered groundwater samples (41 percent frequency), with concentrations ranging between 3.2 and 54 µg/L. Dissolved total chromium was analyzed in each of the 16 wells. Dissolved total chromium was detected once above the 2007 MTCA (WAC 173-340-720) level of 48 µg/L from Well 299-E27-11. As shown in Figure E-7 in Appendix E, dissolved total chromium concentrations above the action level in Well 299-E27-11 are not associated with a trend. Dissolved total chromium was analyzed more than 20 times in this well over the past 10 years. With the exception of the single result, all remaining dissolved total chromium results were less than 14 µg/L. Additionally, all reported Cr(VI) results from this exposure area were also less than the action level. Cr(VI) is not retained as a COPC.

- As shown in Table E-2 in Appendix E, nickel was detected in 104 of 154 unfiltered groundwater samples (68 percent frequency), with concentrations ranging between 4.0 and 198 µg/L. Nickel was analyzed in each of the 16 wells. Nickel was detected above the DWS of 100 µg/L in Well 299-E27-10, where concentrations range between 103 and 198 µg/L. As described in Section 4.4.16, the presence of nickel at concentrations above the DWS at Well 299-E27-10 was determined to be associated with the corrosion of the well casing based on the evaluation of the casing during a television survey. As a result of this evaluation, nickel is not retained as a COPC.

Waste Management Area B-BX-BY Tank Farms

Thirty-nine wells are screened in the unconfined aquifer and monitor contaminants near the B-BX-BY Tank Farms. However, one well (299-E33-25) did not have samples collected within the time frame of interest; therefore, 38 wells are evaluated in this exposure area. Groundwater samples are collected to fulfill CERCLA, RCRA, and AEA monitoring requirements. One or more groundwater samples were analyzed for the following classes of analytes: field parameters, anions, cyanide, metals, radionuclides, VOCs, SVOCs, and pesticides. All sample results for pesticides were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-3 of Appendix E, 14 of 27 radionuclides analyzed were detected in groundwater. Cobalt-60, gross alpha, iodine-129, technetium-99, and tritium concentrations were greater than their respective DWSs. Each of the 38 wells was analyzed for cobalt-60, technetium-99, and tritium; 37 wells were analyzed for gross alpha; and 31 wells were analyzed for iodine-129. Radionuclides reported at concentrations above their respective DWSs are discussed below.

- Cobalt-60 was detected in 144 of 357 groundwater samples (40 percent frequency), with concentrations ranging between 3.9 and 1,040 pCi/L. Two of 38 wells reported concentrations greater than the DWS of 100 pCi/L. Cobalt-60 was reported twice above the DWS at Well 299-E33-7 during 2008, with concentrations decreasing to 36 pCi/L in 2012. Cobalt-60 was analyzed once at Well 299-E33-4 (1,040 pCi/L) during the 6-year time frame. Previous cobalt-60 measurements at this well ranged between 105 and 599 pCi/L. Based on these results, cobalt-60 is retained as a COPC.

- Gross alpha was detected in 331 of 435 groundwater samples (76 percent frequency), with concentrations ranging between 1.5 and 2,300 pCi/L. Thirty-one of 36 wells reported concentrations greater than the DWS of 15 pCi/L. The following six wells reported concentrations less than the DWS: 299-E28-8, 299-E33-14, 299-E33-17, 299-E33-20, 299-E33-21, and 299-E33-39. Gross alpha is an indicator of uranium and is retained as a COPC.

- Gross beta was detected in each of the 462 groundwater samples (100 percent frequency), with concentrations ranging between 16 and 26,000 pCi/L. The presence of gross beta is generally consistent with that of iodine-129, technetium-99, 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 6.4.4.

- Iodine-129 was detected in 131 of 139 groundwater samples (94 percent frequency), with concentrations ranging between 0.73 and 6.7 pCi/L. Twenty-nine of the 31 wells reported concentrations greater than the DWS of 1 pCi/L. Wells 299-E33-14 and 299-E33-39 reported concentrations less than the DWS. Iodine-129 is retained as a COPC.

- Technetium-99 was detected in all 596 groundwater samples (100 percent frequency), with concentrations ranging between 23 and 39,000 pCi/L. Each of the 38 wells reported concentrations greater than the DWS of 900 pCi/L. Technetium-99 is retained as a COPC.

- Tritium was detected in 576 of 577 groundwater samples (greater than 99 percent frequency), with concentrations ranging between 190 and 91,000 pCi/L. Ten of the 38 wells reported concentrations above the DWS of 20,000 pCi/L. The following wells reported concentrations above the DWS: 299-E33-13, 299-E33-15, 299-E33-18, 299-E33-26, 299-E33-3, 299-E33-342, 299-E33-38, 299-E33-47, 299-E33-7, and 299-E33-9. Tritium is retained as a COPC.

- **VOCs:** As shown in Table E-3 in Appendix E, carbon tetrachloride, chloroform, and methylene chloride were detected in groundwater. VOCs were analyzed in 21 of 39 wells.

  - Carbon tetrachloride was detected in 4 of 64 groundwater samples (6.3 percent frequency), with concentrations ranging between 1.2 and 5.9 µg/L. Carbon tetrachloride was detected above the 2007 MTCA (WAC 173-340-720) level of 0.63 µg/L in Wells 299-E33-341, 299-E33-342, and 299-E3-343. Figures E-8 through E-10 in Appendix E provide time-series plots of carbon tetrachloride at each of the three wells over the last 10 years. As shown in these figures, carbon tetrachloride is not associated with a trend at these wells. At Wells 299-E33-341 and 299-E33-342, carbon tetrachloride was analyzed nine times over the past 10 years; it was detected once and was reported as nondetected in eight samples. At Well 299-E33-343, carbon tetrachloride was analyzed nine times over the past 10 years; it was detected twice in two nonconsecutive samples and was reported as nondetected in seven samples. Based on these results, carbon tetrachloride is not retained as a COPC.

- Chloroform was detected in 2 of 64 groundwater samples (3.1 percent frequency), with concentrations ranging between 1.4 and 1.5 µg/L. Chloroform was reported in Well 299-E33-343 at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 1.4 µg/L. Figure E-11 in Appendix E provides time-series plot of chloroform at this well over the last 10 years. As shown in Figure E-11, chloroform is not associated with a trend at this well. Chloroform was analyzed nine times over the past 10 years; it was detected once and was reported as nondetected in eight samples. Based on these results, chloroform is not retained as a COPC.

- Methylene chloride was detected in one of 64 groundwater samples (1.6 percent frequency), with the single detection reported at a concentration of 1.8 µg/L. All methylene chloride results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 5 µg/L. Based on these results, methylene chloride is not retained as a COPC.

- **SVOCs:** As shown in Table E-3 in Appendix E, acetophenone, bis(2-ethylhexyl)phthalate (BEHP), butylbenzylphthalate, methyl methanesulfonate, n-nitroso-n-dipropylamine, phenol, and tributyl phosphate were detected in groundwater. SVOCs were analyzed in 21 of 39 wells.

  - Acetophenone was detected in one of 74 groundwater samples (1.4 percent frequency), with the single detection reported at a concentration of 1.7 µg/L. All acetophenone results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 800 µg/L. Based on these results, acetophenone is not retained as a COPC.

  - BEHP was detected in 9 of 106 groundwater samples (8.5 percent frequency), with concentrations ranging between 1.4 and 9.6 µg/L. BEHP was detected once above the DWS of 6 µg/L at Well 299-E33-44. Figure E-12 in Appendix E provides time-series plot of BEHP at this well during the last 10 years. As shown in Figure E-12, BEHP is not associated with a trend at this well. BEHP was analyzed six times over the past 10 years; it was detected in two consecutive samples and was reported as nondetected in four samples. Additionally, BEHP is a common laboratory contaminant that is introduced in the laboratory after the sample is collected in the field. Based on these results, BEHP is not retained as a COPC.

  - Butylbenzylphthalate was detected in one of 74 groundwater samples (1.4 percent frequency), with the single detection reported at a concentration of 2.8 µg/L. All butylbenzylphthalate results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 46 µg/L. Based on these results, butylbenzylphthalate is not retained as a COPC.

  - Methyl methanesulfonate was detected in one of 74 groundwater samples (1.4 percent frequency), with the single detection reported at a concentration of 340 µg/L. The single detection was measured at Well 299-E33-47, which was greater than the 2007 MTCA (WAC 173-340-720) level of 0.88 µg/L. Figure E-13 in Appendix E provides a time-series plot of methyl methanesulfonate at this well over the last 10 years. As shown in Figure E-13, methyl methanesulfonate is not associated with a trend at this well. Methyl methanesulfonate was analyzed six times over the past 10 years. A parent and field duplicate were collected on February 7, 2013; one sample was reported as nondetected, and the second sample was reported at a concentration of 340 µg/L. The remaining five sample results were all reported as nondetected. Based on these results, methyl methanesulfonate is not retained as a COPC.

  - n-Nitrosodi-n-dipropylamine was detected in 2 of 98 groundwater samples (2.0 percent frequency), and both samples were reported at concentrations ranging between 2.6 and 3.5 µg/L. n-Nitrosodi-n-dipropylamine was detected in Wells 299-E33-334 and 299-E33-42 at

concentrations greater than the 2007 MTCA (WAC 173-340-720) level of 0.013 µg/L. Figures E-14 and E-15 in Appendix E provide time-series plots of n-nitrosodi-n-dipropylamine at these two wells over the last 10 years. As shown in the two figures, n-nitrosodi-n-dipropylamine is not associated with a trend at either well. At Well 299-E33-334, n-nitrosodi-n-dipropylamine was analyzed six times over the past 10 years; it was detected once, and it was reported as nondetected in five samples. At Well 299-E33-42, n-nitrosodi-n-dipropylamine was analyzed five times over the past 10 years; it was detected once, and it was reported as nondetected in four samples. Based on these results, n-nitrosodi-n-dipropylamine is not retained as a COPC.

- Phenol was detected in 2 of 106 groundwater samples (1.9 percent frequency), and both samples were reported at a concentration of 1.1 µg/L. All phenol results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 2,400 µg/L. Based on these results, phenol is not retained as a COPC.

- Tributyl phosphate was detected in one of 106 groundwater samples (0.9 percent frequency), with the single detection reported at a concentration of 1.1 µg/L. All tributyl phosphate results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 9.7 µg/L. Based on these results, tributyl phosphate is not retained as a COPC.

- **Anions:** As shown in Table E-3 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater. Anions were analyzed in each of the 38 wells.

  - Chloride was detected in all 642 groundwater samples, with concentrations ranging between 11,500 and 284,000 µg/L. One result was reported in Well 299-E33-49 at a concentration greater than the secondary DWS of 250,000 µg/L. Figure E-16 in Appendix E provides the time-series plot of chloride at Well 299-E33-49. As shown in this figure, chloride concentrations above the comparison is not associated with a trend. Chloride was analyzed approximately 40 times over the past 10 years. With the exception of a single result reported on January 4, 2010 (284,000 µg/L), all chloride results were at least an order of magnitude less than this result. Two additional samples were collected on January 4, 2010, and both results were reported as 17,100 and 17,400 µg/L. Based on these results, chloride is not retained as a COPC.

  - Fluoride was detected in 573 of 641 groundwater samples (89 percent frequency), with concentrations ranging between 35 and 1,100 µg/L. One fluoride result was reported in Well 299-E33-31 at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 960 µg/L. Figure E-17 in Appendix E provides the time-series plot of fluoride at Well 299-E33-31. As shown in this figure, the fluoride concentration above the action level is not associated with a trend. Fluoride was analyzed 40 times over the past 10 years. With the exception of a single result reported on September 15, 2008 (1,100 µg/L), all fluoride results were reported at concentrations less than 960 µg/L. Based on these results, fluoride is not retained as a COPC.

  - Nitrate was detected in each of the 642 groundwater samples, with concentrations ranging between 22,800 and 1,700,000 µg/L. Each of the 38 wells reported concentrations greater than the DWS of 45,000 µg/L. Nitrate is retained as a COPC.

  - Nitrite was detected in 105 of the 629 groundwater samples (17 percent frequency), with concentrations ranging between 21 and 14,400 µg/L. Wells 299-E33-342 and 299-E33-345 reported concentrations above the DWS of 3,300 µg/L. Figures E-18 and E-19 in Appendix E provide time-series plots of nitrite at these two wells, respectively, over the past 10 years. As shown in Figure E-18, the nitrite concentration above the DWS is not associated with a trend

at Well 299-E33-342. Nitrite was analyzed 20 times over the past 10 years. With the exception of a single result reported on December 22, 2009 (14,400 µg/L), all nitrite results were reported at concentrations less than the DWS. A duplicate sample was analyzed on December 22, 2009, and reported at a concentration of 296 µg/L. As shown in Figure E-19, nitrite concentrations above the DWS are associated with a downward trend at Well 299-E33-345. Nitrite concentrations have not been reported above the DWS since December 22, 2008. Nitrite was reported as nondetected (less than 131 µg/L) during January 2014. Based on these results, nitrite is not retained as a COPC.

- Sulfate was detected in each of the 642 groundwater samples, with concentrations ranging between 52,800 and 374,000 µg/L. Nineteen of 38 wells reported concentrations greater than the secondary DWS of 250,000 µg/L. Wells that reported concentrations above the secondary DWS include 299-E33-13, 299-E33-15, 299-E33-16, 299-E33-17, 299-E33-18, 299-E33-1A, 299-E33-205, 299-E33-26, 299-E33-3, 299-E33-31, 299-E33-341, 299-E33-342, 299-E33-38, 299-E33-39, 299-E33-44, 299-E33-47, 299-E33-5, 299-E33-7, and 299-E33-9. Sulfate is retained as a COPC.

- **Cyanide:** As shown in Table E-3 in Appendix E, cyanide was detected in 370 of 620 groundwater samples (60 percent frequency), with concentrations ranging between 2.2 and 1,730 µg/L. Each of the 38 wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, chromium, cobalt, Cr(VI), manganese, nickel, silver, and uranium, all metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-3 in Appendix E, antimony was detected in 40 of 106 unfiltered groundwater samples (38 percent frequency), with concentrations ranging between 0.11 and 213 µg/L. Antimony was analyzed in 32 of the 38 wells. A total of 34 of 40 detected concentrations were greater than the DWS of 6 µg/L. A total of 23 of 40 detected concentrations were less than the 90th percentile Hanford Site background level of 55 µg/L. Antimony results reported using Method 6010 are not accurate at concentrations at or near the DWS or the Hanford Site background concentration. Groundwater samples from 11 wells (299-E13-18, 299-E33-32, 299-E33-334, 299-E33-339, 299-E33-38, 299-E33-41, 299-E33-42, 299-E33-43, 299-E33-44, 299-E33-47, and 299-E33-7) were analyzed using Methods 6010 and 200.8 to identify the differences in analytical method sensitivity. Figures E-20 through E-30 in Appendix E provide time-series plots of antimony results for both analytical methods. All MDLs for Method 6010 are greater than the DWS, and many are greater than the Hanford Site background level of 55 µg/L, whereas the MDLs for Method 200.8 are all less than the DWS (less than 1 µg/L). Results show that when groundwater samples are analyzed using Method 200.8, antimony concentrations are less than the DWS and Hanford Site background. Based on these results, antimony is not retained as a COPC.

  - As shown in Table E-3 in Appendix E, arsenic was detected in 231 of the 233 unfiltered groundwater samples (99 percent frequency), with concentrations ranging between 3 and 99 µg/L. Arsenic was analyzed in 31 of 38 wells, and all detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. With the exception of Wells 299-E33-16 and 299-E33-44, all arsenic concentrations in unfiltered samples are less than the 90th percentile Hanford Site

background concentration. As shown in Figure E-31 in Appendix E, arsenic concentrations at Well 299-E33-44 are within the range of naturally occurring levels at the Hanford Site. As shown in Figure E-32, arsenic concentrations at Well 299-E33-16 are associated with a downward trend. Arsenic concentrations measured at Well 299-E33-16 were approximately 99 µg/L in 2011 and decreased to approximately 35 µg/L in 2013. As described in Section 4.4.12, the presence of arsenic at Well 299-E33-16 may be the result of hydrolysis of natural arsenic when hydrochloric acid and acetic acid were discharged to the 216-B-8 Crib to improve poor drainage conditions at this waste site. Based on these results, arsenic is retained as a COPC at Well 299-E33-16.

- As shown in Table E-3 in Appendix E, total chromium was detected in 512 of the 621 unfiltered groundwater samples (82 percent frequency), with concentrations ranging between 2.9 and 356 µg/L. Chromium (total) was analyzed in 37 of 38 wells. Four of 37 wells reported chromium (total) concentrations above the DWS of 100 µg/L. Wells that reported chromium above the DWS include 299-E33-16, 299-E33-26, 299-E33-337, and 299-E33-339. As shown in Figures E-33 through E-36 in Appendix E, chromium concentrations in these wells are associated with a downward trend. The highest chromium concentrations were measured above the DWS during 2011 and subsequently decreased to concentrations less than 50 µg/L in 2013. Based on these results, chromium (total) is not retained as a COPC.

- As shown in Table E-3 in Appendix E, dissolved total chromium (evaluated as Cr(VI)) was detected in 512 of the 621 unfiltered groundwater samples (82 percent frequency), with concentrations ranging between 2.9 and 356 µg/L. Dissolved total chromium was analyzed in each of the 38 wells. Fifteen of 38 wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 48 µg/L for Cr(VI). Wells that reported dissolved total chromium as Cr(VI) include 299-E33-1A, 299-E33-2, 299-E33-7, 299-E33-13, 299-E33-15, 299-E33-16, 299-E33-17, 299-E33-18, 299-E33-20, 299-E33-44, 299-E33-47, 299-E33-337, 299-E33-341, 299-E33-342, and 299-E33-345. Cr(VI) is retained as a COPC.

- As shown in Table E-3 in Appendix E, cobalt was detected in 31 of 594 unfiltered groundwater samples (5.2 percent frequency), with concentrations ranging between 0.2 and 69 µg/L. Cobalt was analyzed in 37 of the 38 wells. Eight of 37 wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Wells that reported cobalt above the action level include 299-E33-2, 299-E33-3, 299-E33-15, 299-E33-31, 299-E33-38, 299-E33-44, 299-E33-337, and 299-E33-339. As shown in Figures E-37 through E-44 in Appendix E, cobalt concentrations in all wells (except 299-E33-337 and 299-E33-339) are not associated with a trend. As described in Section 4.4.16, the presence of cobalt at concentrations above the action level at Wells 299-E33-337 and 299-E33-339 were determined to be associated with the corrosion of the well casings based on the evaluation of the casing during a television survey. Cobalt concentrations were above the action level during 2011 and subsequently decreased to concentrations less than the action level in 2013. Based on these results, cobalt is not retained as a COPC.

- As shown in Table E-3 in Appendix E, Cr(VI) was detected in 100 of the 114 unfiltered groundwater samples (88 percent frequency), with concentrations ranging between 2 and 80 µg/L. Cr(VI) was analyzed in 29 of 38 wells. Eight of 29 wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 48 µg/L. Wells that reported Cr(VI) above the action level include 299-E33-15, 299-E33-16, 299-E33-17, 299-E33-18, 299-E33-341, 299-E33-345, 299-E33-44, and 299-E33-47. In addition to the wells listed above, dissolved chromium (total) concentrations are above the action level at Well 299-E33-20. Dissolved chromium concentrations are infrequently above the action level at Wells 299-E33-13, 299-E33-1A, 299-E33-2, 299-E33-337, 299-E33-342, and 299-E33-7. Cr(VI) is retained as a COPC.

- As shown in Table E-3 in Appendix E, manganese was detected in 243 of the 630 unfiltered groundwater samples (39 percent frequency), with concentrations ranging between 0.9 and 632 µg/L. Manganese was analyzed in each of the 38 wells. A single detection of manganese at Well 299-E33-337 was above the 2007 MTCA (WAC 173-340-720) level of 384 µg/L. Figure E-45 in Appendix E provides the time-series plot of manganese at this well over the last 10 years. As shown in Figure E-45, manganese concentrations above the action level are not associated with a trend. Manganese was analyzed more than 40 times over the past 10 years. A parent and duplicate sample were collected on July 14, 2011; both samples were greater than the action level (632 and 556 µg/L). All of the remaining sample results were less than the action level. As described in Section 4.4.14, the presence of manganese at concentrations above the action level at Well 299-E33-337 was determined to be associated with the corrosion of well casings based on the results of television surveys. Based on these results, manganese is not retained as a COPC.

- As shown in Table E-3 in Appendix E, nickel was detected in 189 of the 630 unfiltered groundwater samples (30 percent frequency), with concentrations ranging between 3.8 and 4,070 µg/L. Nickel was analyzed in 37 of 38 wells. Nickel concentrations were reported above the DWS of 100 µg/L in Wells 299-E33-337 and 299-E33-339, where the presence of nickel is the result of degradation of the well casing. A single detection of nickel at Well 299-E33-48 was above the DWS. Figure E-46 in Appendix E provides the time-series plot for nickel at Well 299-E33-48 over the past 10 years. Nickel was analyzed more than 40 times over the past 10 years. A parent and duplicate sample were collected on November 2, 2012; one sample was reported at a concentration less than the DWS (87 µg/L), and the second sample was reported at a concentration of 158 µg/L. All remaining concentrations were less than the DWS. As described in Section 4.4.16, the presence of nickel at concentrations above the DWS at Wells 299-E33-337 and 299-E33-339 was determined to be associated with the corrosion of the well casing based on the evaluation of the casing during a television survey. As shown in Figure E-46, the single nickel detection at Well 299-E33-48 that was above the DWS is not associated with a trend. Based on these results, nickel is not retained as a COPC.

- As shown in Table E-3 in Appendix E, silver was detected in 21 of the 622 unfiltered groundwater samples (3.4 percent frequency), with concentrations ranging between 4 and 158 µg/L. Silver was analyzed in 37 of 38 wells. A single detection of silver at Well 299-E33-42 was above the 2007 MTCA (WAC 173-340-720) level of 80 µg/L. As shown in Figure E-47 in Appendix E, silver concentrations above the action level are not associated with a trend. Silver was analyzed 40 times over the past 10 years. A parent and duplicate sample were collected on May 3, 2011; one sample was reported at a concentration less than the action level (32 µg/L), and the second sample was reported at a concentration of 158 µg/L. All of the

remaining concentrations were less than the action level. Based on these results, silver is not retained as a COPC.

- As shown in Table E-3 in Appendix E, uranium was detected in each of the 573 groundwater samples (100 percent frequency), with concentrations ranging between 2.9 and 5,550 µg/L. Uranium was analyzed in 37 of 38 wells. Thirty-one of 37 wells reported concentrations above the DWS of 30 µg/L. Wells that reported uranium above the DWS include 299-E33-13, 299-E33-15, 299-E33-16, 299-E33-18, 299-E33-1A, 299-E33-205, 299-E33-26, 299-E33-2, 299-E33-31, 299-E33-32, 299-E33-334, 299-E33-335, 299-E33-337, 299-E33-338, 299-E33-339, 299-E33-341, 299-E33-342, 299-E33-343, 299-E33-345, 299-E33-38, 299-E33-41, 299-E33-42, 299-E33-43, 299-E33-44, 299-E33-47, 299-E33-48, 299-E33-49, 299-E33-5, and 299-E33-9. Wells that infrequently report uranium above the DWS include 299-E33-3 and 299-E33-7. Uranium is retained as a COPC.

Waste Management Area C

Twelve wells are screened in the unconfined aquifer and monitor contaminants in the C Tank Farm. Groundwater samples are collected to fulfill RCRA and AEA monitoring requirements. One or more groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, VOCs, phenols, SVOCs, and pesticides. All sample results for phenols, and pesticides were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-4 in Appendix E, iodine-129 and technetium-99 concentrations were greater than their respective DWSs. Each of the 12 wells was analyzed for iodine-129 and technetium-99. Radionuclides reported at concentrations above their respective DWSs are discussed below.

  - Gross beta was detected in 242 of 243 groundwater samples (greater than 99 percent frequency), with concentrations ranging between 8.4 and 16,000 pCi/L. The presence of gross beta is generally consistent with that of iodine-129 and technetium-99. 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 6.4.4.

  - Iodine-129 was detected in each of the 92 groundwater samples (100 percent frequency), with concentrations ranging between 1.3 and 7.5 pCi/L. Each of the 12 wells reported concentrations greater than the DWS of 1 pCi/L. Iodine-129 is retained as a COPC.

  - Technetium-99 was detected in 245 of the 259 groundwater samples (95 percent frequency), with concentrations ranging between 7 and 26,000 pCi/L. Seven of the 12 wells reported concentrations greater than the DWS of 900 pCi/L. Wells with concentrations above the DWS included 299-E27-13, 299-E27-14, 299-E27-155, 299-E27-21, 299-E27-23, 299-E27-24, and 299-E27-4. Technetium-99 is retained as a COPC.

- **VOCs:** As shown in Table E-4 in Appendix E, carbon tetrachloride was detected in groundwater. VOCs were analyzed in each of the 12 wells.

- Carbon tetrachloride was detected in 3 of 112 groundwater samples (2.7 percent frequency), with concentrations ranging between 0.22 and 1.3 µg/L. A single detection of carbon tetrachloride above the 2007 MTCA (WAC 173-340-720) level of 0.63 µg/L was reported in Well 299-E27-155. Figure E-48 in Appendix E provides the time-series plots of carbon tetrachloride at Well 299-E27-155 over the past 10 years. As shown in Figure E-48, carbon tetrachloride is not associated with a trend at this well. Carbon tetrachloride was analyzed more than 20 times over the past 10 years; it was detected in a parent and duplicate sample collected on March 9, 2009 (1.2 and 1.3 µg/L). All remaining results at this well were nondetected. Based on these results, carbon tetrachloride is not retained as a COPC.

- **Anions:** As shown in Table E-4 in Appendix E, chloride, fluoride, nitrate, and nitrite were detected in groundwater samples. All fluoride and nitrite results (detected concentrations and MDLs) were less than their respective action levels.

  - Chloride was detected in each of the 280 groundwater samples, with concentrations ranging between 11,300 and 297,000 µg/L. One chloride result was greater than the secondary DWS of 250,000 µg/L. Figure E-49 in Appendix E provides the time-series plot of chloride at Well 299-E27-7. As shown in this figure, chloride concentrations above the secondary DWS are not associated with a trend. Chloride was analyzed approximately 40 times over the past 10 years. With the exception of a single result reported on February 16, 2010 (297,000 µg/L), all chloride results were at least an order of magnitude less than this result. Five additional samples were collected on January 4, 2010, and results ranged between 17,100 and 46,500 µg/L. Based on these results, chloride is not retained as a COPC.

  - Nitrate was detected in each of the 280 groundwater samples, with concentrations ranging between 8,280 and 118,000 µg/L. Seven of 12 wells reported concentrations greater than the DWS of 45,000 µg/L. Wells that reported nitrate above the DWS include 299-E27-14, 299-E27-155, 299-E27-21, 299-E27-23, 299-E27-24, 299-E27-25, and 299-E27-4. Nitrate is retained as a COPC.

  - Sulfate was detected in each of the 280 groundwater samples, with concentrations ranging between 51,800 and 333,000 µg/L. Four of 12 wells reported concentrations greater than the secondary DWS of 250,000 µg/L. Wells that reported concentrations above the secondary DWS include 299-E27-14, 299-E27-24, 299-E33-25, and 299-E27-7. Sulfate is retained as a COPC.

- **Cyanide:** As shown in Table E-4 in Appendix E, cyanide was detected in 89 of the 269 groundwater samples (33 percent frequency), with concentrations ranging between 3.3 and 41 µg/L. Eight of the 12 wells reported concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Wells that reported concentrations above the action level include 299-E27-12, 299-E27-14, 299-E27-155, 299-E27-21, 299-E27-23, 299-E27-24, 299-E27-4, and 299-E27-7. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, chromium, copper, nickel, and uranium, all metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-4 in Appendix E, antimony was detected in 8 of the 48 unfiltered groundwater samples (17 percent frequency), with concentrations ranging between 3.6 and 74 µg/L. Antimony was analyzed in each of the 12 wells. Seven of the eight detected concentrations were greater than the DWS of 6 µg/L. Five of the eight detected concentrations were less than the 90th percentile Hanford Site background level of 55 µg/L. Antimony results reported using Method 6010 are not accurate at concentrations at or near the DWS or the

Hanford Site background concentration. Groundwater samples from one well (299-E27-4) were analyzed using Methods 6010 and 200.8 to identify the differences in analytical method sensitivity. Figure E-50 in Appendix E provides the time-series plots of antimony results for both analytical methods. All MDLs for Method 6010 are greater than the DWS and many are greater than the Hanford Site background level of 55 µg/L, whereas MDLs for Method 200.8 are all less than the DWS (less than 1 µg/L). Results show that when groundwater samples are analyzed using Method 200.8, antimony concentrations are less than the DWS and Hanford Site background. Based on these results, antimony is not retained as a COPC.

- As shown in Table E-4 in Appendix E, arsenic was detected in 61 of the 62 unfiltered groundwater samples (98 percent frequency), with concentrations ranging between 4.1 and 16 µg/L. Arsenic was analyzed in each of the 12 wells. All detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. With the exception of nonrecurring detections of elevated arsenic concentrations in Wells 299-E27-14, 299-E27-15, 299-E27-21, 299-E27-22, 299-E27-23, and 299-E27-25, all arsenic concentrations in unfiltered samples are within the range of the Hanford Site background concentration. As shown in Figures E-51 through E-56 in Appendix E, arsenic concentrations are within the range of naturally occurring levels at the Hanford Site. Based on these results, arsenic is not retained as a COPC.

- As shown in Table E-4 in Appendix E, total chromium was detected in 143 of the 271 unfiltered groundwater samples (53 percent frequency), with concentrations ranging between 2.4 and 106 µg/L. Chromium (total) was analyzed in each of the 12 wells. A single detection was reported above the DWS of 100 µg/L in Well 299-E27-25. As shown in Figure E-57 in Appendix E, chromium concentrations above the DWS in Well 299-E27-25 are not associated with a trend. Total chromium was analyzed approximately 20 times in this well during the past 10 years. A parent and duplicate sample were collected on June 10, 2012. One sample result was greater than the DWS (106 µg/L), and the duplicate sample was less than the DWS (18 µg/L); all of the remaining sample results were less than the DWS. Based on these results, total chromium is not retained as a COPC.

- As shown in Table E-4 in Appendix E, copper was detected in 14 of the 274 unfiltered groundwater samples (5.1 percent frequency), with concentrations ranging between 0.62 and 1,720 µg/L. Copper was analyzed in each of the 12 wells. A single detection was reported above the 2007 MTCA (WAC 173-340-720) level of 640 µg/L at Well 299-E27-14. As shown in Figure E-58 in Appendix E, copper concentrations above the action level in Well 299-E27-14 are not associated with a trend. Copper was analyzed more than 40 times in this well over the past 10 years. A parent and duplicate sample were collected on September 3, 2012; one sample result was greater than the action level (1,720 µg/L), and the duplicate sample was less than the action level (less than 4 µg/L). All remaining sample results were less than the action level. Based on these results, copper is not retained as a COPC.

- As shown in Table E-4 in Appendix E, nickel was detected in 121 of the 274 unfiltered groundwater samples (44 percent frequency), with concentrations ranging between 0.23 and 293 µg/L. Nickel was analyzed in each of the 12 wells. Two detections were reported at Well 299-E27-4 above the DWS of 100 µg/L. As shown in Figure E-59 of Appendix E, concentrations above the DWS in Well 299-E27-4 are not associated with a consistent trend. Nickel was analyzed more than 40 times in this well during the past 10 years. A parent and duplicate sample were collected on September 3, 2012, and again on September 18, 2013.

Both sample results were greater than the DWS on those dates; however, all remaining nickel results were less than the DWS. Based on these results, nickel is not retained as a COPC.

- As shown in Table E-4 in Appendix E, uranium was detected in 237 of the 239 groundwater samples (99 percent frequency), with concentrations ranging between 0.51 and 38 µg/L. Uranium was analyzed in each of the 12 wells. A single detection was reported above the DWS of 30 µg/L at Well 299-E27-15 on June 11, 2008 (38 µg/L). As shown in Figure E-60 in Appendix E, uranium concentrations above the DWS in Well 299-E27-15 are not associated with a trend. Uranium was analyzed approximately 40 times at this well over the past 10 years, and all remaining results were less than the DWS. Uranium is not retained as a COPC.

B Plant

Fourteen wells are screened in the unconfined aquifer and monitor contaminants in the B Plant area. Groundwater samples are collected to fulfill CERCLA, RCRA, and AEA monitoring requirements. Groundwater samples within the exposure area were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, VOCs, and SVOCs. All sample results for VOCs and SVOCs were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-5 in Appendix E, cesium-137, gross alpha, iodine-129, plutonium-239/240, strontium-90, and technetium-99 concentrations were greater than their respective DWSs. Each of the 14 wells was analyzed for iodine-129, 12 wells were analyzed for gross alpha and strontium-90, 11 wells were analyzed for plutonium-239/240, and 10 wells were analyzed for technetium-99 and cesium-137. Radionuclides reported at concentrations above their respective DWSs are discussed below.

  - Cesium-137 was detected in 16 of 36 groundwater samples (44 percent frequency), with concentrations ranging between 35 and 2,430 pCi/L. Well 299-E28-23 reported concentrations above the DWS of 200 pCi/L, with concentrations ranging between 1,650 to 2,430 pCi/L. Cesium-137 is retained as a COPC.

  - Gross alpha was detected in 37 of 43 groundwater samples (86 percent frequency), with concentrations ranging between 2 and 45 pCi/L. Three of the 12 wells (299-E28-18, 299-E28-23, and 299-E28-24) reported concentrations greater than the DWS of 15 pCi/L. Gross alpha is an indicator of uranium and is retained as a COPC.

  - Gross beta was detected in all 44 of the groundwater samples (100 percent frequency), with concentrations ranging between 6.1 and 34,000 pCi/L. The presence of gross beta is generally consistent with that of cesium-137, iodine-129, strontium-90, and technetium-99. 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 6.4.4.

  - Iodine-129 was detected in 29 of the 41 groundwater samples (71 percent frequency), with concentrations ranging between 0.23 and 3.3 pCi/L. Seven of the 14 wells reported concentrations greater than the DWS of 1 pCi/L. Wells that reported concentrations above the DWS include 299-E24-25, 299-E28-2, 299-E28-23, 299-E28-24, 299-E28-25, 299-E28-5, and 299-E28-7. Iodine-129 is retained as a COPC.

  - Plutonium-239/240 was detected in 19 of the 32 groundwater samples (59 percent frequency), with concentrations ranging between 0.028 and 52 pCi/L. One of the 11 wells reported

plutonium-239/240 greater than the DWS of 15 pCi/L. Well 299-E28-23 reported concentrations above the DWS, ranging between 16 and 52 pCi/L. Plutonium-239/240 is retained as a COPC.

- Strontium-90 was detected in 26 of the 41 groundwater samples (63 percent frequency), with concentrations ranging between 2.8 and 4,900 pCi/L. Five of the 12 wells reported concentrations greater than the DWS of 8 pCi/L. Wells that reported concentrations greater than the DWS include 299-E28-2, 299-E28-23, 299-E28-24, 299-E28-25, and 299-E28-7. Strontium-90 is retained as a COPC.

- Technetium-99 was detected in each of the 23 groundwater samples (100 percent frequency), with concentrations ranging between 24 and 5,700 pCi/L. One of nine wells reported with a single detection greater than the DWS of 900 pCi/L. Well 299-E28-24 was analyzed twice for technetium-99 during the past 6 years (56 pCi/L in 2012, and 5,700 pCi/L in 2013); all other technetium-99 results were less than the DWS. Based on these results, technetium-99 is retained as a COPC.

- **Anions:** As shown in Table E-5 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater. Anions were analyzed in each of the 14 wells. All chloride, nitrite, and sulfate results (detected concentrations and MDLs) were less than their respective action levels.

  - Fluoride was detected in each of the 57 groundwater samples (100 percent frequency), with concentrations ranging between 99 and 3,270 µg/L. One of the 14 wells reported concentrations greater than the 2007 MTCA (WAC 173-340-720) level of 960 µg/L. Well 299-E28-24 reported concentrations greater than the action level, with concentrations ranging between 2,660 and 3,270 µg/L. Figure E-61 in Appendix E provides the time-series plot of fluoride concentrations at Well 299-E28-24 during the past 10 years. As described in Section 4.4.11, the presence of fluoride at Well 299-E28-24 may be the result of lanthanum fluoride waste discharges. Fluoride concentrations at this location remain elevated because the well screen may be within less permeable Ringold sediments, which have not yet established equilibrium conditions. Based on these results, fluoride is retained as a COPC at Well 299-E28-24.

  - Nitrate was detected in each of the 57 groundwater samples, with concentrations ranging between 30,100 and 420,000 µg/L. Twelve of the 14 wells reported concentrations greater than the DWS of 45,000 µg/L. Wells that reported nitrate concentrations greater than the DWS include 299-E28-13, 299-E28-17, 299-E28-18, 299-E28-21, 299-E28-23, 299-E28-24, 299-E28-25, 299-E28-2, 299-E28-30, 299-E28-5, 299-E28-6, and 299-E29-54. Nitrate is retained as a COPC.

- **Cyanide:** As shown in Table E-5 in Appendix E, cyanide was detected in four of seven groundwater samples (57 percent frequency), with concentrations ranging between 4.2 and 9.0 µg/L. Three of the five wells reported cyanide concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. One the of two cyanide results (less than 4 and 6 µg/L) at Well 299-E28-5 is above the action level of 4.8 µg/L. Well 299-E28-30 (9 µg/L) was analyzed once for cyanide, which was above the action level. One of the two cyanide results (less than 4 and 5 µg/L) at Well 299-E29-54 is above the action level of 4.8 µg/L. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, cadmium, and uranium, all metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-5 in Appendix E, antimony was detected in five of eight unfiltered groundwater samples (63 percent frequency), with concentrations ranging between 44 and 85 µg/L. Antimony was analyzed in 7 of 14 wells. All of the detected concentrations were greater

than the DWS of 6 µg/L. One of the five detected concentrations was less than the 90th percentile Hanford Site background level of 55 µg/L. As discussed previously, antimony results reported using Method 6010 are not accurate at concentrations at or near the DWS or the Hanford Site background concentration. Based on these results, antimony is not retained as a COPC.

- As shown in Table E-5 in Appendix E, arsenic was detected in each of the 18 unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 1.2 and 6.7 µg/L. Arsenic was analyzed in 9 of 14 wells. All of the detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All of the arsenic concentrations in unfiltered samples were less than the 90th percentile Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

- As shown in Table E-5 in Appendix E, cadmium was detected in one of 28 unfiltered groundwater samples (3.6 percent frequency), with the single detection reported at 5.1 µg/L. Cadmium was analyzed in 12 of 14 wells. The single detection at Well 299-E28-17 was above the DWS of 5 µg/L. As shown in Figure E-62 in Appendix E, cadmium concentrations above the action level are not associated with a trend. Two samples were collected from Well 299-E28-17 on July 8, 2008, and analyzed for cadmium; one sample result was above the DWS (5.1 µg/L) and one result was below the DWS (4.3 µg/L). Five remaining results were reported as nondetected. Based on these results, cadmium is not retained as a COPC.

- As shown in Table E-5 in Appendix E, uranium was detected in each of the 64 groundwater samples (100 percent frequency), with concentrations ranging between 2.6 and 47 µg/L. Uranium was analyzed in each of the 14 wells. Five of the 14 wells reported concentrations above the DWS of 30 µg/L. Wells that reported multiple uranium detections above the DWS include 299-E28-17, 299-E28-18, 299-E28-6, and 299-E29-54. Well 299-E28-25 reported a single sample result above the DWS. Uranium is retained as a COPC.

Semiworks

Two wells are screened in the unconfined aquifer and monitor contaminants in the Semiworks area. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. Groundwater samples in this exposure area were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, SVOCs, and VOCs. All sample results for cyanide, VOCs, and SVOCs were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-6 in Appendix E, iodine-129 concentrations were greater than the DWS of 1 pCi/L. Wells 299-E24-25 and 299-E24-8 were analyzed for iodine-129. Radionuclides reported at concentrations above their respective DWSs are discussed below.

  - Gross beta was detected in the single groundwater sample analyzed and reported with a concentration of 26 pCi/L. The presence of gross beta is generally consistent with that of iodine-99. 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 6.4.4.

  - Iodine-129 was detected in all three groundwater samples (100 percent frequency), with concentrations ranging between 0.69 and 1.8 pCi/L. Iodine-129 was reported at concentrations

of 0.69 and 1.8 pCi/L in Well 299-E24-25 and was detected at 1.7 pCi/L in Well 299-E24-8. Iodine-129 is retained as a COPC.

- **Anions:** As shown in Table E-6 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater samples. All of the sample results (detected concentrations and MDLs) for these anions were less than their respective action levels.

- **Metals:** With the exception of arsenic, all metals results (detected concentrations and MDLs) were less than their respective action levels.

  – As shown in Table E-6 in Appendix E, arsenic was detected in both of the unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 1 and 4 µg/L. Arsenic was analyzed in both wells. Both detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. Both arsenic concentrations in unfiltered samples are less than the 90th percentile Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

Liquid Effluent Retention Facility

Four wells are screened in the unconfined aquifer and monitor contaminants near the LERF. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. Groundwater samples were analyzed for the following classes of analytes: field parameters, anions, metals, radionuclides, VOCs, phenols, and SVOCs. All of the sample results for phenols and SVOCs were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-7 in Appendix E, all radionuclide results (detected concentrations and MDLs) were less than their respective DWSs. All four wells were analyzed for iodine-129, tritium, gross alpha, and gross beta.

  – Gross beta was detected in 40 of 44 groundwater samples (91 percent frequency), with concentrations ranging between 6.7 and 480 pCi/L. The presence of gross beta is an indicator of low-level detections of iodine-129 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 6.4.4.

- **VOCs:** As shown in Table E-7 in Appendix E, carbon tetrachloride was detected in groundwater. VOCs were analyzed in all four wells.

  – As shown in Table E-7 in Appendix E, carbon tetrachloride was detected in 2 of the 31 groundwater samples (6.5 percent frequency), with concentrations ranging between 2.3 and 2.4 µg/L. Carbon tetrachloride was detected in two wells at concentrations above the 2007 MTCA (WAC 173-340-720) level of 0.63 µg/L. Carbon tetrachloride was detected in one of eight samples collected from Well 299-E26-77 (2.3 µg/L) and in one of eight samples collected from Well 299-E26-79 (2.4 µg/L); both results were flagged with a "J" laboratory qualifier, indicating that they are estimated results. Carbon tetrachloride is not retained as a COPC.

- **Anions:** As shown in Table E-7 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater samples. All of the chloride, fluoride, and nitrite results (detected

concentrations and MDLs) are less than their respective action levels. Anions were analyzed in each of the four wells.

- Nitrate was detected in each of the 39 groundwater samples, with concentrations ranging between 14,600 and 57,500 µg/L. Wells 299-E26-10 and 299-E26-77 reported concentrations above the DWS. Well 299-E26-79 reported one of nine results above the DWS. Nitrate is retained as a COPC.

- Sulfate was detected in each of the 39 groundwater samples, with concentrations ranging between 103,000 and 279,000 µg/L. Wells 299-E26-10 and 299-E26-77 reported concentrations above the secondary DWS. Sulfate is retained as a COPC.

- **Metals:** With the exception of arsenic, all of the metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-7 in Appendix E, arsenic was detected in each of the 32 unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 2.5 and 5.5 µg/L. Arsenic was analyzed in all four wells. All detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All of the arsenic concentrations in unfiltered samples were less than the 90th percentile Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

Gable Mountain Pond

Six wells are screened in the unconfined aquifer and monitor contaminants near Gable Mountain Pond. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. Groundwater samples were analyzed for the following classes of analytes: anions, metals, and radionuclides. None of the sample results for SVOCs and TPH-diesel exceeded action levels and are not further discussed in this section

- **Radionuclides:** As shown in Table E-8 in Appendix E, strontium-90 concentrations were greater than the DWS. Each of the six wells was analyzed for strontium-90. Radionuclides that were reported at concentrations above their respective DWSs are discussed below.

  - Gross beta was detected in all 16 of the groundwater samples (100 percent frequency), with concentrations ranging between 5.3 and 1,100 pCi/L. The presence of gross beta is generally consistent with that of strontium-90. 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 6.4.4.

  - Strontium-90 was detected in 18 of the 24 groundwater samples (75 percent frequency), with concentrations ranging between 16 and 522 pCi/L. Five of six wells reported concentrations above the DWS of 8 pCi/L and include 699-53-47A, 699-53-47B, 699-53-48A, 699-54-48, and 699-54-49. Strontium-90 is retained as a COPC.

- **Anions:** As shown in Table E-8 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater samples. All of the chloride, fluoride, and nitrite results (detected concentrations and MDLs) were less than their respective action levels; therefore, they are not retained as COPCs.

- Nitrate was detected in each of the 24 groundwater samples, with concentrations ranging between 6,820 and 173,000 µg/L. Four of six wells reported concentrations above the DWS. Wells 699-53-47A, 699-53-47B, 699-53-48A, and 699-54-49 reported results above the DWS. Nitrate is retained as a COPC.

- Sulfate was detected in each of the 24 groundwater samples, with concentrations ranging between 19,900 and 281,000 µg/L. One of six wells reported concentrations above the secondary DWS. Well 699-53-48A reported concentrations above the secondary DWS. Sulfate is retained as a COPC.

- **Metals:** With the exception of antimony and arsenic, all of the metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-8 in Appendix E, antimony was detected in one of two unfiltered groundwater samples (50 percent frequency), with the single reported concentration of 72 µg/L. Antimony was analyzed in two of six wells. The single detection in Well 699-53-47B was greater than the DWS of 6 µg/L and greater than the 90th percentile Hanford Site background level of 55 µg/L. As discussed previously, antimony results reported using Method 6010 are not accurate at concentrations at or near the DWS or the Hanford Site background concentration. Based on these results, antimony is not retained as a COPC.

  - As shown in Table E-8 of Appendix E, arsenic was detected in one unfiltered groundwater sample (100 percent frequency), with a concentration of 4.7 µg/L. The detected concentration was greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. The detected arsenic concentration in unfiltered samples is less than the 90th percentile Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

200-BP-5 West

Seventeen wells are screened in the unconfined aquifer and monitor contaminants in the 200-BP-5 west area of the OU. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. One or more groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, VOCs, SVOCs, and TPH-diesel.

- **Radionuclides**. As shown in Table E-9 in Appendix E, iodine-129, strontium-90, and technetium-99 concentrations were greater than their respective DWSs. Seventeen wells were analyzed for technetium-99, 15 wells were analyzed for iodine-129, and 12 wells were analyzed for strontium-90. Radionuclides that were reported at concentrations above their respective DWSs are discussed below.

  - Gross beta was detected in 60 of 62 groundwater samples (97 percent frequency), with concentrations ranging between 3.2 and 3,800 pCi/L. The presence of gross beta is generally consistent with that of iodine-129, strontium-90, and technetium-99. 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 6.4.4.

  - Iodine-129 was detected in 28 of 78 groundwater samples (36 percent frequency), with concentrations ranging between 0.31 and, 4.0 pCi/L. Five of the 15 wells reported concentrations greater than the DWS of 1 pCi/L, including Wells 699-49-57A, 699-50-59, 699-55-60A, 699-57-59, and 699-59-58. Iodine is retained as a COPC.

- Strontium-90 was detected in 2 of 33 groundwater samples (6.1 percent frequency), with concentrations ranging between 2.9 and 180 pCi/L. One of 12 wells reported concentrations greater than the DWS of 8 pCi/L. A single detection of 180 pCi/L was reported at Well 699-50-56 during 2010; however, a duplicate sample collected on the same date, four previous sampling rounds between 2007 and 2009, and two subsequent sampling rounds in 2010 and 2011 reported strontium-90 as nondetected. Based on these results, strontium-90 is retained as a COPC at Well 699-50-56.

- Technetium-99 was detected in 84 of 98 groundwater samples (86 percent frequency), with concentrations ranging between 8.3 and 5,800 pCi/L. Six of 17 wells reported concentrations greater than the DWS of 900 pCi/L, including 699-49-57A, 699-50-56, 699-50-59, 699-53-55B, 699-53-55C, and 699-55-57. Technetium-99 is retained as a COPC.

- **VOCs:** As shown in Table E-9 in Appendix E, carbon disulfide, carbon tetrachloride, and chloroform were detected in groundwater. All of the carbon disulfide and chloroform results (detected concentrations and MDLs) were less than their respective action levels.

  - Carbon tetrachloride was detected in 2 of 22 groundwater samples (9.1 percent frequency), with concentrations ranging between 2 and 5.4 µg/L. Two results were reported above the 2007 MTCA (WAC 173-340-720) level of 0.63 µg/L. Carbon tetrachloride was detected in one of four samples collected from Well 699-52-55 (2 µg/L) and was detected in one of three samples collected from Well 699-54-45A (5.4 µg/L). The result reported from Well 699-52-55 was flagged with a "J" laboratory qualifier, indicating that it is an estimated result. Figures E-63 and E-64 in Appendix E provide time-series plots of carbon tetrachloride at Wells 699-52-55 and 699-54-45A, respectively, during the past 10 years. As shown in Figures E-63 and E-64, carbon tetrachloride is not associated with a trend at either well. Based on these results, carbon tetrachloride is not retained as a COPC.

- **SVOCs:** As shown in Table E-9 in Appendix E, BEHP and tributyl phosphate were detected in groundwater. All BEHP and tributyl phosphate results (detected concentrations and MDLs) were less than their respective action levels.

- **TPH-diesel:** As shown in Table E-9 of Appendix E, TPH-diesel was detected in 2 of 6 groundwater samples (33 percent frequency). All TPH-diesel results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) Method A value of 500 µg/L. Based on these results, TPH-diesel is not retained as a COPC.

- **Anions:** As shown in Table E-9 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater. Each of the 17 wells was analyzed for anions. All chloride, fluoride, nitrite, and sulfate results (detected concentrations and MDLs) were less than their respective action levels.

  - Nitrate was detected in 96 of 100 groundwater samples (96 percent frequency), with concentrations ranging between 248 and 322,000 µg/L. Six of the 17 wells reported concentrations greater than the DWS of 45,000 µg/L. Wells that reported nitrate above the DWS include 699-49-57A, 699-50-56, 699-50-59, 699-53-55B, 699-53-55C, and 699-55-57. Nitrate is retained as a COPC.

- **Cyanide:** As shown in Table E-9 in Appendix E, cyanide was detected in 74 of 87 groundwater samples (85 percent frequency), with concentrations ranging between 4 and 195 µg/L. Thirteen of the 14 wells reported cyanide concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Wells reporting concentrations above the action level include 699-48-50B, 699-49-57A,

699-50-56, 699-50-59, 699-52-55, 699-53-55A, 699-53-55B, 699-53-55C, 699-55-57, 699-55-60A, 699-57-59, 699-59-58, and 699-60-60. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, cadmium, cobalt, iron, manganese, and zinc, all of the metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-9 in Appendix E, antimony was detected in 2 of the 16 unfiltered groundwater samples (13 percent frequency), with concentrations ranging between 52 and 59 µg/L. Antimony was analyzed in 10 of 17 wells. Both detected results were greater than the DWS of 6 µg/L, and one of two results was greater than the 90th percentile Hanford Site background level of 55 µg/L. As discussed previously, antimony results reported using Method 6010 are not accurate at concentrations at or near the DWS or the Hanford Site background concentration. Based on these results, antimony is not retained as a COPC.

  - As shown in Table E-9 in Appendix E, arsenic was detected in 23 of the 30 unfiltered groundwater samples (77 percent frequency), with concentrations ranging between 3.1 and 8.1 µg/L. Arsenic was analyzed in 10 of the 17 wells. All detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All arsenic concentrations in unfiltered samples are within the range of naturally occurring Hanford Site background concentrations. Based on these results, arsenic is not retained as a COPC.

  - As shown in Table E-9 in Appendix E, cadmium was detected in 5 of the 60 unfiltered groundwater samples (8.3 percent frequency), with concentrations ranging between 0.20 and 35 µg/L. Cadmium was analyzed in 16 of 17 wells. Two cadmium detections were greater than the DWS at Well 699-52-55. In both cases, a parent and duplicate sample were collected from the well; one result was greater than the DWS, and the duplicate result was reported as nondetected (less than the DWS). One additional sample was collected from this well and was also reported as nondetected (less than the DWS). Figure E-65 in Appendix E shows the time-series plot for cadmium at Well 699-52-55 over the past 10 years. As shown in Figure E-65, cadmium concentrations in this well above the action level are not associated with a trend. Based on these results, cadmium is not retained as a COPC.

  - As shown in Table E-9 in Appendix E, total chromium was detected in 24 of the 60 unfiltered groundwater samples (40 percent frequency), with concentrations ranging between 3.2 and 140 µg/L. Total chromium was analyzed in 16 of 17 wells. A single detection was reported above the DWS of 100 µg/L in Well 699-55-57. Chromium was analyzed twice at Well 699-55-57; the chromium result reported on May 8, 2008 (140 µg/L) was greater than the DWS, and the second result reported on November 8, 2011 (8 µg/L) was less than the DWS. No other total chromium results were reported above the DWS. Based on these results, total chromium is not retained as a COPC.

  - As shown in Table E-9 in Appendix E, cobalt was detected in 11 of 59 unfiltered groundwater samples (19 percent frequency), with concentrations ranging between 0.14 and 34 µg/L. Cobalt was analyzed in 16 of 17 wells. Six of the 11 cobalt results were above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Wells that reported cobalt above the action level include 699-50-56, 699-52-55, and 699-54-45A. Figures E-66 through E-68 in Appendix E show time-series plots for cobalt from these three wells during the past 10 years. Cobalt concentrations in these wells are associated with the degradation of the well casings; additionally, these wells are

scheduled to be surveyed for signs of degradation. Generally, cobalt results are reported using Method 6010, which are not accurate at the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. Many of the cobalt results are flagged with a "B" laboratory qualifier, indicating that the result is estimate. As described in Section 4.4.14, based on the presence of cobalt at concentrations above the action level at Well 699-52-55, it was determined that the well was potentially impacted by corrosion of unrecovered drill bit pieces, bumper bar pieces, split-spoon sampler pieces, and potentially damaged permanent casing that occurred during drilling and well installation. As described in Section 4.4.14, the presence of cobalt at concentrations above the action level at Well 699-54-45A was determined to be associated with the corrosion of the well casing based on the evaluation of the casing during a television survey. As shown in Figure E-66 in Appendix E, Well 699-50-56 shows nonconsecutive cobalt concentrations above the action level, interspersed with nondetected concentrations less than the action level. The presence of cobalt at this well is not associated with a release or trend, but is instead the result of analytical variability. Based on these results, cobalt is not retained as a COPC.

- As shown in Table E-9 in Appendix E, iron was detected in 53 of 60 unfiltered groundwater samples (88 percent frequency), with concentrations ranging between 20 and 18,900 µg/L. Iron was analyzed in 16 of 17 wells. Five iron results are above the 2007 MTCA (WAC 173-340-720) level of 11,200 µg/L. Wells that reported iron above the action level include 699-52-55 and 699-54-45A. Figures E-69 and E-70 in Appendix E show time-series plots for iron from both wells during the past 10 years. Iron was measured during four separate sampling events during 2009 and 2010 at Well 699-52-55. Three of the four sampling events included the collection of a duplicate sample, which showed inconsistent results. In all three cases, one sample was nondetected or at low concentrations, and the duplicate sample was above the action level. Iron was measured during three separate sampling events during 2010 at Well 699-54-45A, where iron concentrations have shown a steady increase. As described in Section 4.4.14, due to the presence of iron at concentrations above the action level at Well 699-52-55, it was determined that the well was potentially impacted by corrosion of unrecovered drill bit pieces, bumper bar pieces, split-spoon sampler pieces, and potentially damaged permanent casing that occurred during drilling and well installation. As described in Section 4.4.14, the presence of iron at concentrations above the action level at Well 699-54-45A was determined to be associated with the corrosion of the well casing based on the evaluation of the casing during a television survey. Based on these results, iron is not retained as a COPC.

- As shown in Table E-9 in Appendix E, manganese was detected in 27 of 60 unfiltered groundwater samples (45 percent frequency), with concentrations ranging between 4 and 1,190 µg/L. Manganese was analyzed in 16 of the 17 wells. Two of the 27 manganese results are above the 2007 MTCA (WAC 173-340-720) level of 384 µg/L. Well 699-52-55 has reported manganese above the action level. Figure E-71 in Appendix E shows time-series plots for manganese at Well 699-52-55 during the past 10 years. As shown in Figure E-71, manganese concentrations above the action level are not associated with a trend. Manganese concentrations in this well are associated with suspected degradation of the well casing; additionally, this well is scheduled to be surveyed for signs of degradation. Manganese was measured during four separate sampling events during 2009 and 2010 at Well 699-52-55. Three of the four sampling events included the collection of a duplicate sample, which showed inconsistent results. In two instances, one sample was measured at a concentration less than the action level, and the duplicate sample was above the action level. Based on these results, manganese is not retained as a COPC.

- As shown in Table E-9 in Appendix E, zinc was detected in 28 of 60 unfiltered groundwater samples (47 percent frequency), with concentrations ranging between 4.3 and 5,450 µg/L. Zinc was analyzed in 16 of 17 wells. Two of the 28 zinc results are above the 2007 MTCA (WAC 173-340-720) level of 4,800 µg/L. Well 699-54-45A reported zinc above the action level. Figure E-72 in Appendix E shows time-series plots for zinc at Well 699-54-45A over the past 10 years. Zinc was measured during three separate sampling events at Well 699-54-45A during 2010, and concentrations showed a steady increase. The concentrations in this well are associated with degradation of the well casing; additionally, this well is scheduled to be surveyed for signs of degradation. Based on these results, zinc is not retained as a COPC.

200-BP-5 Far-Field (North of Gable Gap)

Eight wells are screened in the unconfined aquifer and monitor contaminants in the 200-BP-5 far-field area north of Gable Gap. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. Groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, VOCs, and TPH-diesel. All of the sample results for cyanide, VOCs, and TPH-diesel were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-10 in Appendix E, all of the radionuclide results (detected concentrations and MDLs) were less than their respective DWSs.
  - Gross beta was detected in each of the 27 of the groundwater samples (100 percent frequency), with concentrations ranging between 4.2 and 110 pCi/L. The presence of gross beta is generally consistent with low-level detections of technetium-99 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 6.4.4.
- **Anions:** As shown in Table E-10 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater samples. All of the anion results (detected concentrations and MDLs) were less than their respective action levels.
- **Metals:** With the exception of arsenic, all of the metals results (detected concentrations and MDLs) were less than their respective action levels.
  - As shown in Table E-10 in Appendix E, arsenic was detected in each of the 14 unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 3.6 and 15 µg/L. Arsenic was analyzed in five of eight wells. All detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5, 8.8, and 7.85 µg/L, respectively. Arsenic concentrations at Well 699-62-43F ranged between 14 and 15 µg/L and at Well 699-65-50 ranged between 9.1 and 11 µg/L. All of the arsenic concentrations in unfiltered samples are within the range of naturally occurring Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

200-BP-5 Near-River

Seven wells are screened in the unconfined aquifer and monitor contaminants in 200-BP-5 near-river area. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. One or more groundwater samples were analyzed for the following classes of analytes: anions, cyanide, metals, radionuclides, VOCs, SVOCs, pesticides, TPH-diesel, and TPH-gasoline. All of the sample results for

cyanide, SVOCs, pesticides, and TPH-gasoline were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-11 in Appendix E, all of the radionuclide results (detected concentrations and MDLs) were reported with concentrations less than their respective DWSs.
  - Gross beta was detected in 21 of 22 groundwater samples (95 percent frequency), with concentrations ranging between 4.6 and 80 pCi/L. The presence of gross beta is generally consistent with low-level detections of iodine-129, technetium-99, 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 6.4.4.
- **VOCs:** As shown in Table E-11 in Appendix E, chloroform and TCE were detected in groundwater. All of the chloroform results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) level of 1.4 µg/L.
  - TCE was detected in 14 of the 17 groundwater samples (82 percent recovery), with concentrations ranging between 0.25 and 3.9 µg/L. TCE was detected in four of five wells at concentrations greater than the Ecology Cleanup Levels and Risk Calculations (CLARC) guidance level of 0.54 µg/L. Figures E-73 through E-76 in Appendix E show time-series plots for TCE in Wells 199-K-31, 699-65-72, 699-70-68, and 699-72-73 during the past 10 years. TCE was detected each of the three samples collected and analyzed from Well 199-K-31 during 2009 and 2010, with concentrations ranging between 3.1 and 3.9 µg/L. TCE was detected in all three of the samples collected from Well 699-65-72, with concentrations ranging between 0.99 and 1.3 µg/L (one of the three detections, 1.3 µg/L, is the result of laboratory contamination and is not considered); these samples were analyzed in 2010. TCE was detected in all three samples collected from Well 699-70-68, with concentrations ranging between 1.1 and 1.7 µg/L (one of three detections, 1.7 µg/L, is the result of laboratory contamination and is not considered); these samples were analyzed in 2010. TCE was detected in two of three samples collected and analyzed from Well 699-72-73 in 2009 and 2010, with concentrations ranging between 0.89 and 0.98 µg/L. Although all four of the wells are located within the 200-BP-5 OU, the TCE results associated with these wells were collected to fill data gaps associated with the 100-K RI/FS or 100-BC RI/FS processes. TCE detections measured in these wells are not associated with releases from the 200-BP-5 OU. The TCE results will be addressed upon completion of the BRA for each of the two groundwater OUs. TCE is not retained as a COPC.
- **TPH-diesel:** As shown in Table E-11 in Appendix E, TPH-diesel was detected in one of the nine groundwater samples analyzed (11 percent frequency) at a concentration of 180 µg/L. All of the TPH-diesel results (detected concentrations and MDLs) were less than the 2007 MTCA Method A groundwater cleanup level of 500 µg/L.
- **Anions:** As shown in Table E-11 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater samples. All of the anion results (detected results and MDLs) were less than their respective action levels.
- **Metals:** With the exception of aluminum, arsenic, lead, thallium, and zinc, all of the metals results (detected concentrations and MDLs) were less than their respective action levels.
  - As shown in Table E-11 in Appendix E, aluminum was detected in 7 of 34 unfiltered groundwater samples (21 percent frequency) and was detected in one of 34 filtered groundwater

samples (2.9 percent frequency). Aluminum concentrations ranged between 15 and 37 µg/L in unfiltered samples, and the single detection in the filtered sample was reported at 366 µg/L. Aluminum was analyzed in six of seven wells. Although groundwater concentrations were compared to AWQC of 87 µg/L, these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the 2007 MTCA (WAC 173-340-720) level of 16,000 µg/L; all of the results (detected concentrations and MDLs) were less than the 2007 MTCA level. The single detection of aluminum was measured at Well 199-K-31 during November 2012. Although the filtered result was greater than the AWQC, the corresponding unfiltered aluminum result (27 µg/L) was less than the AWQC. Figure E-77 in Appendix E shows the time-series plot for filtered aluminum in Well 199-K-31 over the past 10 years (note that the figure shows two nonconsecutive detections above the AWQC). Based on these results, aluminum is not retained as a COPC.

- As shown in Table E-11 in Appendix E, arsenic was detected in 32 of 34 unfiltered groundwater samples (94 percent frequency), with concentrations ranging between 1.3 and 4.8 µg/L. Arsenic was analyzed in six of seven wells. All of the detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All of the arsenic concentrations in unfiltered samples are within the range of naturally occurring Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

- As shown in Table E-11 in Appendix E, dissolved total chromium was detected in 34 of the 40 filtered groundwater samples (85 percent frequency), with concentrations ranging between 0.68 and 13 µg/L. Dissolved total chromium was analyzed in six of seven wells. One well (199-K-31) reported dissolved total chromium at a concentration above the state surface water quality standard (WAC 173-201A) of 10 µg/L. One of the 14 results from Well 199-K-31 was above the standard of 10 µg/L; this result (13.7 µg/L) was based on Method 6010 and was reported on October 27, 2008. Dissolved total chromium was analyzed using Method 200.8 and reported concentrations less than the standard of 10 µg/L. Similar to Cr(VI), dissolved total chromium is not retained as a COPC.

- As shown in Table E-11 in Appendix E, lead was detected in 8 of 34 unfiltered groundwater samples (24 percent frequency) and was detected in 7 of 34 filtered groundwater samples (21 percent frequency). Lead concentrations ranged between 0.18 and 16 µg/L in unfiltered samples and between 0.19 and 2.3 µg/L in filtered samples. Lead was analyzed in six of seven wells. Although groundwater concentrations were compared to AWQC or state surface water quality standards (WAC 173-201A), these concentrations would need to be measured as close as practicable to the groundwater/surface water interface or biologically active zone. Wells located inland would need to meet the DWS of 15 µg/L. At Well 699-73-61, lead was measured in one of six unfiltered samples above the DWS. Figure E-78 in Appendix E shows time-series plots for unfiltered lead in Well 699-73-61 during the past 10 years. Lead is not associated with a trend at this well. Results reported above the DWS are analyzed using Method 6010, which is not accurate at or near the DWS. Results reported by trace analytical methods (Method 200.8) reported concentrations less than the DWS. Lead was measured in one of six filtered samples above the state water quality standard at Well 699-73-61. One of the six filtered lead results (2.3 µg/L) from Well 699-73-61 was above the state water quality standard of 2.1 µg/L. Lead concentrations from five previous sampling rounds (concentrations ranging from 0.19 to

1.2 µg/L) were less than the standard of 2.1 µg/L. Figure E-79 in Appendix E shows time-series plots for filtered lead in Well 699-73-61 over the past 10 years. Lead is not associated with a trend at this well. The results reported above the state water quality standard of 2.1 µg/L are analyzed using Method 6010, which is not accurate at or near the state surface water standard. Results reported by trace analytical methods (Method 200.8) reported concentrations less than the standard. Based on these results, lead is not retained as a COPC.

- As shown in Table E-11 in Appendix E, thallium was detected in one of 34 unfiltered groundwater samples (2.9 percent frequency) at a concentration of 1.8 µg/L. Thallium was analyzed in six of seven wells. The single detection was greater than the DWS of 0.5 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.9 µg/L, 1.73 µg/L, and 1.67 µg/L, respectively. The single thallium detection in the unfiltered sample from Well 199-K-31 is within the range of naturally occurring Hanford Site background concentrations. Figure E-80 in Appendix E shows time-series plots for unfiltered thallium in Well 199-K-31 during the past 10 years. Based on these results, thallium is not retained as a COPC.

- As shown in Table E-11 in Appendix E, zinc was detected in 12 of 34 unfiltered groundwater samples (35 percent frequency) and was detected in 12 of 34 filtered groundwater samples (35 percent frequency). Concentrations ranged between 2 and 1,270 µg/L in unfiltered samples and between 1.82 and 281 µg/L in filtered samples. Zinc was analyzed in six of seven wells. Although all of the monitoring wells within the groundwater area were compared to the state water quality standard (WAC 173-201A) of 91 µg/L, only near-river wells would need to meet this standard. Wells located inland would need to meet the 2007 MTCA (WAC 173-340-720) level of 4,800 µg/L; all of the zinc results (detected concentrations and MDLs) are less than the 2007 MTCA level. All of the zinc measurements greater than the state surface water quality standard were measured at Well 699-73-61. Figure E-81 in Appendix E shows time-series plots for filtered zinc in Well 699-73-61 over the past 10 years. Zinc is consistently detected above the state water quality standard at this well (91 µg/L). Well 699-63-61 has a galvanized steel screen, and the presence of zinc is suspected to be associated with casing corrosion. Based on these results, zinc is not retained as a COPC.

4.5.1.3 Comparison Results for the Confined Aquifer

As previously discussed, wells screened in the confined aquifer were combined into a single exposure area. Groundwater data for this exposure area were compiled and statistically analyzed, and the results are presented in Appendix E, Table E-12. This table presents the summary statistics for each analyzed detected within the exposure area; the background concentrations in Hanford Site groundwater (DOE/RL-96-61), where available; and the action level for each analyte.

200-BP-5 Confined Aquifer

Sixteen wells are screened in the confined aquifer and monitor contaminants within the 200-BP-5 OU. Groundwater samples are collected to fulfill CERCLA and AEA monitoring requirements. One or more groundwater samples were analyzed for the following classes of analytes: cyanide, metals, radionuclides, VOCs, SVOCs, and pesticides. All of the sample results for pesticides were reported as nondetected and are not further discussed in this section.

- **Radionuclides:** As shown in Table E-12 in Appendix E, iodine-129 and technetium-99 were reported with concentrations greater than their respective DWSs.

- Gross beta was detected in 71 of 72 groundwater samples (99 percent frequency), with concentrations ranging between 46 and 800 pCi/L. The presence of gross beta is generally consistent with that of iodine-129 and technetium-99. 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 6.4.4.

- Iodine-129 was detected in 11 of 61 groundwater samples (18 percent frequency), with concentrations ranging between 0.18 and 3.2 pCi/L. One of 14 wells reported concentrations greater than the DWS of 1 pCi/L. Iodine-129 was reported above the DWS at Well 699-45-42, where concentrations range between 1.9 and 3.2 pCi/L. Iodine-129 is retained as a COPC.

- Technetium-99 was detected in 28 of 68 groundwater samples (41 percent frequency), with concentrations ranging from 6.7 and 1,300 pCi/L. One of 13 wells reported concentrations greater than the DWS of 900 pCi/L. Technetium-99 is reported above the DWS at Well 299-E33-12, where concentrations range between 920 and 1,300 pCi/L. Technetium-99 is retained as a COPC.

- **VOCs:** As shown in Table E-12 in Appendix E, benzene, carbon tetrachloride, chloroform, and toluene were detected in groundwater. All of the chloroform and toluene results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) levels of 1.4 and 640 µg/L, respectively. Chloroform and toluene are not retained as COPCs.

  - Benzene was detected in one of 21 groundwater samples (4.8 percent frequency) at a concentration of 2.5 µg/L. Benzene was detected in one of four wells. Benzene was detected in one of six samples (2.5 µg/L) collected from Well 699-52-55B at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 0.8 µg/L. Figure E-82 in Appendix E shows time-series plots for benzene in Well 699-52-55B during the past 10 years. The single detection of benzene was flagged with a "J" laboratory qualifier, indicating that it is considered an estimated result. The presence of benzene at Well 699-52-55B is not associated with a trend. Benzene is not retained as a COPC.

  - Carbon tetrachloride was detected in one of 21 groundwater samples (4.8 percent frequency) at a concentration of 2.3 µg/L. Carbon tetrachloride was detected in one of four wells. Carbon tetrachloride was detected in one of six samples (2.3 µg/L) collected from Well 699-52-55B at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 0.63 µg/L. The single detection was flagged with a "J" laboratory qualifier, indicating that it is considered an estimated result. Figure E-83 in Appendix E shows time-series plots for carbon tetrachloride in Well 699-52-55B during the past 10 years. The presence of carbon tetrachloride at Well 699-52-55B is not associated with a trend. Carbon tetrachloride is not retained as a COPC.

- **SVOCs:** As shown in Table E-12 in Appendix E, BEHP, phenol, and tributyl phosphate were detected in groundwater. All of the phenol and tributyl phosphate results (detected concentrations and MDLs) were less than the 2007 MTCA (WAC 173-340-720) levels of 2,400 and 9.7 µg/L, respectively. Phenol and tributyl phosphate are not retained as COPCs.

  - BEHP was detected in 5 of the 21 groundwater samples (24 percent frequency) at concentrations ranging between 0.97 and 11 µg/L. BEHP was detected in two of five samples collected from Well 699-52-55B, with concentrations ranging between 1.2 and 11 µg/L (single detection greater than the DWS of 6 µg/L). BEHP is a common laboratory contaminant that is introduced into the sample after it is collected in the field. Figure E-84 in Appendix E shows time-series plots for

BEHP in Well 699-52-55B during the past 10 years. The presence of BEHP at Well 699-52-55B is not associated with a trend. BEHP is not retained as a COPC.

- **Anions:** As shown in Table E-12 in Appendix E, chloride, fluoride, nitrate, nitrite, and sulfate were detected in groundwater samples. All of the anion results (detected concentrations and MDLs) were less than their respective action levels. Anions are not retained as COPCs.

- **Cyanide:** As shown in Table E-12 in Appendix E, cyanide was detected in 7 of 47 groundwater samples (15 percent frequency), with concentrations ranging between 4.4 and 31 µg/L. Three of the eight wells reported cyanide concentrations above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. All three results collected from Well 299-E33-12 (24 to 31 µg/L), three of six cyanide results from Well 299-E33-340 (less than 4 to 6.4 µg/L), and one of two results from Well 299-E33-40 (less than 4 to 5 µg/L) were greater than the action level. Cyanide is retained as a COPC.

- **Metals:** With the exception of antimony, arsenic, and cobalt, all of the metals results (detected concentrations and MDLs) were less than their respective action levels.

  - As shown in Table E-12 in Appendix E, antimony was detected in 2 of 10 unfiltered groundwater samples (20 percent frequency), with concentrations ranging between 41 and 42 µg/L. Antimony was analyzed in 5 of 16 wells. Both detected concentrations were greater than DWS of 6 µg/L; however, both detected concentrations were less than the 90th percentile Hanford Site background level of 55 µg/L. Based on these results, antimony is not retained as a COPC.

  - As shown in Table E-12 in Appendix E, arsenic was detected in each of the 37 unfiltered groundwater samples (100 percent frequency), with concentrations ranging between 1.1 and 5.6 µg/L. Arsenic was analyzed in 7 of 16 wells. All of the detected concentrations were greater than the 2007 MTCA (WAC 173-340-720) level of 0.058 µg/L. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively. All of the detected arsenic concentrations in unfiltered samples are less than the 90th percentile Hanford Site background concentration. Based on these results, arsenic is not retained as a COPC.

  - As shown in Table E-12 in Appendix E, cobalt was detected in 2 of 72 unfiltered groundwater samples (2.8 percent frequency), with concentrations ranging between 0.12 and 5.6 µg/L. Cobalt was analyzed in 15 of 16 wells. A single result was above the 2007 MTCA (WAC 173-340-720) level of 4.8 µg/L. One of 17 results from Well 299-E33-340 was above the action level. Figure E-85 in Appendix E shows time-series plots for cobalt in Well 299-E33-340 over the past 10 years. The presence of cobalt at Well 299-E33-340 is not associated with a trend. Based on these results, cobalt is not retained as a COPC.

4.5.1.4 Summary of Analytes Greater than Action Levels

Table 4-8 summarizes the outcome of the evaluation of individual groundwater concentrations. Analytes that are retained as COPCs include arsenic, cesium-137, cobalt-60, cyanide, Cr(VI), fluoride, gross alpha, iodine-129, nitrate, plutonium-239/240, strontium-90, sulfate, technetium-99, tritium, and uranium. Groundwater analytes that are retained as COPCs because there are detections above the DWS or 2007 MTCA (WAC 173-340-720) screening level in localized areas include arsenic, cobalt-60, fluoride, and sulfate. Sulfate is detected above the secondary DWS at several exposure areas and is retained as a COPC. Gross alpha is detected above the DWS and is retained as a COPC; gross alpha is an indicator of uranium.

The information in this chapter will be used in Chapter 5 to evaluate the F&T of groundwater contaminants associated with the 200-BP-5 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 BRA, which is presented in Chapter 6. The groundwater BRA 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. Additional analytes may be identified as COPCs based on cumulative health effects.

Table 4-8. Summary of COPCs Retained for 200-BP-5 OU Based on Evaluation of Measured Groundwater Concentrations

LLWMA-1
Cyanide, gross alpha,[a] iodine-129, nitrate, technetium-99, tritium, and uranium
LLWMA-2 and 216-B-63 Trench
Cyanide, iodine-129, nitrate, sulfate,[b] technetium-99, and uranium
WMA B-BX-BY Tank Farms
Arsenic[c], cobalt-60,[c] cyanide, Cr(VI), gross alpha,[a] iodine-129, nitrate, sulfate,[b] technetium-99, tritium, and uranium
WMA C Tank Farm
Cyanide, iodine-129, nitrate, sulfate,[b] and technetium-99
B Plant
Cesium-137, cyanide, fluoride,[c] gross alpha,[a] iodine-129, nitrate, plutonium-239/240, strontium-90, technetium-99, and uranium
Semiworks
Iodine-129
Liquid Effluent Retention Facility
Nitrate and sulfate[b]
Gable Mountain Pond
Nitrate, sulfate,[b] and strontium-90
200-BP-5 West
Cyanide, iodine-129, nitrate, strontium-90,[c] and technetium-99
200-BP-5 Far-Field (North of Gable Gap)
None identified
200-BP-5 Near-River
None identified
200-BP-5 Confined
Cyanide, iodine-129, and technetium-99

a. Gross alpha is an indicator of the presence of uranium.

b. Groundwater concentrations exceed secondary DWS.

c. Retained as a COPC due to localized contamination.

COPC = contaminant of potential concern
Cr(VI) = hexavalent chromium
LLWMA = low-level waste management area
WMA = waste management area

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5 Contaminant Fate and Transport

This chapter presents an assessment and evaluation of the anticipated behavior of COPCs present in groundwater at the 200-BP-5 OU, which further refines the CSM and provides information for the CEM, as discussed in Chapter 6. The conditions affecting contaminant behavior, simulation methods used (numerical F&T modeling), and the results, as well as uncertainties, are also discussed. Numerical modeling was used to predict the F&T of eight selected COPCs currently present in the unconfined aquifer at the 200-BP-5 OU. These COPCs include cyanide, nitrate, uranium, strontium-90, technetium-99, iodine-129, tritium, and Cr(VI). Three COPCs (technetium-99, uranium, and nitrate) are anticipated to continue to be released from the vadose zone to groundwater in two locations. These continuing sources were included in certain model simulations to evaluate their influence (Section 5.2.2).

These predictions were then used as a basis to evaluate potential future contaminant transport within the OU. A three-dimensional, scale-appropriate numerical model of the unconfined aquifer was developed to evaluate contaminant F&T within the OU and the downgradient areas. This model, designated as the Plateau-to-River Groundwater Transport Model (P2R Model), was implemented using configuration-managed versions of the numerical simulation codes MODFLOW-2000 and MT3DMS, which include modifications to incorporate minimum saturated thickness features needed for simulating conditions in the transient Hanford Site unconfined aquifer. The model describes groundwater movement, as well as contaminant F&T in three dimensions, within the Central Plateau unconfined aquifer system over the area of interest. The conceptual and numerical models are described in Section 5.1.

For the purposes of this discussion of F&T modeling, a "scenario" is considered to be a single realization of the model, defined by a single COPC and a set of physical and geochemical parameters (e.g., hydraulic conductivity, porosity, and partition coefficient), boundary conditions (river stage, recharge, etc.), initial conditions (e.g., initial heads and contaminant concentrations), and simulation period. To illustrate the various groundwater components, a range of scenarios was developed and analyzed. The scenarios are described in Section 5.2.

The result for any given scenario is contaminant concentrations over space and time. The model domain spans an area of hundreds of square kilometers and thousands of model grid blocks. Accordingly, as discussed in Section 5.3, the model domain was divided into several subregions, for which three statistical measures of concentration were calculated. These concentrations are the maximum, 90th percentile, and mean. These values were calculated to evaluate contaminant concentrations over time.

5.1 Model Construction and Parameterization

A complete description of the P2R Model is provided in CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1* (provided in Appendix F), and its application to simulate contaminant F&T for the scenarios is detailed in ECF-Hanford-13-0031, *Fate and Transport Modeling for Baseline Conditions for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* (provided in Appendix F). A summary of the features of the P2R Model is presented in the following discussion.

The MODFLOW and MT3DMS software programs were used to simulate groundwater flow and contaminant transport, respectively. MODFLOW solves the groundwater flow equation to calculate hydraulic head and groundwater flow velocities. MT3DMS uses the resultant 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. Both software programs were

modified to incorporate minimum saturated thickness features needed for simulating transient conditions in the unconfined aquifer. A detailed description of model basis and development is presented in CP-57037 (provided in Appendix F).

The following physical processes primarily control the mass transport of contaminants and, therefore, impact contaminant concentrations over time and distance in the 200-BP-5 OU, but do not result in a reduction of contaminant mass within the aquifer:

- Advection of the contaminants occurs along the flow gradients leading to distribution of mass downgradient and away from the contaminant source or high groundwater concentration areas. Advection is the primary mass transport process in the 200-BP-5 OU. Reduction in contaminant concentration may occur along the flow path from dilution as additional uncontaminated water mixes with the contaminated water. This can include uncontaminated groundwater entering the model domain from the lateral boundaries, meteoric water entering the aquifer from the top of the domain as a fraction of the annual precipitation falling on the ground surface, and clean water discharges to the aquifer from continuing operations at the Hanford Site.

- Mechanical dispersion of the dissolved contaminants, with a reduction in groundwater concentrations, occurs as groundwater moves through the aquifer system. Contaminants tend to become more dispersed as groundwater flows through a porous medium. Dispersion occurs because of small, localized variations in the groundwater flow velocity that result from local-scale heterogeneities in the porous medium. This results in a more widespread distribution of the contaminant mass as distance from the point of origin increases. This process is quantified by the coefficient of hydrodynamic dispersion.

- Diffusion of dissolved contaminants occurs because of concentration gradients within the aquifer. The result of diffusion is similar to that of dispersion. The original contaminant mass becomes more widespread throughout the aquifer over time, and overall concentrations are reduced. This process is quantified by the coefficient of molecular diffusion. The effect of molecular diffusion toward mass transport of contaminants in the 200-BP-5 OU is expected to be negligibly small compared to the mass transport by advection and mechanical dispersion. As a result, the molecular diffusion process was not simulated, thus making predicted concentrations slightly overestimated.

In addition to the advective-dispersive processes, contaminant-specific processes also affect groundwater contaminant concentrations over time and distance. These processes were included in the F&T simulations and result in reductions of dissolved mass within the aquifer:

- Radioactive decay of radionuclides (iodine-129, technetium-99, tritium, uranium, and strontium-90) as quantified by the first-order decay constant, which is inversely proportional to the half-life of the radionuclide. For the evaluation timeframe (1,000 years), radioactive decay is only relevant for tritium and strontium-90.

- Interaction of the contaminants with the solid-phase portion of the aquifer system (sorption of contaminants to geologic aquifer materials) reduces the mass of dissolved contaminants at any particular time and/or location. This process is quantified by the contaminant-specific distribution coefficient (K_d) simulated using a linear relationship between concentration sorbed to the soil and dissolved in the groundwater The linear K_d term is nonzero for iodine-129, uranium, and strontium-90.

The MODFLOW/MT3DMS family of numerical groundwater simulators used to implement the P2R Model estimates groundwater flow and F&T using packages that represent certain processes occurring in nature. For this simulation, the processes and corresponding simulation packages are shown in Table 5-1. The table includes any limitations that the implementation of the particular package in MODFLOW/MT3DMS may impose on the model.

Table 5-1. Groundwater Processes, Simulated Packages, and Limitations for the P2R Model

Groundwater Process		MODFLOW/MT3DMS Package	Limitations (if any)
Groundwater flow	Recharge	Recharge package	Considered recharge that reaches the groundwater.
	Columbia River	River package	
	Injection/extraction	Well package	
	Head at model boundaries	CHB package	Assessment of remedial alternatives that effect flow of water should be sufficiently far from boundaries as to not significantly influence flow through the CHB boundaries.
	May Junction Fault	HFB package	
Transport processes	Soil adsorption	Reaction package	Only linear sorption is considered. Uranium sorption could be more complex.
	Radioactive decay	Reaction package	
	Dispersion	Dispersion package	
	Continuing sources	Source/sink mixing package	

CHB = constant head boundary
HFB = horizontal flow barrier

5.1.1 Domain and Spatial Discretization

The model domain incorporates the southern portion of the 200-BP-5 OU (south of the Gable Gap area) and the 200-PO-1 OU (Figure 5-1). The northern portion of the 200-BP-5 OU was not included in the model domain because contaminants simulated in the model above DWSs are not currently detected north of Gable Gap, and flow direction for the simulated contaminants since 2011 has generally been southeast with the 200-BP-5 OU portion of the model domain.

For effective support of contaminant F&T calculations from the Central Plateau east to the Columbia River, the P2R Model structure was designed to span those portions of the 200-BP-5 and 200-PO-1 OUs that could potentially serve as a future flow path for contaminants in the unconfined aquifer. Additionally, the model domain was selected to take advantage of natural (i.e., hydraulically significant) features to bound the domain and provide adequate spatial resolution while allowing simulations to be carried out within acceptable computer run times. The resulting P2R Model is composed of 135 rows, 155 columns, and 7 layers. Discretization on the horizontal plane is uniform across the model, with grid blocks spaced at 200 m (656.2 ft) intervals aligned along lines of easting and northing. The seven model layers are used

to represent HSUs within the P2R Model as discussed in Section 5.3.1 in this chapter. The model origin at the lower left-hand corner of the grid is 564,000 m and 116,000 m easting and northing, respectively, in the Washington State Plane South NAD83 projection.

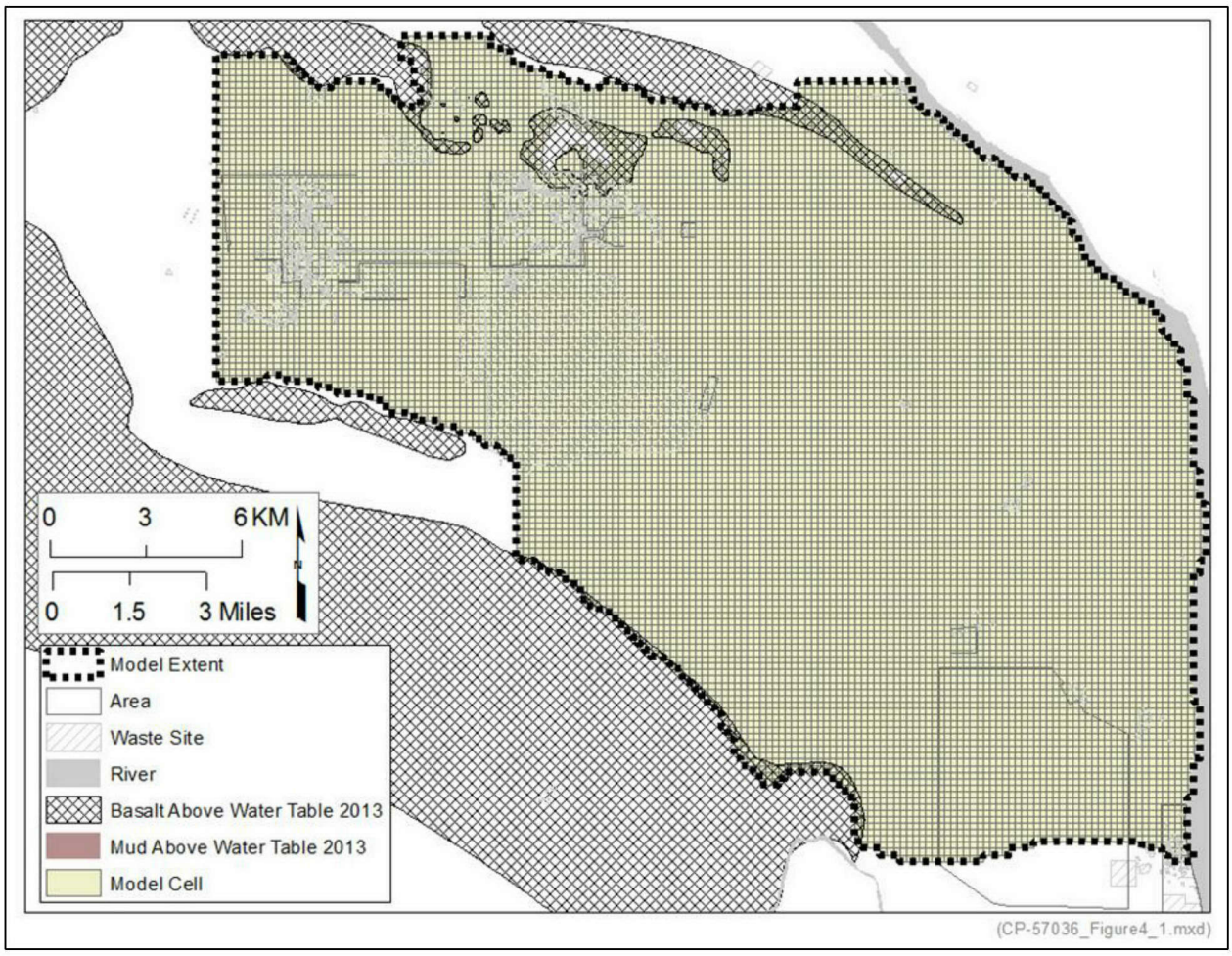


Figure 5-1. P2R Model Extent

5.1.2 Simulation Periods

A 1,000-year simulation was completed to support the RI. The start date of the simulation was January 1, 2013. The first 50 years are simulated using yearly stress periods. At this point, decadal stress periods are used for the next 50 years. Two more stress periods are simulated with lengths of 200 years and 700 years. The boundary conditions for the final two stress periods are identical, except for a sensitivity simulation regarding continuing sources. After the first 100 years, 200-year and 700-year stress periods were used for this evaluation. The shorter initial stress periods accommodate changes in the values assigned at boundary conditions based on expected behavior. By the end of the first 50 years, the conditions at the boundaries are expected to remain relatively stable, so increased temporal discretization is not necessary.

5.1.3 Hydrostratigraphy

The geologic representation for the model is derived from the Hanford South Geoframework Model (HSGM) (ECF-Hanford-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*; provided in Appendix F). Seven model layers are used to represent the seven

HSUs and are defined in the HSGM. The HSU definitions that are presented in ECF-Hanford-13-0029 include the Hanford and Cold Creek formations and the Ringold Formation with the Taylor Flat, Unit E, Upper Mud, and Unit A members of that formation. However, the HSGM only includes one classification for the Hanford formation; this definition does not capture the large-scale hydraulic features of the groundwater flow within the model domain. Two additional HSU definitions were added to the Hanford formation and used to assign contrasting hydraulic properties to the model cells. The CCU was also split into two HSU definitions to represent contrasting hydraulic properties. Assignment of a numerical cell to an HSU is not dependent on the model layer. The decision regarding assignment of these zones was a result of the calibration process, as these HSUs were not delineated as part of the geologic framework.

5.1.4 Boundary Conditions

The boundary conditions for the numerical model represent interactions with the aquifer by water external to the model. These include water infiltrating through the vadose zone that becomes recharge, movement to and from the Columbia River, liquid discharges from waste sites, and extraction and injection at well locations. The details of each of these boundary conditions are discussed below.

5.1.4.1 Lateral Boundary Conditions

Figure 5-2 illustrates the locations and types of the lateral boundary conditions used in the P2R Model. The lateral boundaries of the model domain are set to coincide (as much as practicable) with natural features that bound the flow regime. Basalt outcrops to the north and south of the model domain form no-flow boundaries. A hydraulic no-flow boundary occurs along the southernmost margin of the model domain, where it was observed in the 2013 annual Hanford Site groundwater monitoring report (Figure I.5 of DOE/RL-2014-32) that the direction of groundwater flow is from west to east, parallel to the boundary (a situation that is formally indistinguishable from the presence of an impermeable barrier). Note that if substantial changes to the observed magnitude or direction of groundwater flow at this location occur in the future, this boundary may need to be reconsidered.

The Columbia River, extending along the eastern margin of the domain, was modeled as a third-type boundary condition using the MODFLOW river package in the uppermost model layer. Stage values at each Columbia River grid block were assigned by calculating the hydraulic gradient along the river based on stage data obtained from May 2006 through September 2012. Grid blocks in layers 2 through 7 directly underlying the Columbia River grid blocks were represented as no-flow boundaries.

In addition to these natural lateral boundary conditions, four separate specified head (i.e., first-type) boundary conditions are defined in the model and are labeled as west, northeast, southwest, and Gable Gap groups (Figure 5-2). These represent boundaries across which groundwater can flow either into or out of the model domain. In each case, the location was selected to coincide with a groundwater monitoring well in order to assign a specified head at that position during calibration.

5.1.4.2 Upper Boundary Conditions (Recharge)

The recharge boundary condition represents water that from the top surface of the model infiltrates through the vadose zone until reaching the saturated zone. Mathematically, recharge is represented by a prescribed-flux type boundary condition. Recharge water can originate from natural or anthropogenic sources. Each of these types of sources of recharge was included in the model using the MODFLOW recharge package.

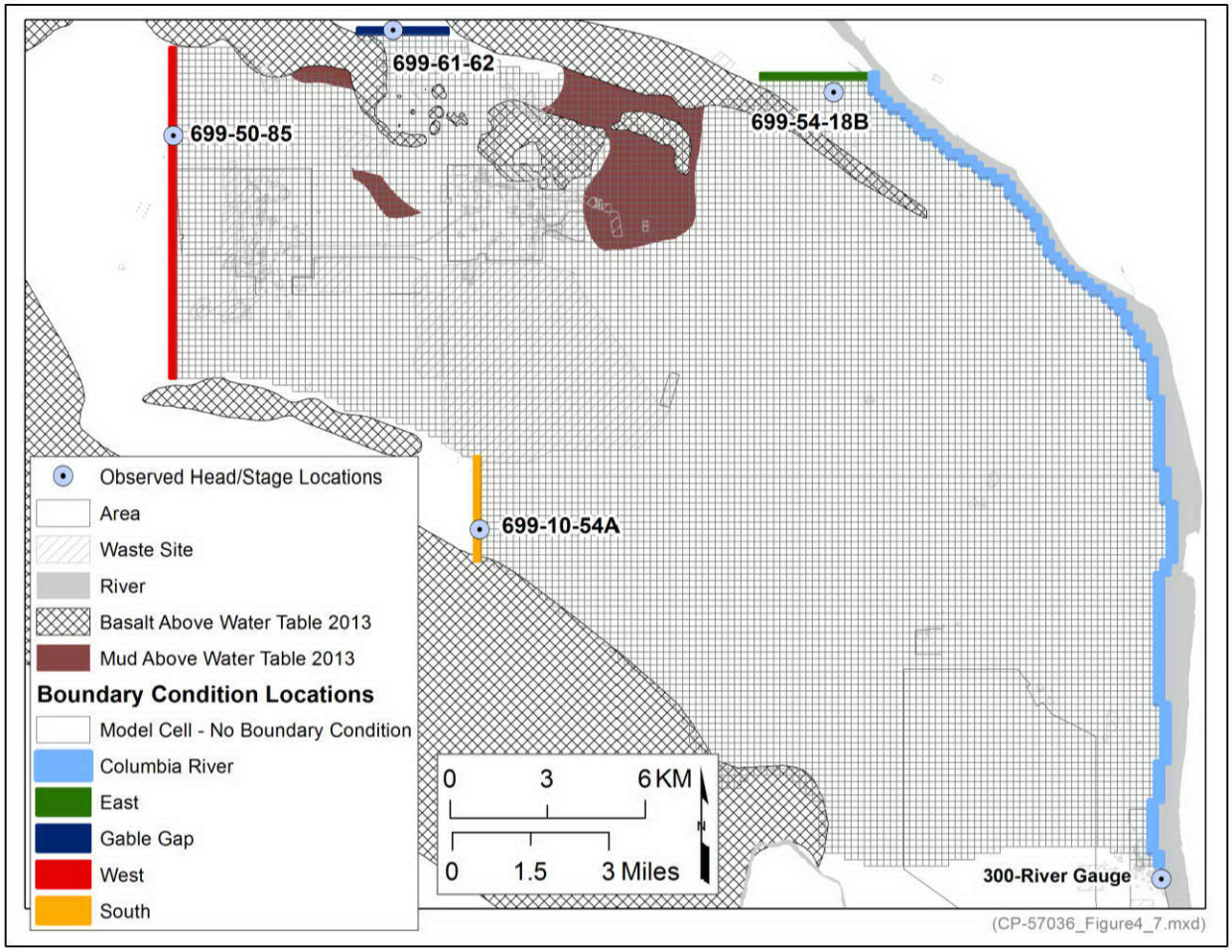


Figure 5-2. P2R Model Lateral Boundary Conditions

The natural component of recharge includes water originating as precipitation and infiltrating through the vadose zone, which ultimately reaches the saturated zone as recharge. In the P2R Model, recharge magnitudes were varied spatially based on soil type (BNWL-243, *Soil Survey Hanford Project in Benton County Washington*). Recharge values by soil type for the Hanford Site were taken from PNNL-14702 to establish the initial range of recharge value by soil type. The major soil types (sand, sandy loam, silty loam, and dune sand) in the P2R Model are listed in Table 5-2. The spatial distribution of these soil types is shown in Figure 5-3.

Anthropogenic recharge from surface water discharge due to operations at the Hanford Site is archived in a data package. The data include the magnitudes and locations of operational discharges for the simulated periods in the model. Locations of discharge include waste sites, ponds, sewer discharge, French drains, and documented UPRs for the entire operational period and projections of future discharges. Waste sites (e.g., cribs and trenches) and tank farms were assigned a recharge magnitude of 50 and 100 mm/yr, respectively. Figure 5-4 shows the locations of discharges and provides an illustration of how locations overlap more than one model cell. The total discharge is distributed on an area-weighted basis to all cells that intersect the footprint of the discharge location. The anthropogenic flux is added to the natural recharge component in order to establish the final total recharge flux used in the simulations. Included discharges have been attenuated to account for travel through the vadose zone.

Table 5-2. Soil Type and Natural Recharge Values

Simulated Soil Type	Soil Types Referenced in PNNL-14702, Rev. 1, Used to Develop Range of Recharge Values	Natural Recharge Values (mm/yr)		
		Minimum	Maximum	Calibrated
Silty loam	Warden silt loam	0.04	0.08	0.04
Sandy loam	Ephrata sandy loam, Burbank loamy sand	1.5	52	3.6
Sand	Rupert sand, Hanford sand	4	44	12
Dune sand	Hanford sand, graveled surface	4	100	55

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

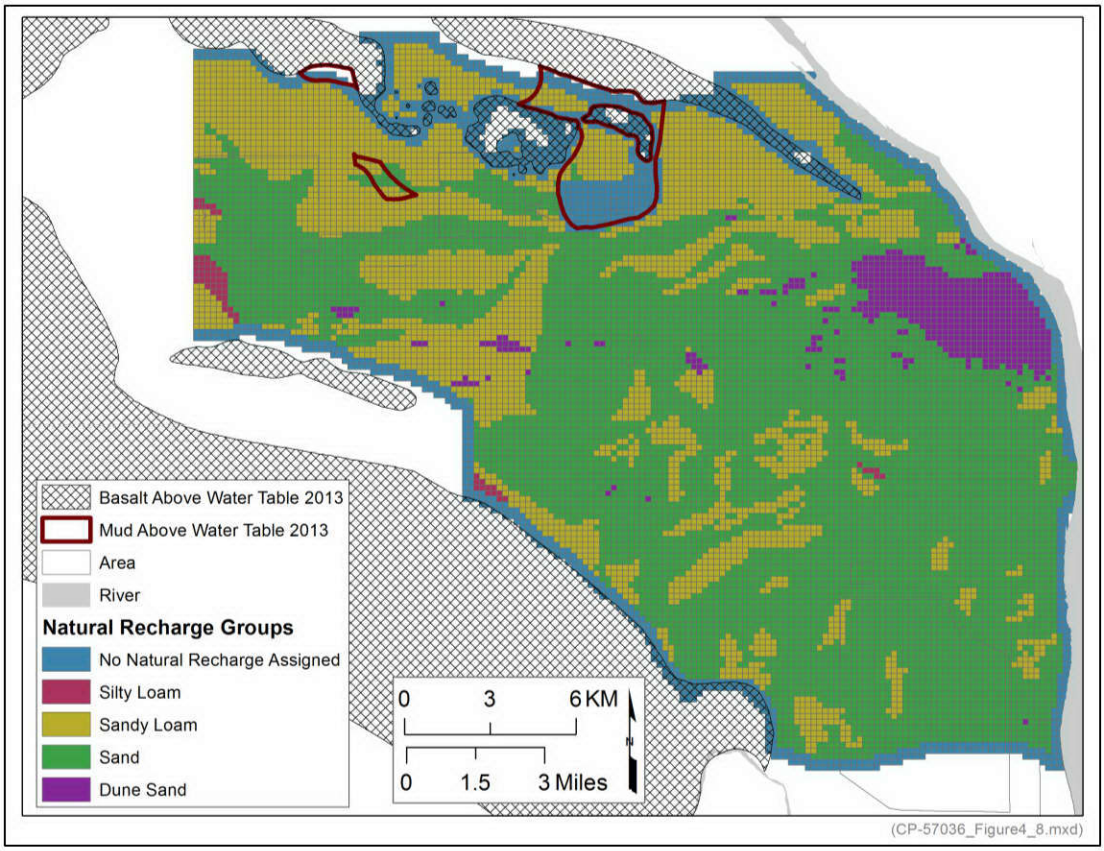


Figure 5-3. Spatial Distribution of Soil Types used to Define Natural Recharge to the Aquifer

One specific discharge point that is key to this calculation is discharge from future use of the TEDF (Figure 5-4). This is discussed in Section 5.2.3.

5.1.4.3 Lower Boundary Condition

The lower boundary of the model (i.e., the bottom of layer 7) represents the contact with the basalt. This boundary is modeled as a no-flow boundary.

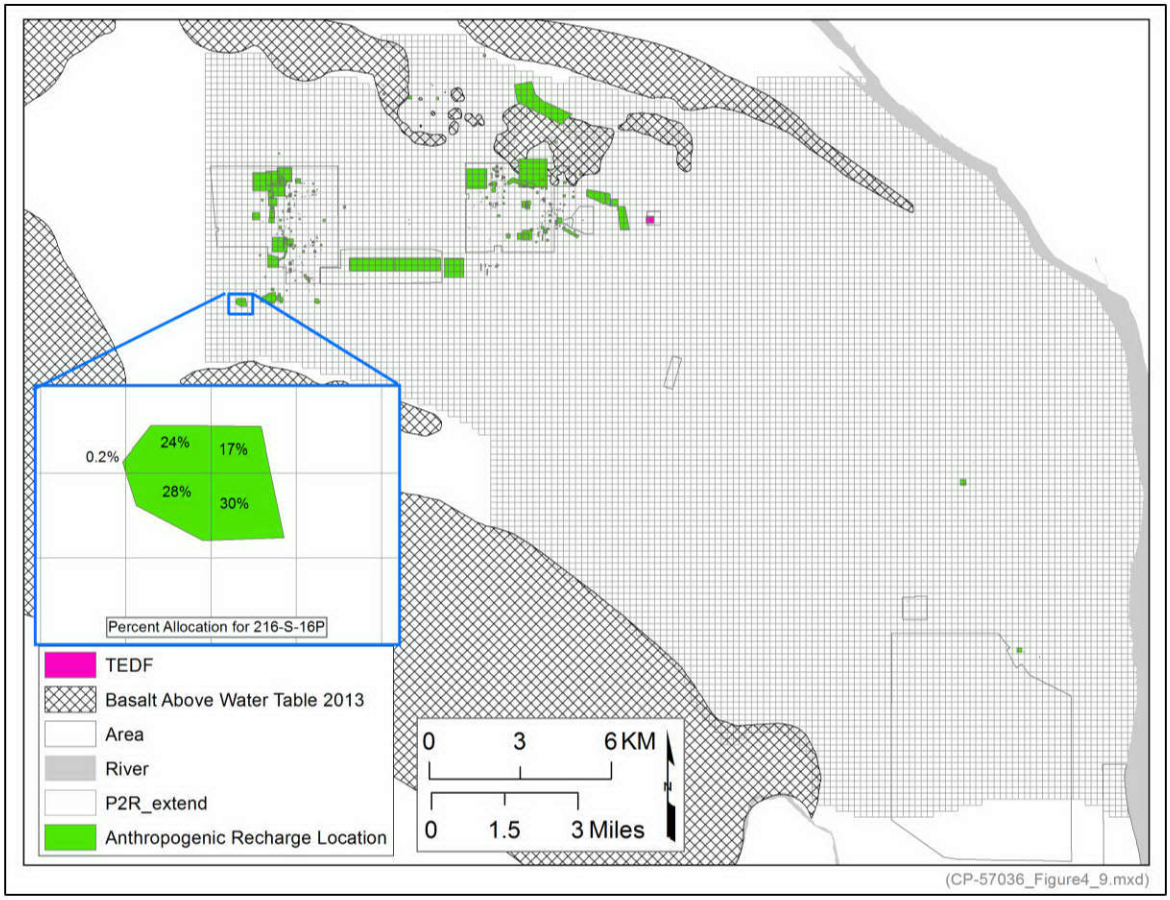


Figure 5-4. Locations of Anthropogenic Recharge in the P2R Model

5.1.4.4 Extraction/Injection Boundary Conditions

Groundwater pump-and-treat remediation systems have been implemented for the 200-UP-1 and 200-ZP-1 OUs at the Hanford Site for cleanup efforts. Since these pump-and-treat systems exist with the model domain, extraction and injection data for these pump-and-treat systems were gathered as part of the model development.

Injection and extraction rates were input using the MODFLOW well package. In locations where the well screen intersected multiple layers of the numerical model, the flow was proportioned based on the relative transmissivity of the screened interval for that well. Locations and rates of the injection and extraction wells are given in ECF-Hanford-13-0031 (provided in Appendix F).

5.1.5 Parameterization and Calibration

The selection of hydraulic parameters for the P2R Model was based on a Pacific Northwest National Laboratory (PNNL) database developed to provide an accessible repository for saturated media hydraulic properties. The PNNL database is based on results and supporting data from aquifer tests conducted at the Hanford Site over the past 50 years (PNNL-17708, *Three-Dimensional Groundwater Models of the 300 Area at the Hanford Site, Washington State*; PNNL-14186, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*). This database includes the results from in situ aquifer tests, including pumping tests, slug tests, injection tests, and tracer tests; however, the database excludes the laboratory analysis of discrete samples (e.g., permeameter testing).

A range of parameter values was initially used for each modeled HSU (Table 5-3). The final parameter values used in the model were developed by calibrating the modeled water levels to measured water levels under both steady-state and transient conditions. In the calibration process model, input parameters were altered in a systematic iterative fashion in order to improve the models fit to the observed data. Both manual and automated calibration to the set of historical water-level data using the PEST parameter estimation software (Doherty, 2007, *PEST Model-Independent Parameter Estimation*) were implemented to optimize the estimate of the model parameter values.

Table 5-3. P2R Model Hydraulic Parameters

Property	Units	HSU	Low	High	Calibrated
Hydraulic conductivity	m/d	Hanford, Cold Creek (paleochannel)	1	370,000	17,000
		Hanford (outside paleochannel)	0.1	19.7	2.27
		Hanford (near Columbia River)	0.9	62	3
		Cold Creek	1	400	109
		Ringold Taylor Flat*	1	20	3.26
		Ringold E	0.1	18.6	1
		Ringold lower mud	2.00E-04	0.03	8.00E-03
		Ringold A	1	8	5
Vertical anisotropy of hydraulic conductivity	-/-	All	0.01	0.1	0.1
Specific yield	m/m	Hanford and Cold Creek	0.1	0.37	0.2
		Ringold	0.05	0.11	0.095
Storativity	1/m	All	2.30E-05	1.20E-03	1.00E-04

* No description for this soil type is within the hydraulic properties database or the previous modeling efforts. Range of values assumed based on pumping test values from other Hanford (outside paleochannel) and Ringold unit E values.

HSU = hydrostratigraphic unit

5.1.6 Initial Hydraulic Head Conditions

The initial hydraulic head distribution was identical for all simulations and is *not* the contaminant concentration initial condition varied in the analysis of differing scenarios documented in Section 5.2.1. Initial heads were determined using a steady-state stress period at the beginning of the simulation where boundary conditions assignments matched the first transient simulation period representing January 1, 2013.

5.1.7 Contaminants of Potential Concern and Transport Properties

F&T of the following eight selected 200-BP-5 OU COPCs was simulated to evaluate future impacts to the unconfined aquifer:

- Cyanide
- Nitrate
- Uranium
- Strontium-90
- Technetium-99
- Iodine-129
- Tritium
- Cr(VI)

Rather than simulating each of the contaminants discussed in previous chapters of this report, these eight contaminants were selected for transport evaluation because the distribution is well defined, occurs in high concentrations, or both. Table 5-4 summarizes the characteristics of these contaminants. The contaminants evaluated in F&T simulations exhibit the common characteristic of being present in the current dissolved-phase groundwater. The transport properties of the P2R Model are provided in Table 5-5.

Table 5-4. Physical Characteristics of COPCs

Chemical Name	CAS Number	Chemical Group	Molecular Weight (g/mole)
Iodine-129	15046841	Radionuclide	129.91
Nitrate	14797558	Anion	62.00
Technetium-99	14133767	Radionuclide	98.91
Tritium*	10028178	Radionuclide	6.03
Uranium-238	N/A	Metal	238.03
Strontium-90	10098972	Radionuclide	89.91
Cyanide	57125	Anion	26.02
Hexavalent chromium	7440473	Inorganic	52.00

* Tritium is generally present as tritiated water.

CAS = Chemical Abstracts Service

COPC = contaminant of potential concern

N/A = not applicable

Table 5-5. P2R Model Transport Properties

Property		Value	Basis
Effective porosity	Hanford and Cold Creek	0.2	Approximate central value from DOE/RL-2007-28, Table D-2
	Ringold E, Taylor Flat, and A	0.15	
	Ringold upper mud	0.3	
Longitudinal dispersivity		6.2 m	Schulze-Makuch (2005) using 200 m (656 ft) horizontal grid size
Transverse dispersivity		1.2 m	20% of longitudinal dispersivity (DOE/RL-2008-56)
Molecular diffusion constant		0 m	Negligible term
Bulk density	Hanford formation	1.93 g/cm^3	PNNL-18564, Table 6.2
	Cold Creek	1.93 g/cm^3	PNNL-18564, Table 6.2
	Ringold	1.90 g/cm^3	PNNL-18564, Table 6.2

Sources: DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit.*

DOE/RL-2008-56, *200 West Area Pre-Conceptual Design for Final Extraction Well Network: Modeling Analyses*.

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*.

Schulze-Makuch, 2005, "Longitudinal Dispersivity Data and Implications for Scaling Behavior."

Sorption processes in any aquifer may include electrostatic ion exchange (cationic or anionic), precipitation reactions, physical adherence on particle surfaces, or combinations of multiple processes. The sorption processes may exhibit varying degrees of reversibility, as well as variations in the rate of reversibility. The K_d of groundwater contaminants varies, generally as a function of the geochemical nature of the aquifer solids. A constituent may exhibit a higher K_d when reacting with fine-textured secondary minerals (e.g., clays) and a lower K_d when reacting with coarse-textured primary minerals. The sorption capacity of the aquifer formation solids generally varies as a function of its relative content of fine-textured particles of active mineral species. The contaminant K_d values used for this study were selected from published reports describing experimental determination of K_d values for specific contaminants of interest conducted on samples of aquifer materials that represent aquifer conditions within the 200-BP-5 OU.

The COPCs exhibit varying levels of mobility in groundwater (Table 5-6). The COPCs are sufficiently water soluble, so their solubility is not a limiting factor to transport in the aquifer system. Maximum observed concentrations for all of the contaminants examined in this simulation were well below their apparent solubility limits in water. The contaminants of interest for this OU fall into three general categories of mobility in groundwater: highly mobile, moderately mobile, and slightly mobile.

Table 5-6. Constituent-Specific Transport Parameter Values

Final COPCs	K_d (mL/g)	Half-Life (yr)	Half-Life (day)	Decay Constant (λ, day^{-1})	Reference for K_d
Nitrate	0	—	—	No decay	PNNL-18564, Table 6.9, sandy-gravel sediment type
Strontium-90	12	2.88×10^{1}	1.05×10^{4}	6.601×10^{-5}	PNNL-18564, Table 6.9, sandy-gravel sediment type
Uranium-238	0.4*	4.47×10^{9}	1.63×10^{12}	4.25×10^{-13}	PNNL-18564, Table 6.9, sandy-gravel sediment type
Iodine-129	0.1	1.57×10^{7}	5.73×10^{9}	1.21×10^{-10}	PNNL-18564, Table 6.9, sandy-gravel sediment type
Technetium-99	0	2.11×10^{5}	7.71×10^{7}	8.99×10^{-9}	PNNL-18564, Table 6.9, sandy-gravel sediment type
Tritium	0	1.23×10^{1}	4.50×10^{3}	1.54×10^{-4}	PNNL-18564, Table 6.9, sandy-gravel sediment type
Cyanide	0	—	—	No decay	PNNL-18564, Table 6.9, sandy-gravel sediment type
Hexavalent chromium	0	—	—	No decay	PNNL-18564, Table 6.9, sandy-gravel sediment type (mobile chromium is assumed to be in the hexavalent oxidation state)

Note: The decay constant (λ) is used to calculate decayed activity according to the equation $A_i = A_0 e^{-\lambda t}$.

Source: PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*.

* K_d estimate assumes that uranium is present as a soluble oxy-anion (e.g., uranyl ion, UO_2^{2+}).

COPC = contaminant of potential concern

K_d = distribution coefficient

Contaminants classified in this study as "highly mobile" move freely with the water in which they are dissolved, exhibiting little to no direct interaction with the solid-phase portion of the aquifer that would remove contaminant mass from the groundwater as it moves through the aquifer. The highly mobile contaminants exhibit a K_d of 0 mL/g (i.e., no retardation). The modeled COPCs for the 200-BP-5 OU that are highly mobile contaminants are cyanide, Cr(VI), nitrate, sulfate, technetium-99, and tritium (K_d = 0 mg/L).

Contaminants classified in this study as "moderately mobile" move readily with groundwater but also exhibit a moderate degree of interaction with aquifer solids. Sorptive processes generally tend to slow the rate of migration of these contaminants through the aquifer; their observed concentration in groundwater decreases with migration downgradient through the aquifer system. The definition of moderately mobile is clearly subjective; for the purposes of this study, moderately mobile contaminants are identified to

be those exhibiting K_d values greater than 0 mL/g but less than 1 mL/g. Uranium and iodine-129 (K_d = 0.1 mL/g) are the modeled COPCs in the 200-BP-5 OU that are moderately mobile contaminants.

Those contaminants classified in this study as "slightly mobile" exhibit a high degree of interaction with aquifer solids and, as a result, migrate slowly through the aquifer. Their dissolved concentration in groundwater decreases dramatically with distance from a source or release point due to the relatively large fraction of the contaminant that becomes sorbed to the aquifer solids. For this study, slightly mobile contaminants are identified as those contaminants that exhibit K_d values greater than one. Strontium-90 (K_d = 12 mL/g) is the only slightly mobile contaminant of the COPCs modeled for the 200-BP-5 OU.

5.2 Model Scenarios

The overall modeling approach for this RI is to develop and simulate a "base case" scenario, representing those features of the hydrogeological system reasonably anticipated to occur across all scenarios, and then exploring the sensitivities to variations on the conceptual model by simulating F&T under a range of permutations of scenarios. The base case is the model documented in CP-57037 (provided in Appendix F). The setup of the base case model is summarized in Section 5.1, and the results are presented in Section 5.3.

A range of scenarios was developed to encompass the response of the model results to several key drivers. These scenarios can be thought of as sensitivity analyses, designed to test the response of the model to perturbations in parameters model's representation of the hydrogeologic system. Application of the P2R Model to simulate the range of contaminant F&T scenarios is presented in ECF-Hanford-13-0031 (provided in Appendix F), and a summary is provided in Sections 5.2.1 and 5.2.3.

The F&T of eight COPCs was modeled under a range of scenarios. The scenarios were developed by varying components of the conceptual model that are the key drivers of outcomes:

- **Contaminant concentration initial conditions:** The concentration of the COPCs at the beginning of the model simulations were calculated either using an average or a maximum basis for derivation of the initial contaminant plume representation (Section 5.2.1).
- **Vadose zone continuing sources:** Three COPCs (technetium-99, uranium, and nitrate) are anticipated to continue to be released from the vadose zone in two locations. These continuing sources were either included or not included in model simulations to evaluate their influence (Section 5.2.2).
- **TEDF:** The hydraulic effect of the TEDF has the potential to influence local hydraulic conditions in the future. This influence was either included or not included, based on project discharges to evaluate its influence (Section 5.2.3).

While each unique combination of COPC, contaminant concentration initial condition basis, inclusion or exclusion of continuing source, and inclusion or exclusion of future TEDF discharges is considered a scenario and is modeled independently of every other scenario, it can be helpful to organize the scenarios along some common features. For this RI, the scenarios are grouped by the combination of the TEDF and/or continuing sources in the model, resulting in four scenario groups, as shown in Table 5-7.

Table 5-7. Scenario Groups

Scenario Group	Description
Base case	The base case scenario represents the expected behavior of the plume migration with no remedial action and will be used for assessing contaminant migration within the remedial investigation. Neither TEDF nor continuing sources are represented.
TEDF future use	These simulations consider the effect of projected future TEDF discharge on the plume migration.
Continuing source	ECF-Hanford-13-0037 (provided in Appendix F) was used to establish the unconfined aquifer source terms for technetium-99, nitrate, and uranium.
TEDF future use with continuing source	This scenario superposes the second and third scenarios into a single set of simulations.

Source: ECF-Hanford-13-0037, *Development of Source Terms for Inclusion in Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* (provided in Appendix F).

TEDF = Treated Effluent Disposal Facility

As shown in Table 5-8, 44 scenarios were simulated. Each scenario is designated by a scenario identification in which the first four letters indicates the contaminant, the second four letters are a flag indicating whether TEDF is included, the third two letters are a flag indicating the whether continuing sources were included, and the last three letters indicate if average or maximum basis for initial conditions were used. Comprehensive results for these 44 scenarios are presented in ECF-Hanford-13-0031 (included in Appendix F). Results for a few selected scenarios are discussed later in this chapter for the purposes of presenting expected contaminant transport for baseline conditions and guiding understanding of the range of conditions simulated in the evaluated scenarios.

Table 5-8. Scenario List

Scenario ID	Group ID	Contaminant	TEDF	Continuing Source	Initial Condition
CRVI-NTED-NS-AVG	Base case	Cr(VI)	No	No	Average
CYAN-NTED-NS-AVG	Base case	Cyanide	No	No	Average
NITR-NTED-NS-AVG	Base case	Nitrate	No	No	Average
I129-NTED-NS-AVG	Base case	Iodine-129	No	No	Average
SR90-NTED-NS-AVG	Base case	Strontium-90	No	No	Average
TC99-NTED-NS-AVG	Base case	Technetium-99	No	No	Average
TRIT-NTED-NS-AVG	Base case	Tritium	No	No	Average
URNM-NTED-NS-AVG	Base case	Uranium	No	No	Average
CRVI-NTED-NS-MAX	Base case	Cr(VI)	No	No	Maximum
CYAN-NTED-NS-MAX	Base case	Cyanide	No	No	Maximum
NITR-NTED-NS-MAX	Base case	Nitrate	No	No	Maximum

Table 5-8. Scenario List

Scenario ID	Group ID	Contaminant	TEDF	Continuing Source	Initial Condition
I129-NTED-NS-MAX	Base case	Iodine-129	No	No	Maximum
SR90-NTED-NS-MAX	Base case	Strontium-90	No	No	Maximum
TC99-NTED-NS-MAX	Base case	Technetium-99	No	No	Maximum
TRIT-NTED-NS-MAX	Base case	Tritium	No	No	Maximum
URNM-NTED-NS-MAX	Base case	Uranium	No	No	Maximum
CRVI-TEDF-NS-AVG	TEDF	Cr(VI)	Yes	No	Average
CYAN-TEDF-NS-AVG	TEDF	Cyanide	Yes	No	Average
NITR-TEDF-NS-AVG	TEDF	Nitrate	Yes	No	Average
I129-TEDF-NS-AVG	TEDF	Iodine-129	Yes	No	Average
SR90-TEDF-NS-AVG	TEDF	Strontium-90	Yes	No	Average
TC99-TEDF-NS-AVG	TEDF	Technetium-99	Yes	No	Average
TRIT-TEDF-NS-AVG	TEDF	Tritium	Yes	No	Average
URNM-TEDF-NS-AVG	TEDF	Uranium	Yes	No	Average
CRVI-TEDF-NS-MAX	TEDF	Cr(VI)	Yes	No	Maximum
CYAN-TEDF-NS-MAX	TEDF	Cyanide	Yes	No	Maximum
NITR-TEDF-NS-MAX	TEDF	Nitrate	Yes	No	Maximum
I129-TEDF-NS-MAX	TEDF	Iodine-129	Yes	No	Maximum
SR90-TEDF-NS-MAX	TEDF	Strontium-90	Yes	No	Maximum
TC99-TEDF-NS-MAX	TEDF	Technetium-99	Yes	No	Maximum
TRIT-TEDF-NS-MAX	TEDF	Tritium	Yes	No	Maximum
URNM-TEDF-NS-MAX	TEDF	Uranium	Yes	No	Maximum
NITR-NTED-CS-AVG	Continuing source	Nitrate	No	Yes	Average
TC99-NTED-CS-AVG	Continuing source	Technetium-99	No	Yes	Average
URNM-NTED-CS-AVG	Continuing source	Uranium	No	Yes	Average
NITR-NTED-CS-MAX	Continuing source	Nitrate	No	Yes	Maximum
TC99-NTED-CS-MAX	Continuing source	Technetium-99	No	Yes	Maximum
URNM-NTED-CS-MAX	Continuing source	Uranium	No	Yes	Maximum
NITR-TEDF-CS-AVG	TEDF and continuing source	Nitrate	Yes	Yes	Average

Table 5-8. Scenario List

Scenario ID	Group ID	Contaminant	TEDF	Continuing Source	Initial Condition
TC99-TEDF-CS-AVG	TEDF and continuing source	Technetium-99	Yes	Yes	Average
URNM-TEDF-CS-AVG	TEDF and continuing source	Uranium	Yes	Yes	Average
NITR-TEDF-CS-MAX	TEDF and continuing source	Nitrate	Yes	Yes	Maximum
TC99-TEDF-CS-MAX	TEDF and continuing source	Technetium-99	Yes	Yes	Maximum
URNM-TEDF-CS-MAX	TEDF and continuing source	Uranium	Yes	Yes	Maximum

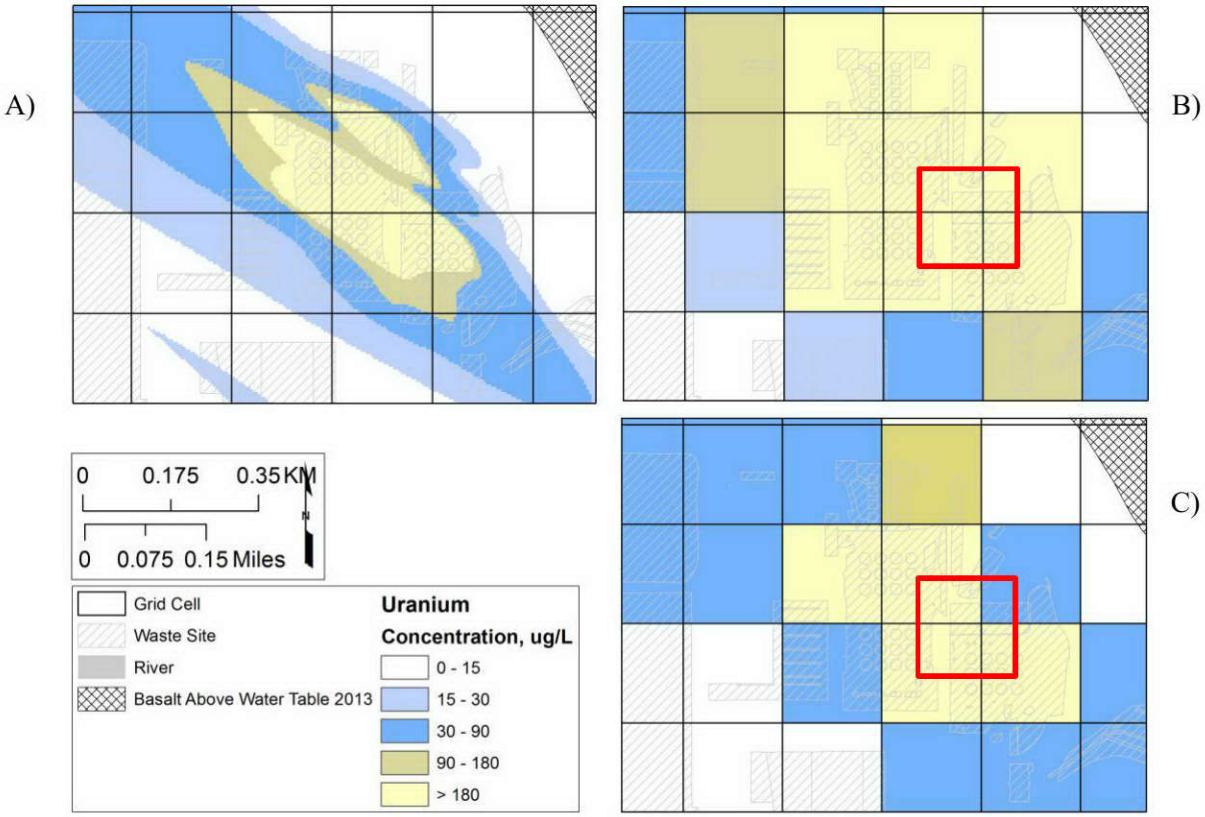
Cr(VI) = hexavalent chromium
ID = identification
TEDF = Treated Effluent Disposal Facility

5.2.1 Initial Contaminant Distribution Scenarios

The initial groundwater contaminant distributions of the eight COPCs identified in Section 5.17 were based on ECF-Hanford-13-0030, *Initial Groundwater Plume Development to Support Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* (provided in Appendix F). The approach documented therein is summarized in the following sections.

Contaminant plumes were created to represent average and maximum concentration initial conditions. Figure 5-5 shows a visual representation of how this was determined The original distributions presented in the 2013 annual Hanford Site groundwater monitoring report (DOE/RL-2014-32) were produced using a 10 m by 10 m (32.8 ft by 32.8 ft) raster estimate of concentrations in the unconfined aquifer. The initial estimate was upscaled to the P2R Model grid based on the on the arithmetic average and peak concentration within each 200 m by 200 m (656.2 ft by 656.2 ft) cell for the average and maximum initial concentration conditions, respectively.

- The “average initial condition” represents the total contaminant mass in any given model cell, but the maximum contaminant concentration may be not represented. The average initial condition is considered to be more representative of total mass within the aquifer.
- The “maximum initial condition” overestimates the total contaminant mass in any given model cell but preserves the peak contaminant concentration occurring in that model cell. The maximum initial condition provides a better visual match with respect to peak concentration but likely overestimates the mass of contaminant in the aquifer.



Note: Upscaling of (a) the original concentration estimate was completed based on the (b) peak concentration for the maximum initial concentration condition and (c) the average value of concentration for the average initial concentration condition.

Figure 5-5. Visual Representation of Contaminant Plume Input for Model

The effect of the choice of initial condition type on the total contaminant inventory at the beginning of simulation in shown in Table 5-9. With the exception of iodine-129, which is unaffected by initial condition, use of the maximum initial condition will increase the inventory by at least 33 percent, and up to more than 242 percent in some cases.

5.2.2 Continuing Source Scenarios

Based on information presented in ECF-Hanford-13-0037, *Development of Source Terms for Inclusion in Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, two areas have been identified within the 200 East Area where continuing sources of contaminant release from the vadose zone into the 200-BP-5 OU are likely to persist over the foreseeable future: WMA C (C Tank Farm area), and the B Complex (B-BX-BY Tank Farms and BY Cribs area). Note that the vadose zone sources described in this section are not associated with TEDF. The primary contaminants of concern that are likely to provide continuing sources from the vadose zone are technetium-99, uranium, and nitrate at the B Complex and technetium-99 at WMA C. The recommended mass and activity from ECF-Hanford-13-0037 are presented in Table 5-10. These values were included in the continuing source simulations using the source/sink mixing package of MT3DMS.

Table 5-9. Initial Mass/Activity of Contaminants for Average and Maximum Initial Conditions

Contaminant	Units	Mass/Activity	
		Average	Maximum
Cr(VI)	kg	2.6	5.2
Cyanide	kg	110	180
Nitrate	kg	760,000	1,100,000
Iodine-129	Ci	0.1	0.1
Strontium-90	Ci	7.3	25
Technetium-99	Ci	11	20
Tritium	Ci	9	12
Uranium	kg	410	1,300

Cr(VI) = hexavalent chromium

Table 5-10. Vadose Zone COPC Continuing Sources

Area	Contaminant	Units	Rate	Duration (years)
WMA C	Technetium-99	Ci/yr	0.2	60
BY Cribs	Technetium-99	Ci/yr	0.22	90
BY Cribs	Nitrate	kg/yr	8,212.5	90
B-BX-BY	Technetium-99	Ci/yr	0.008	300
B-BX-BY	Uranium	kg/yr	3.8	300

Source: ECF-Hanford-13-0037, *Development of Source Terms for Inclusion in Fate and Transport Modeling for Remedial Investigation /Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* (provided in Appendix F).

WMA = waste management area

5.2.3 Treated Effluent Disposal Facility Scenarios

One specific liquid discharge point that is important to this calculation is the Hanford Site 200 Areas TEDF discharge, shown in Figure 5-4. In order to evaluate the possible impact that this facility may have on cleanup times, simulations will be conducted with and without this discharge simulated as anthropogenic recharge.

5.3 Groundwater Contaminant Evaluation

The result of interest for any given scenario is the contaminant concentrations over space and time. The model domain simulated, however, spans an area of hundreds of square kilometers and thousands of model cells. Therefore, to evaluate groundwater impact at relevant scales to support the decision-making

process, the model domain was divided into several subregions, and three statistical measures of concentration (the maximum, 90th percentile, and mean) were calculated for evaluation of remedial time frame in each of these subregions (Section 5.3.1). From these statistics, cleanup times were determined (Section 5.3.2). Base case results are presented for each COPC evaluated in Section 5.3.3 to show expected baseline groundwater conditions and cleanup times, and a summary comparison is provided for the range of scenarios evaluated (ECF-Hanford-13-0031; provided in Appendix F).

5.3.1 Statistical Metrics of Groundwater Impact

At any given time step of a scenario simulation, every one of the thousands of active cells in the model domain has a concentration value. In order to evaluate these results efficiently, the full model domain was divided into subregions, and then each subregion was evaluated statistically.

Figure 5-6 shows the subregions into which the model domain is divided. The subregions represent the groundwater interest areas (or portions of the groundwater interest areas) designated at the Hanford Site. These subregions allow concentrations to be evaluated in the familiar context of the site, but the borders between subregions may not correspond to anything physically meaningful, such as a groundwater divide or the edges of a contaminant plume.

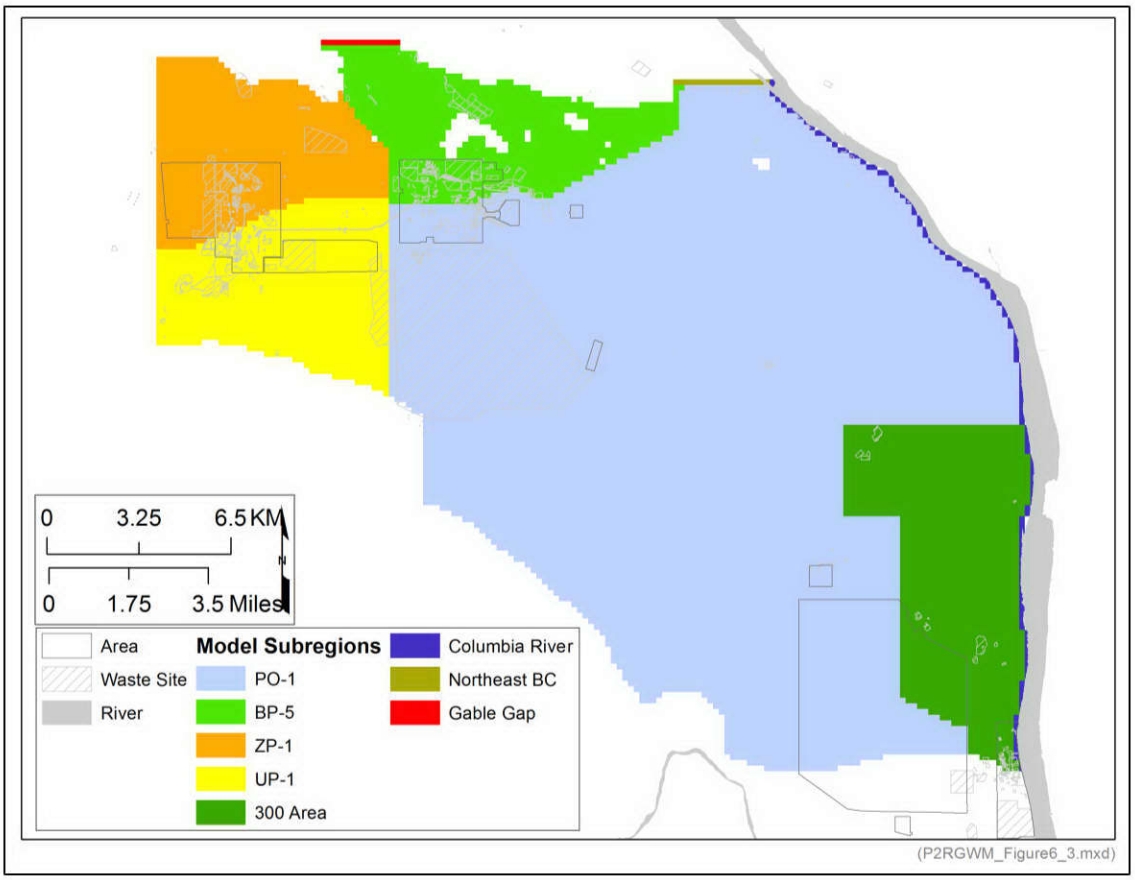


Figure 5-6. Subregions Used to Evaluate the F&T of Contaminants over Time

Each subregion consists of hundreds to thousands of model cells. Three metrics are used to evaluate concentrations in the subregions:

- **Peak concentration:** The maximum concentration value of all model cells in a subregion.
- **C_{90}:** The 90th percentile of all concentration values in a subregion.
- **Mean:** The arithmetic mean of all concentration values in a subregion.

The three statistics are provided only to illustrate contaminant concentration behavior. It is not the intent of this evaluation to demonstrate compliance or to conduct a BRA. These different applications will require different statistics, such as the 95th upper confidence limit (UCL) on the mean, based on actual measurements, not model predictions. For the C_{90} and mean metrics, threshold values may be applied in order to remove bias introduced by the limited extent of the plume. For example, a contaminant plume in the 200-BP-5 OU subregion may only occupy a small part of the OU, meaning that the vast majority of model grid blocks in that subregion will have a concentration very close to zero. In this case, both the C_{90} and mean statistics would be overwhelmed by the near-zero concentrations outside the plume rather than the concentrations within the plume. One way to provide a meaningful statistic would be to calculate the statistic for only those cells within the plume, which might be defined as having concentrations above some limiting value, such as some fraction of the DWS.

In the results presented herein, the 90th percentile is estimated by tabulating all estimated concentration values in a subregion, sorting the values, assigning a Weibull plotting position to determine rank, and selecting the concentration value corresponding to the 90th percentile value. The peak concentration is the concentration with the highest magnitude from any estimated concentration within a given subregion. When calculating the statistical values for mean and 90th percentile, only numerical cells with simulated concentration values above half of the DWS were used in the calculation.

Note that the peak and mean evaluation statistics should not be confused with the maximum and average initial conditions. The former are metrics used to evaluate results from hundreds or thousands of model grid blocks in a simulation at a given time step. The latter are rules used to assign values of concentration from a plume grid map to individual model grid blocks at the start of the simulation.

5.3.2 Cleanup Times

While the statistical methods described in Section 5.3.1 provide a metric of performance, they do not necessarily provide a normative scale. Therefore, cleanup times are determined by identifying the time required for each cleanup statistic to decline to the relevant DWS for each COPC.

5.3.3 Base Case Groundwater Impacts

The "base case" is defined as the set of model scenarios that possesses features of the hydrogeological system reasonably anticipated to occur in across all scenarios, as documented in CP-57037 (provided in Appendix F) and summarized as follows:

- F&T are simulated with the P2R Model.
- Neither TEDF nor continuing sources are represented.
- Initial conditions for contaminant distribution are set using the average conditions.
- The metric of groundwater impact is the C_{90} statistic.

Results for each COPC are presented in Figures 5-7 through 5-14. For each COPC, a map view of the evolution of the contaminant plume is shown. Each of these figures shows a "snapshot" of the contaminant distribution, from the beginning of the simulation to a point in time at which the plume has reached its smallest extent. Note that the spatial extent and time steps for each contaminant are unique and are intended to depict the behavior of that plume.

The cleanup times for all COPCs in the 200-BP-5 OU, presuming that no remedial actions are taken, are presented in Table 5-11.

5.3.4 Continuing Source Groundwater Impacts

The impacts of continuing sources on simulated cleanup times under a no action scenario are shown in Table 5-12. The sources include nitrate, technetium-99, and uranium in the B Complex area, and technetium-99 associated with WMA C. For these continuing source simulations, TEDF discharges were not included, and the average concentration case for each contaminant was used. The Initial conditions for contaminant distribution used the average concentrations. The results for the continuing source simulations are presented in Figures 5-15, 5-16, and 5-17 for nitrate, uranium, and technetium-99, respectively. Each figure shows various times for the three contaminants, from the start of the simulation period to a point at which the plume has reached its smallest spatial extent. After the plume has reached its smallest spatial extent that extent remains relatively consistent until the cleanup times (listed in Table 5-12) are reached.

5.3.5 Comparison of Scenarios/Uncertainty Analysis

A comparison of the results for all scenarios simulated with the average initial condition is provided in Table 5-12. Note that only those contaminants anticipated to be subject to continued release from the vadose zone are included in the "Continuing Source" and the "TEDF and Continuing Source" columns of the table. In addition, an indicated cleanup time of greater than 1,000 years indicates that cleanup was not achieved in the 1,000-year simulation time.

The following conclusions can be made based on the comparison of results:

- The addition of the TEDF to the base case does not change cleanup times for strontium-90, tritium, or Cr(VI).
- The addition of the TEDF to the base case increased cleanup times for technetium-99 and uranium by 50 years and 10 years, respectively.
- The addition of the TEDF to the base case decreased cleanup times for cyanide by 150 years.
- Addition of the continuing source, with or without the TEDF, adds significantly to the cleanup times of the contaminants in question, increasing cleanup times by hundreds of years in all cases except for the TEDF technetium-99 scenarios, in which the addition of the continuing decreased cleanup time by 50 years (i.e., from 850 years to 800 years).

A comparison of results for all scenarios simulated with the maximum initial condition is provided in Table 5-13. In most cases, the maximum initial condition simulations show a similar pattern of minimal or no change with the addition of the TEDF to the base case. The single exception is for uranium, for which addition of the TEDF cuts the cleanup time from 950 years to 260 years.

For the maximum initial condition, cleanup times for uranium, technetium-99, and nitrate all approach the 1,000-year simulation time, even without the continuing source. Therefore, the cleanup time is not

a usable metric, but it may be assumed that addition of the continuing source will raise concentrations and extend cleanup times.

The analysis above described and predicted the time frames that contaminants could migrate through the groundwater in the 200-BP-5 OU. The potential for these contaminants to be harmful depends on specific human and environmental receptors, as well as exposure times and patterns that might bring receptors and contaminates into contact. The ways that the contaminants could come into contact with and impact HHE are referred to as pathways. The BRA presented in Chapters 6 provides the scenarios showing how humans or ecological receptors might come into contact with contaminants in the groundwater (i.e., the CEM) and evaluates the resulting impacts.

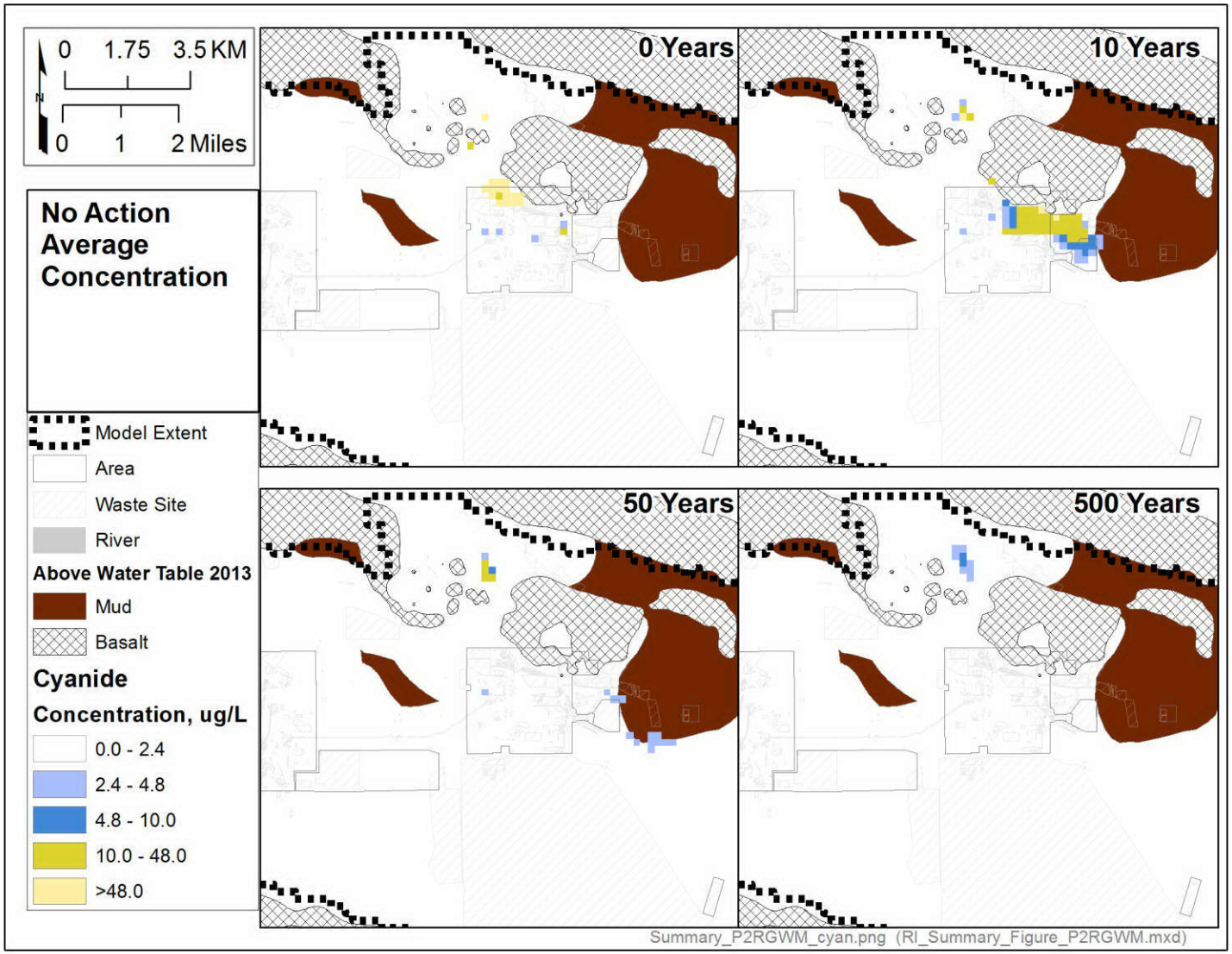


Figure 5-7. Base Case Cyanide Plume Evolution

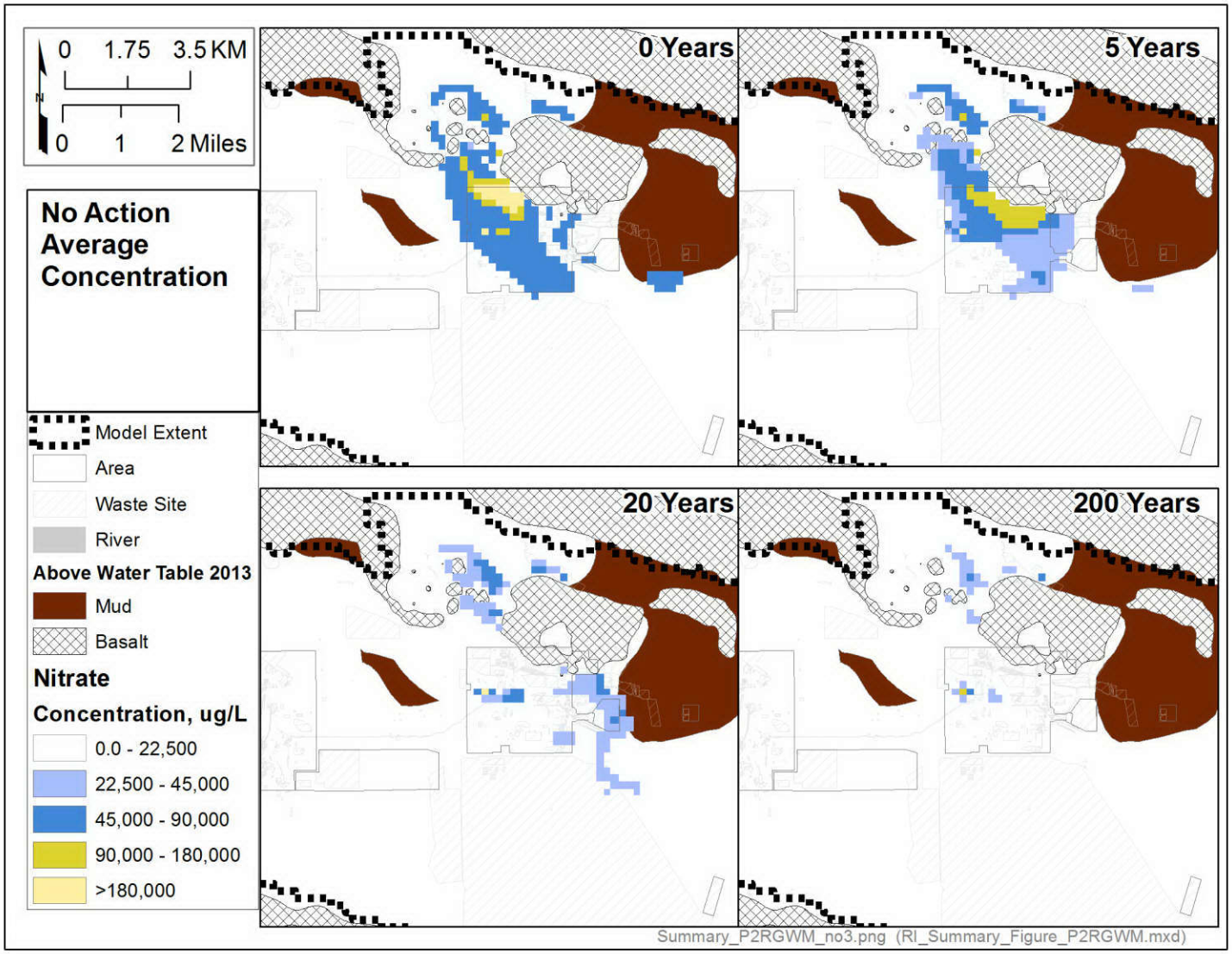


Figure 5-8. Base Case Nitrate Plume Evolution

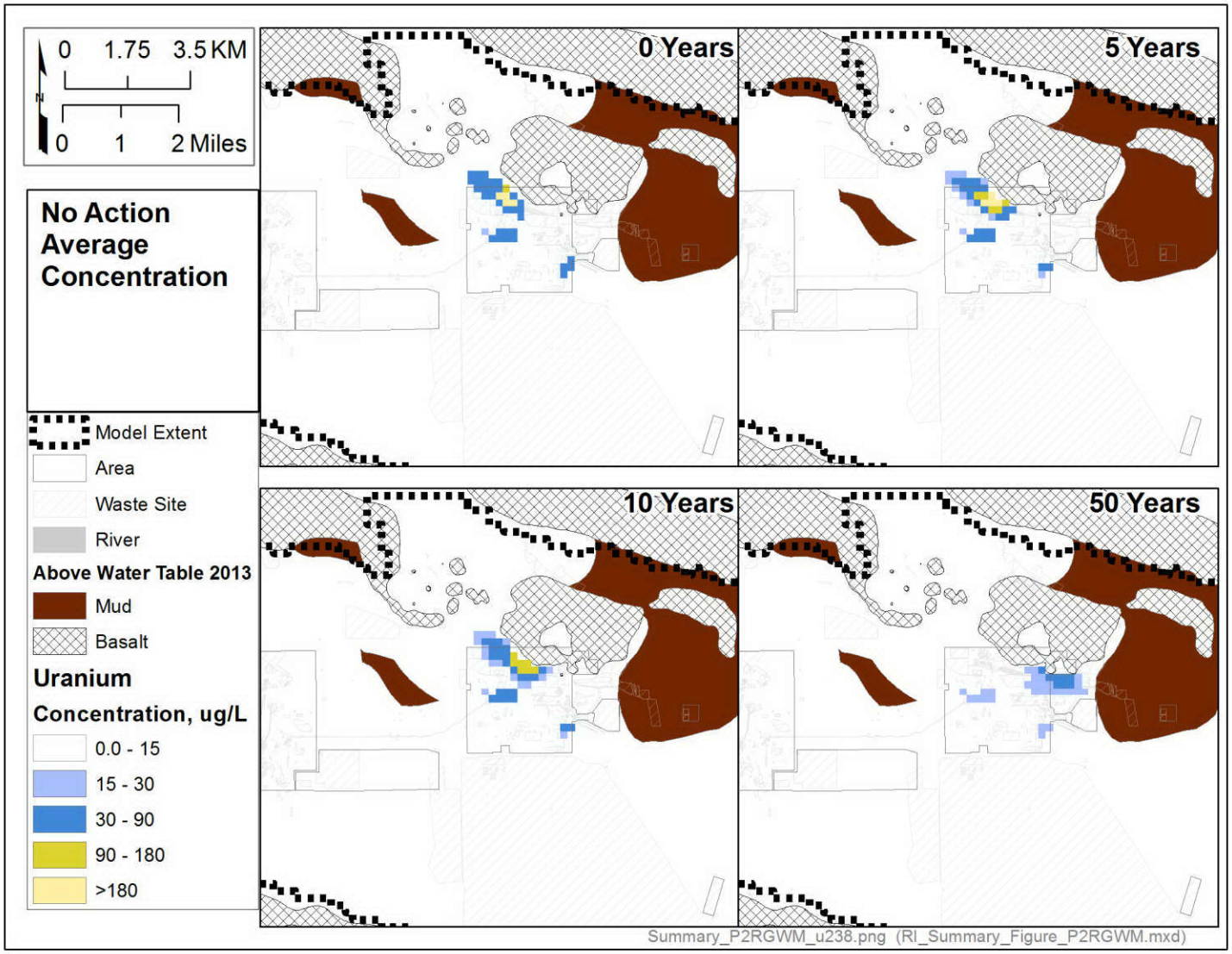


Figure 5-9. Base Case Uranium Plume Evolution

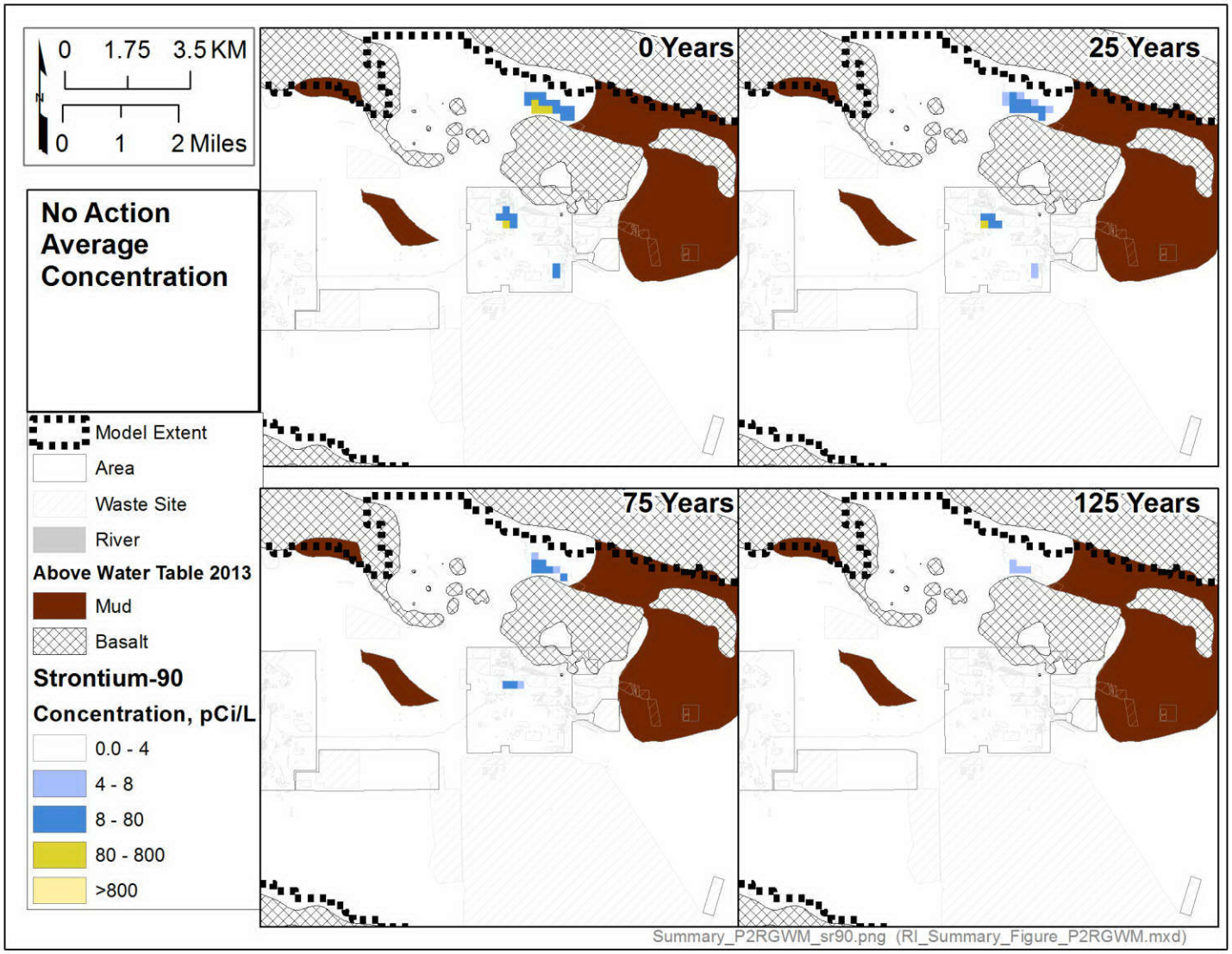


Figure 5-10. Base Case Strontium-90 Plume Evolution

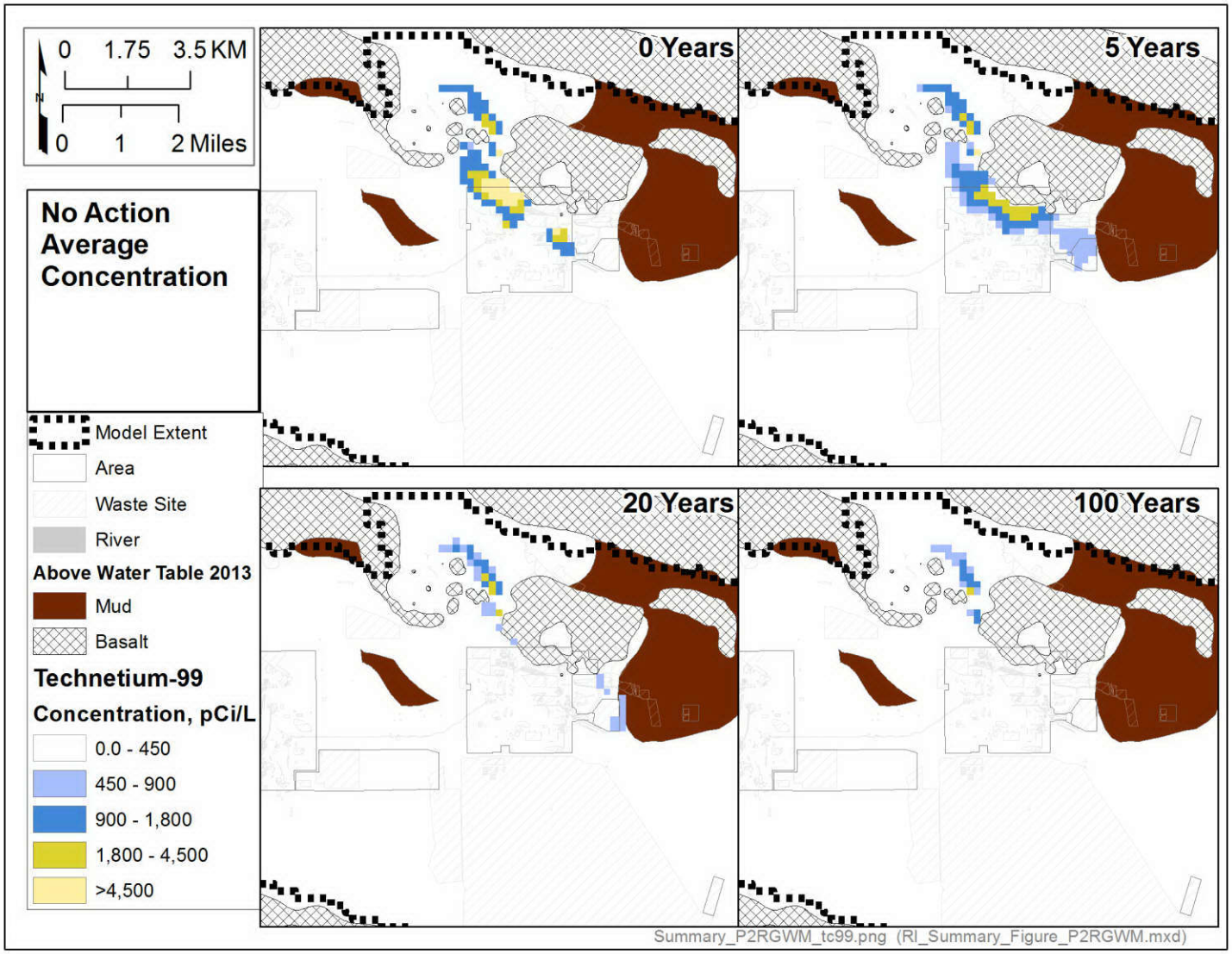


Figure 5-11. Base Case Technetium Plume Evolution

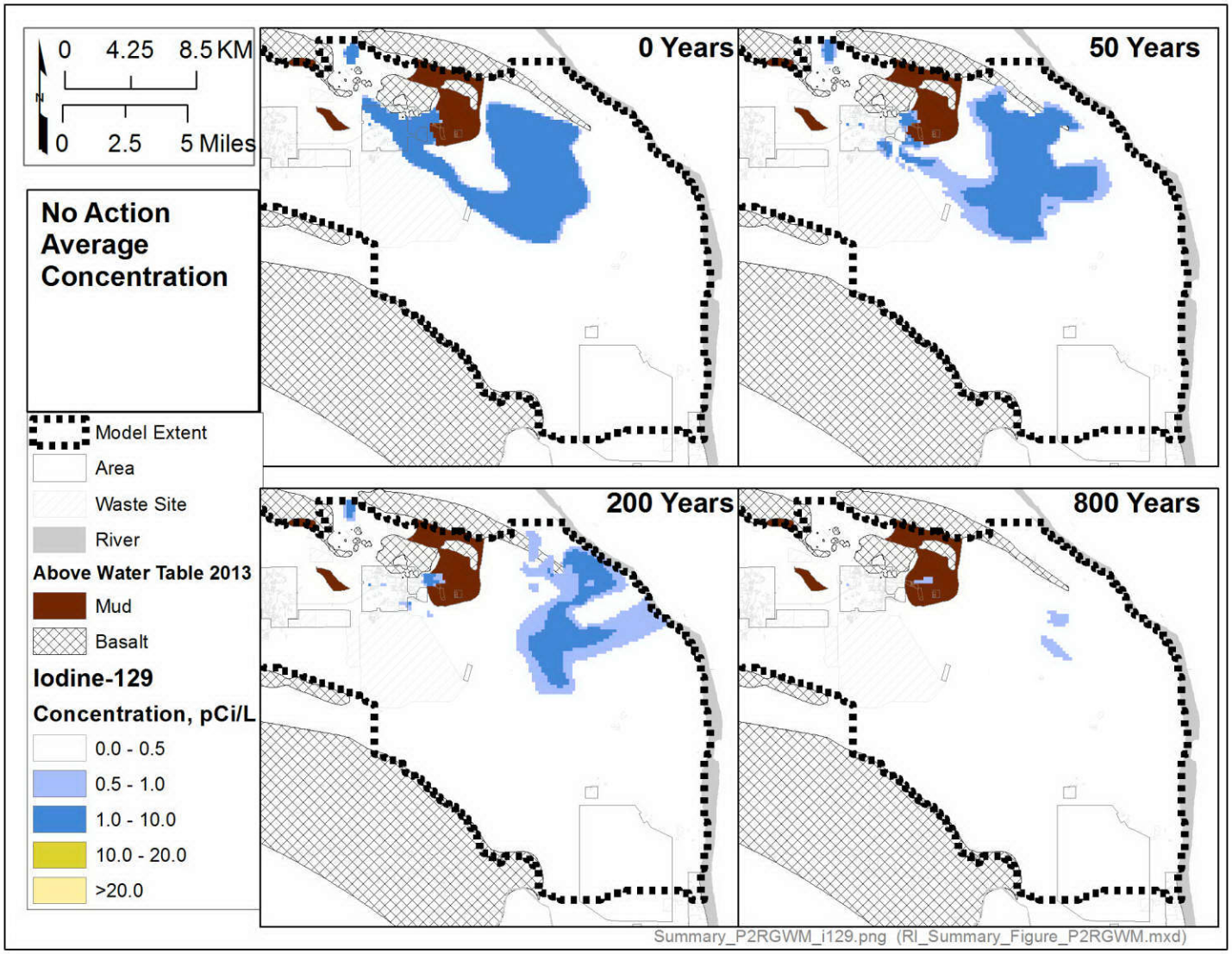


Figure 5-12. Base Case Iodine-129 Plume Evolution

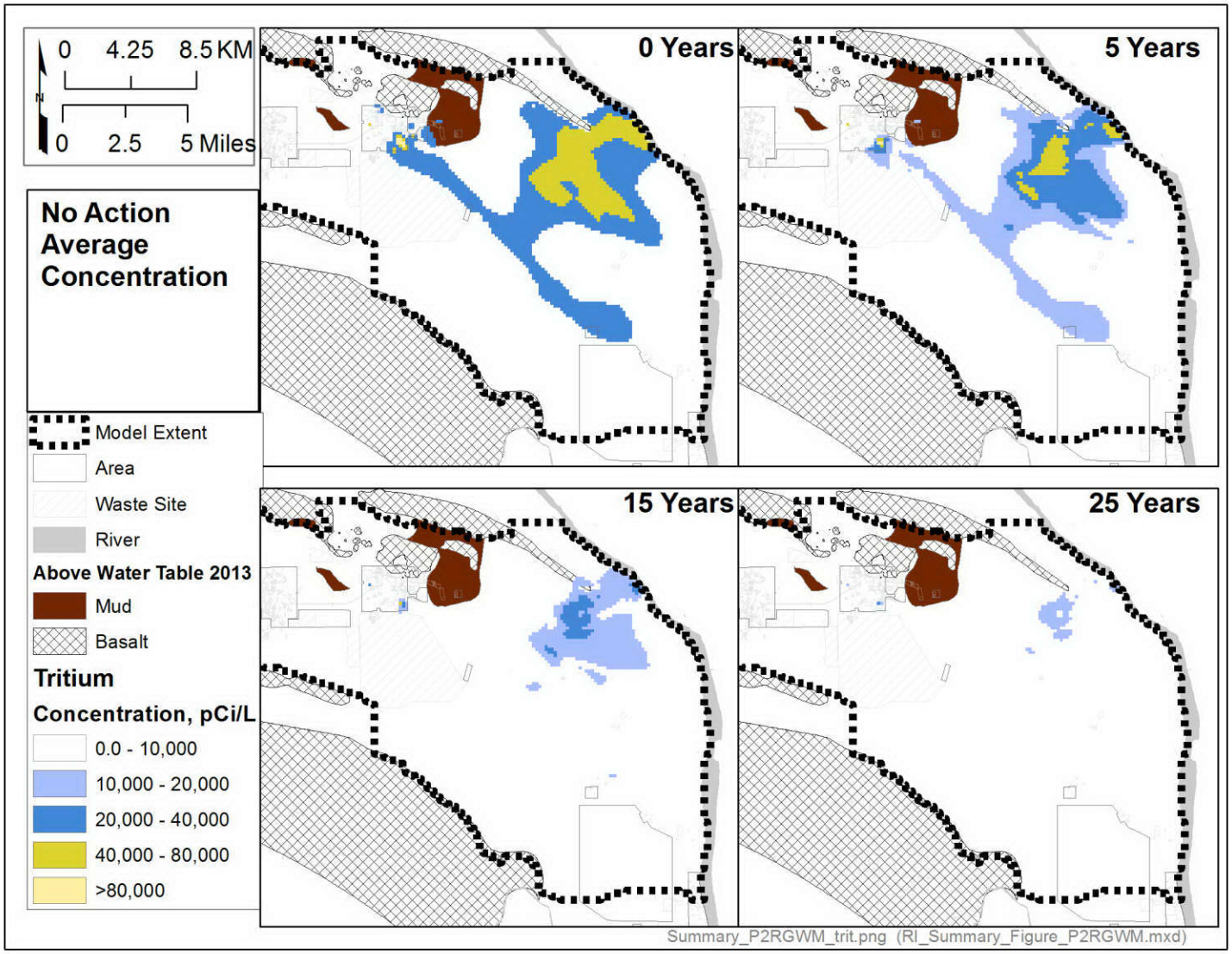


Figure 5-13. Base Case Tritium Plume Evolution

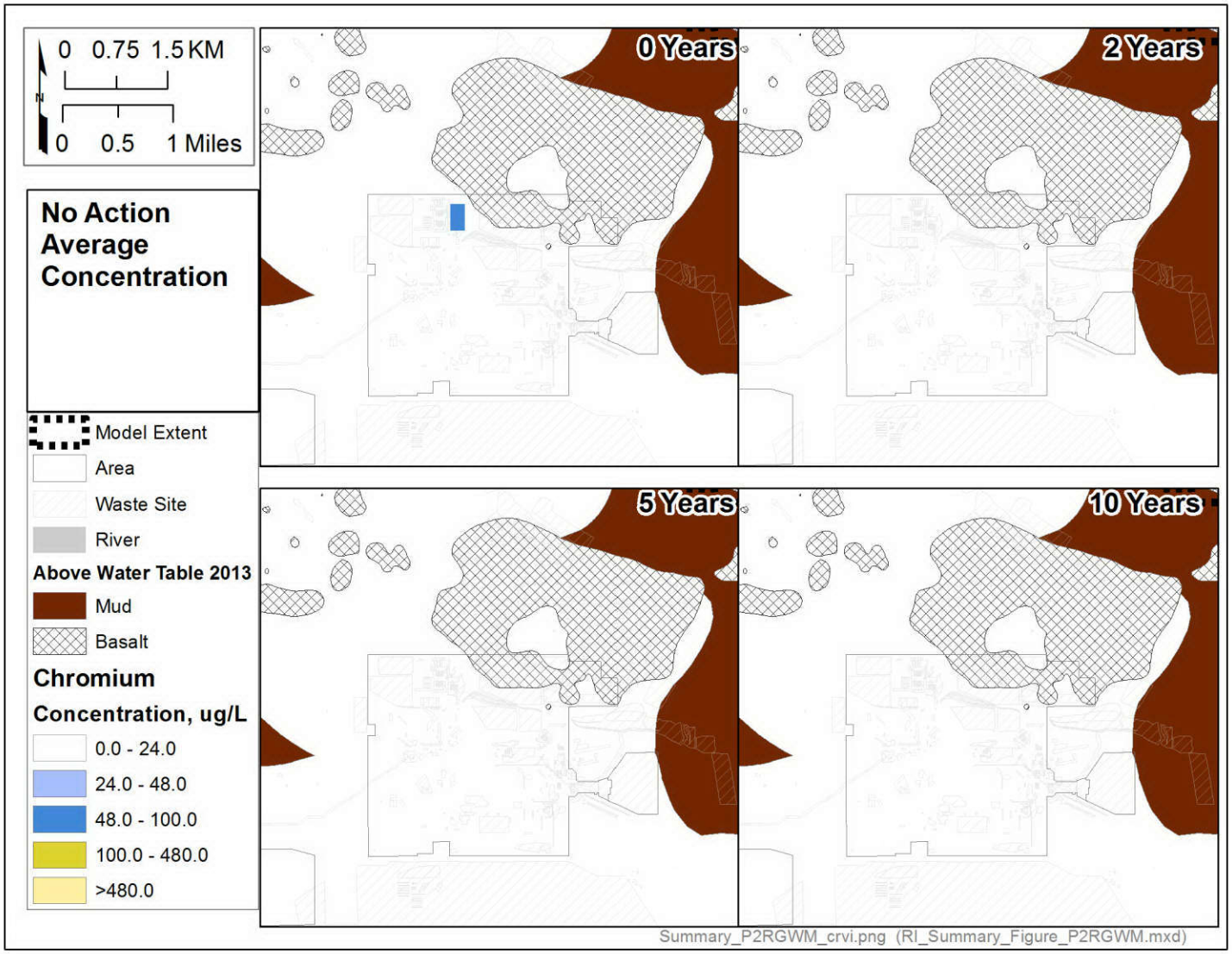


Figure 5-14. Base Case Cr(VI) Plume Evolution

Table 5-11. Base Case 200-BP-5 OU Cleanup Times

Initial Condition	Continuing Sources	TEDF	COPC	Cleanup Time* (yr)
Average	No	No	Cyanide	550
			Nitrate	600
			Uranium	65
			Strontium-90	115
			Technetium-99	800
			Iodine-129	450
			Tritium	16
			Cr(VI)	0.2

* Cleanup time as measured by the C_{90} statistic.
COPC = contaminant of potential concern
Cr(VI) = hexavalent chromium
TEDF = Treated Effluent Disposal Facility

1

Table 5-12. Comparison of Cleanup Times for Average Initial Condition Scenarios

Scenario Group	Cleanup Time* (yr)							
	Cyanide	Nitrate	Uranium	Strontium-90	Technetium-99	Iodine-129	Tritium	Cr(VI)
Base case	550	600	65	115	800	450	16	0.2
TEDF	400	600	75	115	850	550	16	0.2
Continuing source	N/A	>1,000	325	N/A	>1,000	N/A	N/A	N/A
TEDF and continuing source	N/A	600	325	N/A	800	N/A	N/A	N/A

* Cleanup time as measured by the C_{90} statistic.
Cr(VI) = hexavalent chromium
N/A = not applicable
TEDF = Treated Effluent Disposal Facility

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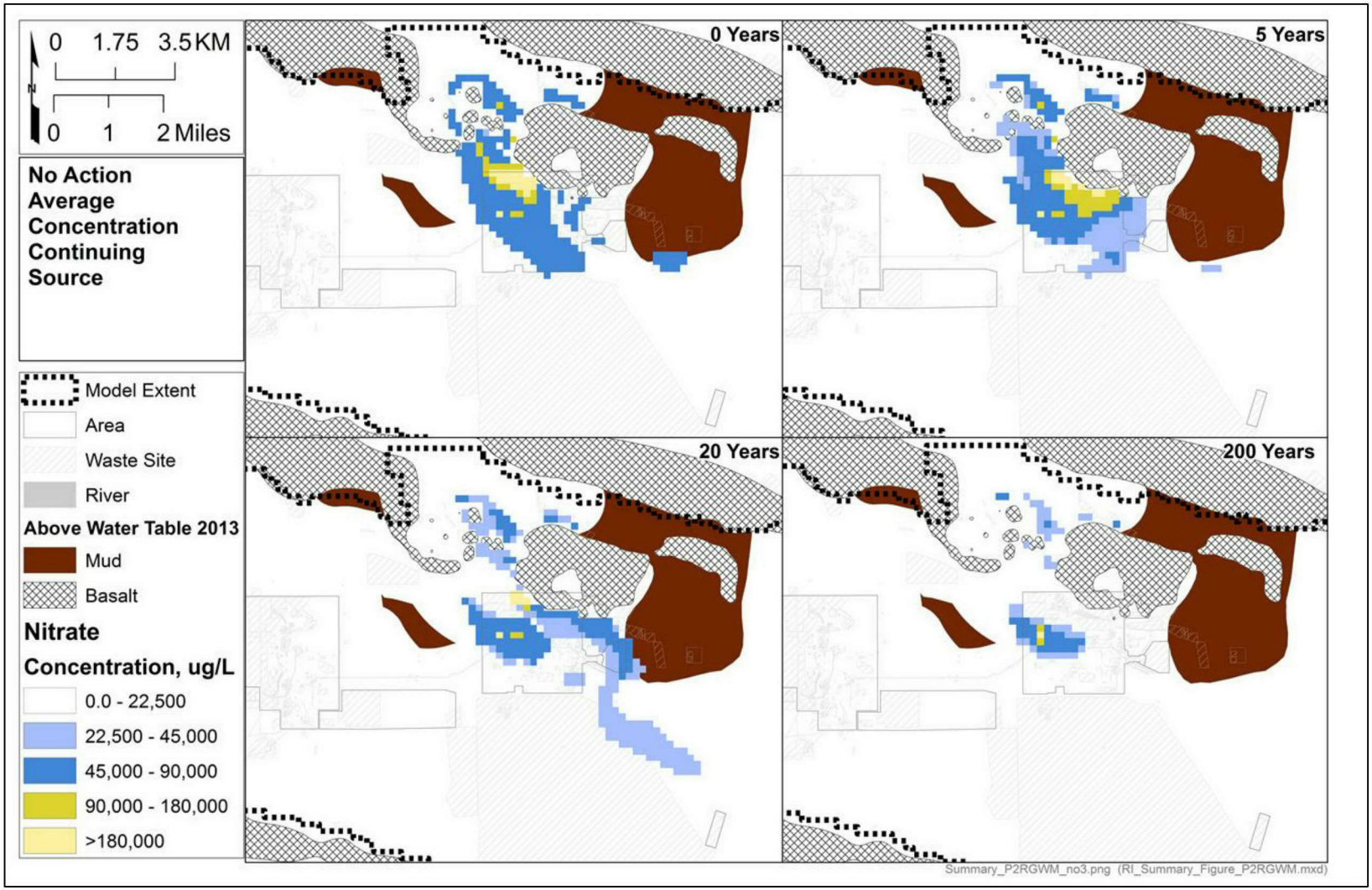

Figure 5-15. Continuing Source Nitrate Plume Evolution

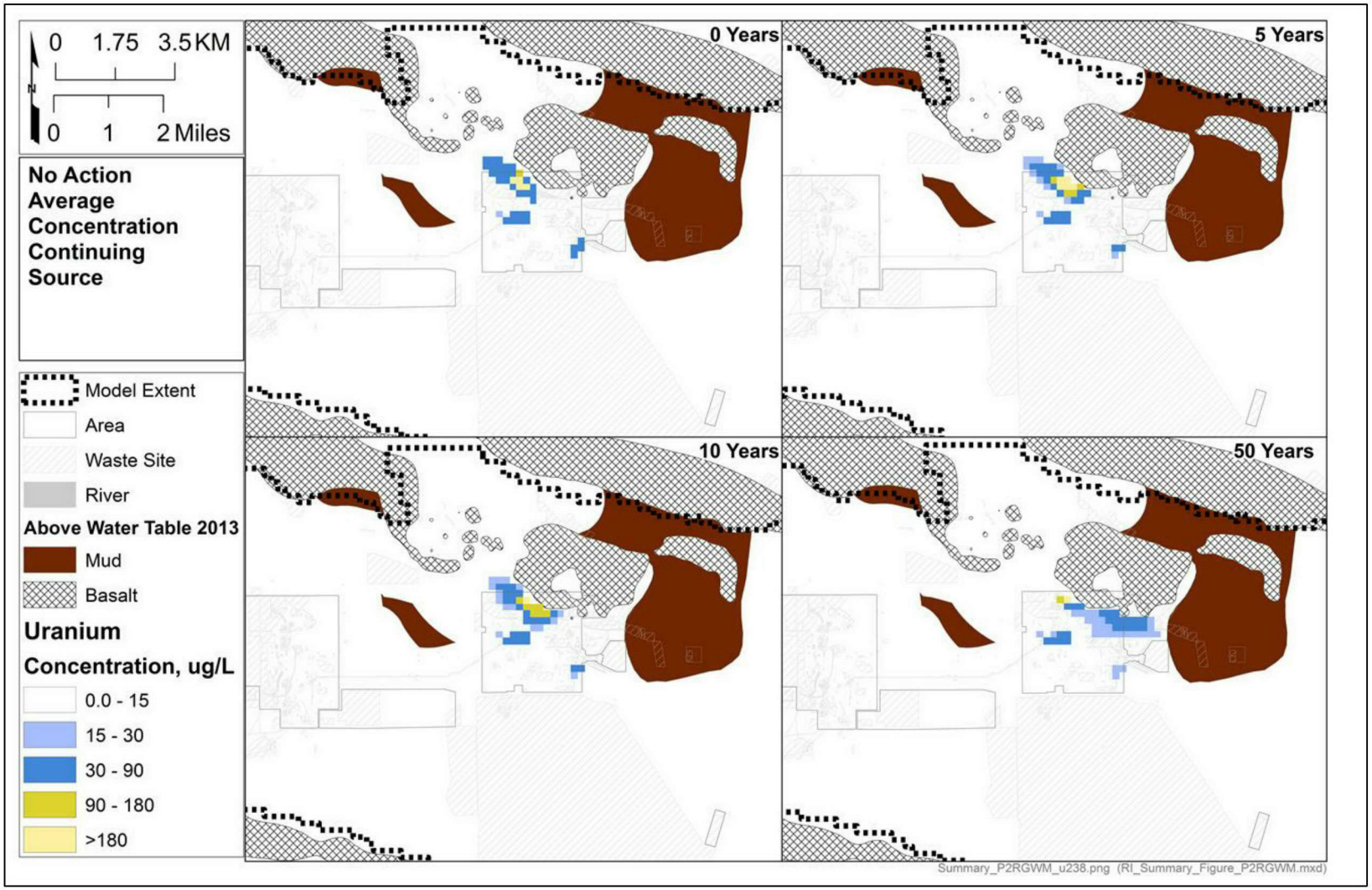

Figure 5-16. Continuing Source Uranium Plume Evolution

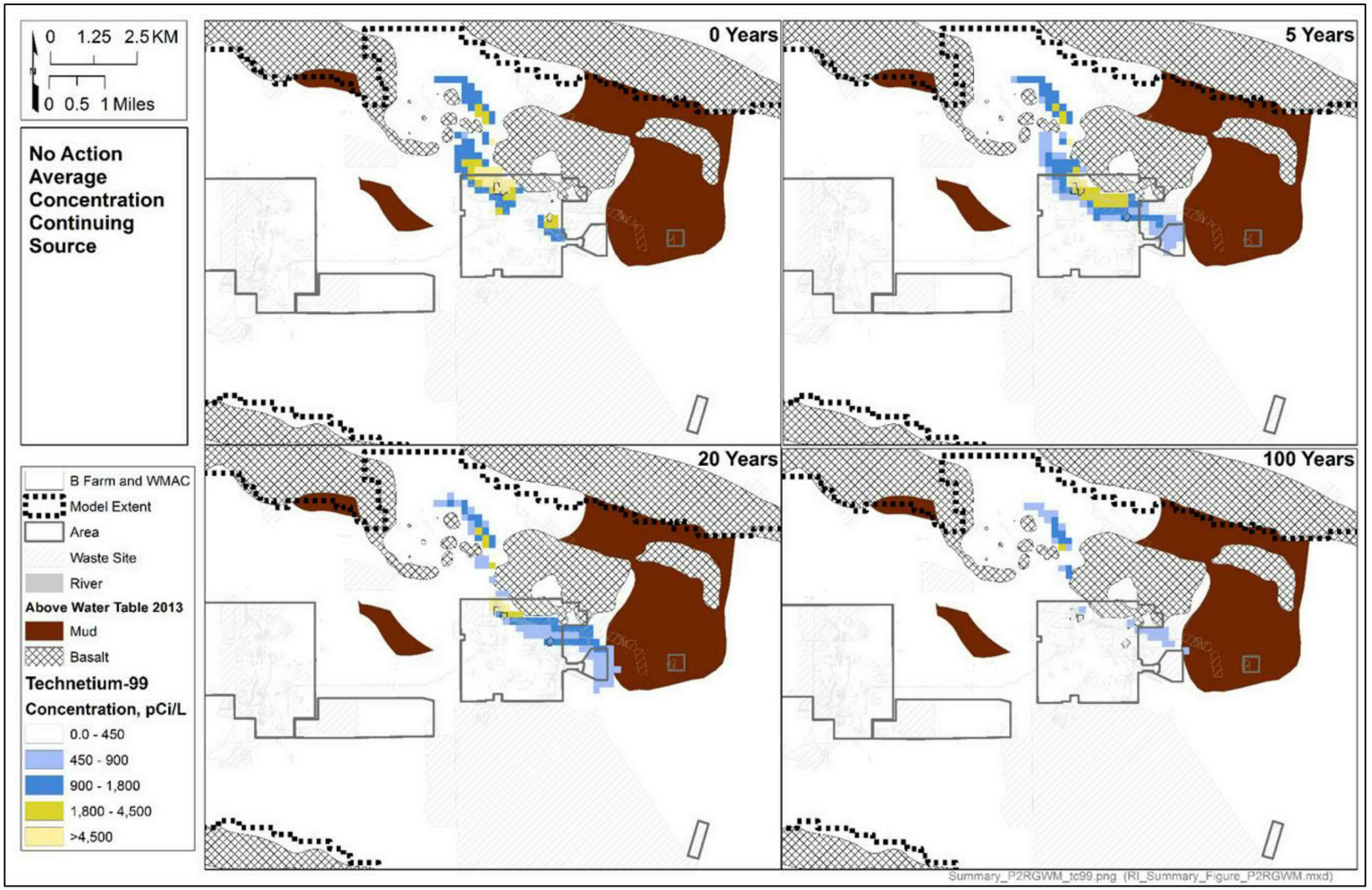

Figure 5-17. Continuing Source Technetium-99 Plume Evolution

Table 5-13. Comparison of Cleanup Times for Maximum Initial Condition Scenarios

Scenario Group	Cleanup Time* (yr)							
	Cyanide	Nitrate	Uranium	Strontium-90	Technetium-99	Iodine-129	Tritium	Hexavalent Chromium
Base Case	550	>1,000	950	180	>1,000	600	21	0.8
Treated Effluent Disposal Facility	425	>1,000	260	180	>1,000	600	22	0.8
Continuing Source	N/A	>1,000	1,000	N/A	>1,000	N/A	N/A	N/A
Treated Effluent Disposal Facility and Continuing Source	N/A	>1,000	1,000	N/A	>1,000	N/A	N/A	N/A

* Cleanup time as measured by the C_{90} statistic.

N/A = not applicable

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6 Baseline 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) quote 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) then continue to clarify when a CERCLA remedial action is appropriate:

> *A CERCLA remedial action generally is appropriate*[1] *in various circumstances, including: a 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 RME for both current and future land use;*[2] *the noncarcinogenic hazard index (HI) is greater than one (using RME assumptions for either the current or reasonably anticipated future land use); or the site contaminants cause adverse environmental impacts.*[1] *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 reasonable maximum exposure (RME) assumptions for either current or future land use exceeds the 10^{-4} excess lifetime cancer risk (ELCR) end of the risk range.[3]
- For groundwater actions, MCLs and nonzero MCLGs will generally be used to gauge whether remedial action is warranted.
- Chemical-specific standards that define acceptable risk levels also may be used to determine whether an exposure is associated with an unacceptable risk to HHE and if remedial action is warranted.

As stated in 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

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[1] See EPA 540-R-97-013, *Rules of Thumb for Superfund Remedy Selection*.

[2] See Clay, 1991, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions."

[3] This risk range is also intended for groundwater actions that are based on returning the groundwater to its highest beneficial use.

compared to the 10^{-4} risk range for radionuclides, the 10^{-5} risk range for hazardous chemicals, and a hazard index (HI) of 1 for noncancer hazards.

Additionally, human health protection was evaluated in Chapter 4 by comparing individual groundwater measurements within the groundwater OU to existing federal or state MCLs or nonzero MCLGs. Individual groundwater measurements were also compared to 2007 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 are used to identify COPCs for which remedial action is warranted.

Aquatic receptor protection was evaluated in Chapter 4 by comparing groundwater concentrations at the point of discharge to the AWQC established under Section 304 or Section 303 of the CWA, as well as Washington State surface water quality standards. The point of compliance for surface water cleanup levels is defined in 2007 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 2007 MTCA (WAC 173-340-730(7)(b)) criteria indicate that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels. 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 Columbia River Component (CRC) (DOE/RL-2010-117, *Columbia River Component Risk Assessment Volume I, Parts 1 & 2: Screening-Level Ecological Risk Assessment*; and *Volume II, Parts 1 & 2: Baseline Human Health Risk Assessment*) included an ecological risk assessment that combines both screening and baseline elements. The CRC (DOE/RL-2010-117) concluded that seven contaminants of ecological concern (COECs) were within sediment, pore water, island soil, and shoreline sediment (aluminum, chromium, Cr(VI), lead, manganese, nickel, and nitrate). Groundwater concentrations from monitoring wells within the 200-BP-5 OU located closest to the river were evaluated to determine if these COECs were present 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:

- Individual groundwater measurements are compared to 2007 MTCA (WAC 173-340-720) to determine if individual measurements are greater than cleanup levels based on a target HI greater than or equal to 1.
- Individual measurements are also compared to 2007 MTCA (WAC 173-340-720) to determine if individual measurements are greater than cleanup levels based on a target risk level of 1 in 1,000,000 (1×10^{-6}).
- Cumulative cancer risks and noncancer hazards for chemicals based on the results of the EPA tap water (residential) scenario are compared to 2007 MTCA (WAC 173-340-708(5)(a), "Human Health Risk Assessment Procedures" [hereafter referred to as MTCA HHRA Procedures]) cumulative cancer and noncancer hazard thresholds.
- 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 for cumulative carcinogenic site risk to an individual based on RME to return groundwater to its highest beneficial use.

EPA guidance clarifies the relationship between two statutory mandates of CERCLA: (1) protect HHE; and (2) attain or waive applicable or relevant and appropriate requirements (ARARs), if justified, based on site-specific circumstances (Fields, 1997a, "Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA"). It remains EPA's policy that ARARs will generally be considered protective, absent multiple contaminants or pathways of exposure. However, the guidance clarifies that, in rare situations, even absent multiple pathways or contaminants, preliminary remediation goals should be set at levels more protective than required by a given ARAR, where application of the ARAR would not protect HHE.

The results presented in Section 4.5 (evaluation of measured groundwater concentrations) indicate that individual concentrations of 15 contaminants in the 200-BP-5 OU exceed action (screening) levels that are listed in Table 4-7. The residential tap water scenario also identifies multiple contaminants within the exposure areas and 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 WAC 173-340-708(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 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, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment*) have provided exposure scenarios. A quantitative groundwater 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-Hanford-13-0036, *Native American Risk Assessment for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* (provided in Appendix G). Section 6.5.5.1 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. This comparison is provided because the Native American scenarios and the EPA tap water scenario include the same exposure pathways and exposure routes but have different exposure assumptions. The EPA tap water scenario includes RME assumptions, whereas the Native American scenarios include high-end exposure assumptions. The Native American scenarios are discussed in more detail in Section 6.5.5.1. The results of the comparison show how the similarities and differences that result in use of RME and high-end assumptions. The results of the tap water risk assessment are provided in ECF-Hanford-13-0035, *Tap Water Risk Assessment for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* (provided in Appendix G).

6.1 Data Analysis

This section describes the sources of data used in the risk assessment (Section 6.1.1), the DQA and data validation process (Section 6.1.1.1), and the process used to identify COPCs in groundwater that could be used as a resource for potential human exposures (Section 6.1.2). During this risk assessment, analytes were evaluated to identify COPCs and to prioritize those estimated to pose an unacceptable risk and warrant evaluation in the FS.

6.1.1 Sources of Analytical Data Used in Risk Assessment

This groundwater risk assessment includes groundwater samples collected and analyzed using the methods documented in the work plan, SAP, and other documents listed as follows:

- DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*
- DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*
- DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*
- DOE/RL-2008-60, *Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*
- DOE/RL-2009-75, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*
- DOE/RL-2009-76, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*
- DOE/RL-2009-77, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*
- DOE/RL-2012-35, *First Determination RCRA Groundwater Quality Assessment Plan for Low-Level Burial Grounds Low-Level Waste Management Area-1*
- DOE/RL-2012-53, *Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area B-BX-BY*

The groundwater data set collected for the RI consists of sampling and analysis data collected from 161 monitoring wells within the 200-BP-5 OU. A list of the monitoring wells is provided in Appendix G, Table G-8. With the exception of 16 monitoring wells that are screened in the confined aquifer, the remaining 145 monitoring wells are screened in the unconfined aquifer. The monitoring 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.

The data set contains the analytical results from groundwater samples collected during the 6-year period from January 1, 2008, through December 31, 2013. However, several groundwater samples were collected in January 2014 and are included in this data set. Sampling and analysis activities for this data set were performed in accordance with the requirements in the 200-BP-5 RI work plan (DOE/RL-2007-18) and SAP (DOE/RL-2001-49), which have been approved by the Tri-Parties and have undergone a series of revisions and modifications over time.

6.1.1.1 Data Quality Assessment and Data Validation

All sampling and analysis data are included in the HEIS database. To support the use of the data in the RI/FS process, the data were downloaded from the HEIS database and validated through a supplemental DQA process. The results of the DQA are documented in the supplement to the DQA report (SGW-56758), and the DQA includes the January 2014 samples. The objective of the DQA was to determine whether the data can support the BRA and the selection of remedial alternatives for the 200-BP-5 OU.

The DQA assesses the laboratory data for groundwater samples obtained from 161 wells in the 200-BP-5 OU for the period from January 2008 to December 2013. The DQA process follows general

DQA guidelines established in EPA/240/B-06/002 and EPA/240/B-06/003. The 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. The supplemental DQA document served as the source of the analytical data used for this risk assessment.

6.1.1.2 Analytical Data Processing

The groundwater data set used for COPC identification includes the analytical results from samples collected from 161 monitoring wells (Appendix G, Table G-8). In total, 145 monitoring wells are screened in the unconfined aquifer, and 16 monitoring wells are screened in the confined aquifer. Note that in the 200-BP-5 OU, Well 299-E24-25 is assigned to two exposure areas: B Plant and Semiworks. Figure 6-1 shows the locations of the 161 wells included in the BRA.

Using the validated data set described in Section 6.1.1.1, the analytical data were processed to obtain a single set of results per sampling location and time of collection.

Following data validation, the data set contained a total of 160,285 records and 379 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 exposure point concentrations (EPCs) contained a total of 63,747 records and 65 analytes. The data-processing steps and the numbers of records associated with each step are presented in Figure 6-2. The validated data set 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 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 to support other monitoring or compliance programs are excluded. 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). Note that the filtered metal results are included in the near-river area data set. Filtered metals are included for comparison of groundwater concentrations to state surface water quality standards and federal AWQC used to determine if concentrations could impact aquatic receptors.

Additionally, a limited number of measurements are available for Cr(VI) relative to the number of total chromium (unfiltered and dissolved) measurements. It has been determined that filtered total chromium concentrations effectively represent Cr(VI) (WHC-SD-EN-TI-302, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*). As a result, the filtered total chromium concentrations are used as a surrogate to estimate exposure from Cr(VI). Additional discussion regarding the use of filtered total chromium concentrations as a surrogate for Cr(VI) is discussed in Section 6.5.1.2.

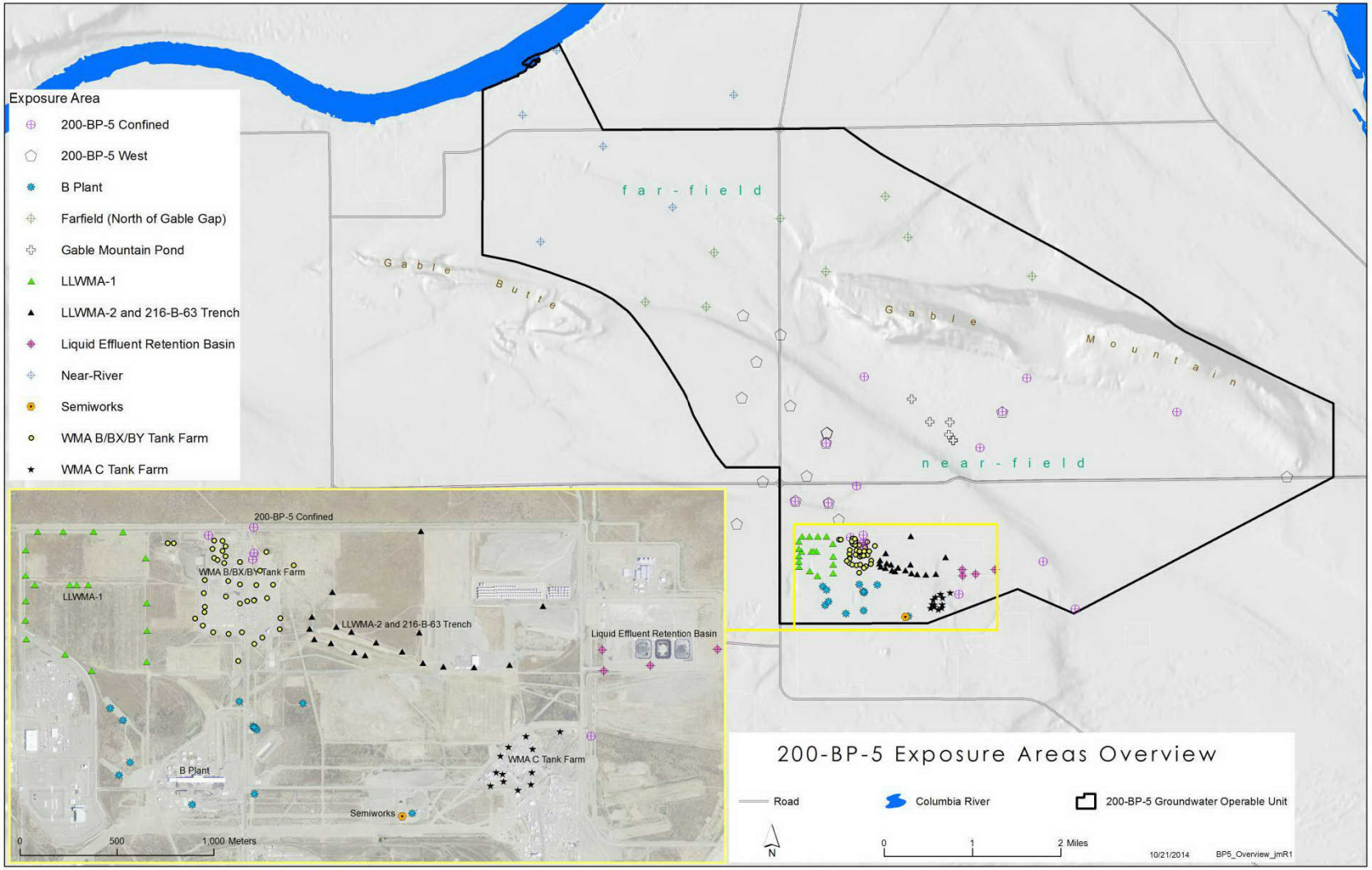

Figure 6-1. Exposure Areas and Associated Monitoring Wells for the 200-BP-5 OU

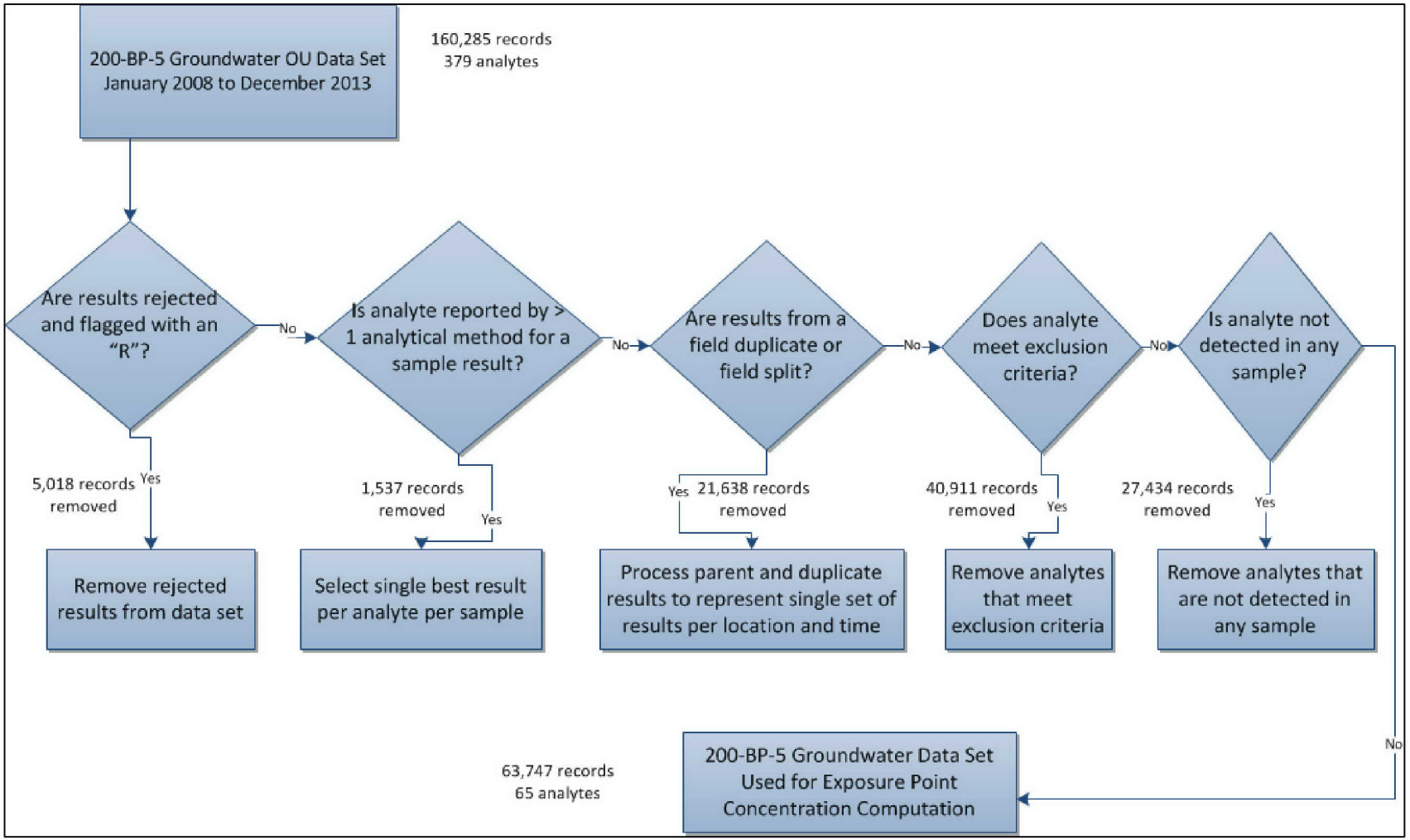

Figure 6-2. Data Processing and Reduction Steps for the 200-BP-5 OU Data Set

EPA risk assessment guide (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*) addresses this issue in providing guidance on estimating exposure concentrations in groundwater:

> *While filtration of groundwater 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.*

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/or qualified sample results are used to calculate the EPCs. Data flags include "U" to indicate analyzed for but not detected above limiting criteria, "J" to indicate an estimated value, and "R" to indicate do not use (further review indicates the result is not valid).

- Sample results flagged with a "U" data qualifier or combinations of qualifiers that include a "U" (e.g., "UJ") are considered nondetected results.
- Sample results without a "U" data qualifier are considered detected concentrations, including results with no qualifier or with a "J" data qualifier.
- Sample results that are rejected and flagged with an "R" validation qualifier are not used in identifying COPCs.

Analytes Reported by Numerous Analytical Methods

Analytes are often 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 data set that best represents the actual concentration will be 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, method sensitivity, and detection limits. The most conservative (i.e., protective of health) 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 of 2 µg/L, or EPA Method 6010 in SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, with an estimated quantitation limit of 50 µg/L. For a sample with lead concentrations reported using both methods, the results reported by EPA Method 200.8 (EPA-600/R-94/111) are selected over EPA Method 6010 (SW-846) because of the more sensitive detection limit.

Field Duplicate and Field Split Results

Field quality control (QC) samples (field duplicates) are collected in the field and are analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (e.g., 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 and 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.

6.1.2 Identification of Contaminants of Potential Concern

For the purposes of this groundwater risk assessment, a COPC is defined as an analyte suspected of being associated with site-related activities that represent a potential threat to HHE, and whose data are of sufficient quality for use in a quantitative BRA.

After extracting and processing the data set, the data set is further reduced by identifying a subset of analytes (COPCs) that will be processed through ProUCL to calculate the UCL (described in Section 6.2.4) and then will be included in the risk characterization step of the risk assessment (Section 6.4). Analytes that meet exclusion criteria or were not detected in any of the groundwater samples analyzed within the 200-BP-5 OU are not carried forward for the statistical calculations and EPC selection. The analyte identification steps and the number of records associated with each of the steps are presented in Figure 6-2.

6.1.2.1 Apply Exclusion Criteria

The first step to identify analytes for UCL calculation is to apply certain exclusion criteria. Analytes that met one or more of the exclusion criteria were eliminated. The eliminated analytes are listed in Appendix G, Table G-9. Analytes that did not meet any of the exclusion criteria were carried forward into the next step. The exclusion criteria include the following:

- Naturally occurring radionuclides associated with background radiation
- Radionuclides that have half-lives of less than 3 years and are not significant daughter products
- Essential nutrients (minerals)
- Analytes without known toxicity information

Seven naturally occurring radionuclides associated with background radiation (potassium-40, radium-226, radium-228, thorium-228, thorium-230, thorium-232, and total alpha energy emitted from radium) were measured in groundwater from the 200-BP-5 OU and were eliminated.

Radioisotopes with half-lives less than or equal to 3 years are eliminated from further consideration because only a small fraction of their original activity remains after 30 years of decay since operations have ceased. Four radioisotopes met this exclusion criterion (antimony-125, beryllium-7, cesium-134, and ruthenium-106). Cesium-134 and ruthenium-106 were not detected in any groundwater sample, and antimony-125 and beryllium-7 were detected in a single sample. Additionally, these isotopes are not significant daughter products associated with a decay chain.

Essential nutrients are those analytes considered essential for human nutrition. The essential nutrients calcium, magnesium, potassium, and sodium were detected in samples in the 200-BP-5 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, 81 analytes were eliminated from further consideration.

Identify Nondetected Analytes

The next step in identifying analytes for UCL calculation 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) were eliminated. All analytes detected at least once were carried forward to the next step.

In total, 197 analytes were not detected in samples from the 200-BP-5 OU. These analytes are listed in Appendix G, Table G-10, with the sampling dates and both minimum and maximum detection limits.

6.1.3 Evaluation Processes for Contaminant of Potential Concern Identification

The identification of groundwater COPCs that warrants evaluation of remedial alternatives in the FS for the 200-BP-5 OU is a three-step process. Analytical measurements from groundwater data collected over the past 6 years were evaluated using the following strategy:

1. Compare individual measurements from the 6-year data set to action levels (provided in Section 4.5.1.1, Tables 4-6 and 4-7) to identify COPCs throughout the 200-BP-5 OU (Figure 6-3). This analysis was performed (as discussed in Chapter 4) 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 summarized in this chapter (Section 6.7).

2. Calculate cumulative ELCR and noncancer hazards using EPCs from the 6-year data set based on the EPA residential tap water scenario (Figure 6-4). 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 risk and hazard drivers within each exposure area identified. The results of this evaluation are provided in Section 6.4.4.

3. Calculate the sum of fractions and 4 mrem/yr dose equivalent 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. The results of this evaluation are provided in Section 6.4.4.

The exposure assessment, including the methodology used to calculate EPCs, is discussed in Section 6.2, and the toxicity assessment is presented in Section 6.3. Section 6.4 describes the risk characterization step for the EPA tap water scenario and calculation of cumulative annual dose.

6.2 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:

- Contaminant source (or release point)
- Mechanism of chemical release
- Environmental transport mechanism
- Exposure point

- Exposure route
- 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.[4] Figure 6-5 schematically presents the exposure pathway analysis in the form of a human and ecological CEM.

6.2.1 Contaminant Release Points

The main CERCLA sites monitored in the 200-BP-5 OU for contributions to groundwater include the following: (1) B Pond and Gable Mountain Pond, (2) BY Cribs and proximal waste sites, (3) 216-B-5 Injection Well, and (4) B Plant waste sites (including the 216-B-9, 216-B-12, and 216-B-62 Cribs). The main RCRA sites monitored are as follows: (1) SST farms at WMA B-BX-BY and WMA C, (2) LLWMA-1 and LLWMA-2, (3) LERF, (4) 216-B-63 Trench, and (5) 216-B-3 Pond. A detailed description of the sources of groundwater contamination is provided in Section 4.2.

Solid waste materials disposed to ground (e.g., dumps, pits, or burial grounds) are generally not considered to have impacted groundwater at this time. Those waste materials were not disposed along with large volumes of water or wastewater and are not expected to affect groundwater in the future.

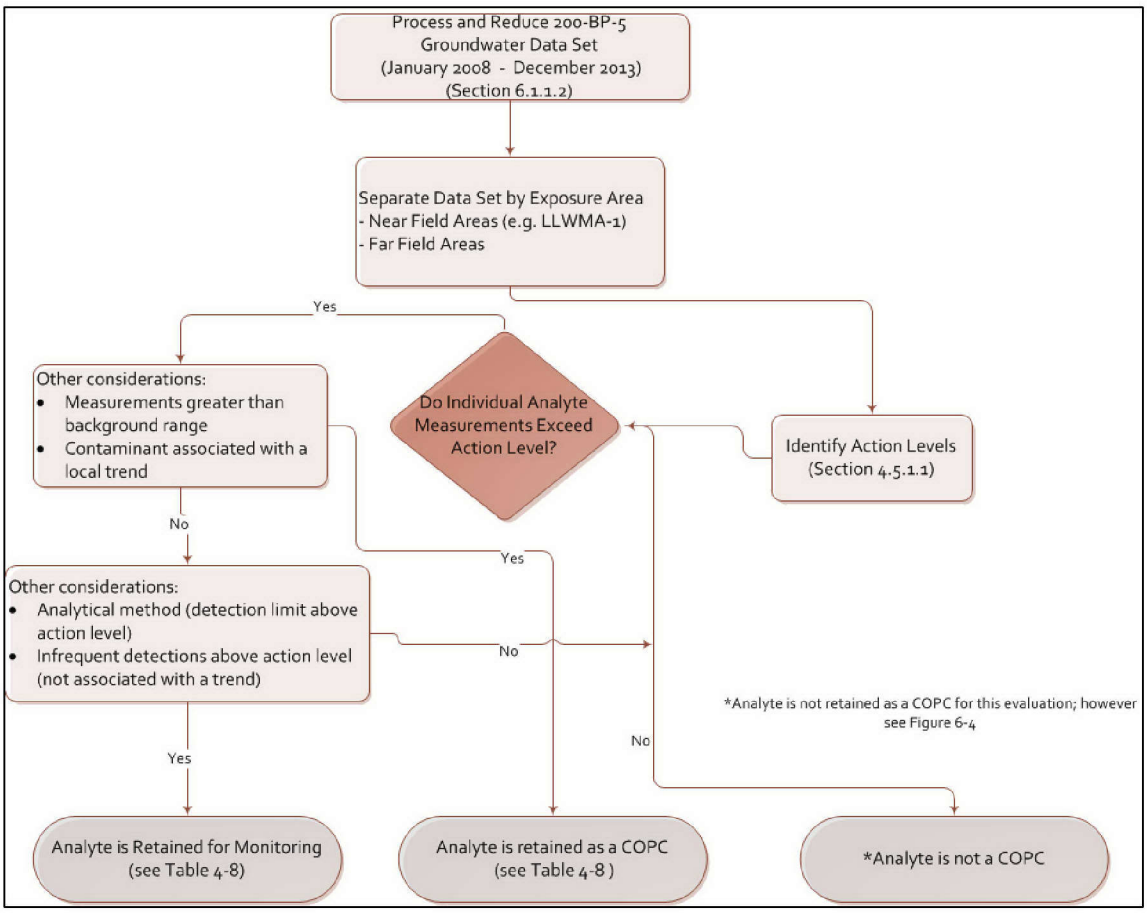

Figure 6-3. Individual Contaminant Evaluation Process

[4] 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.

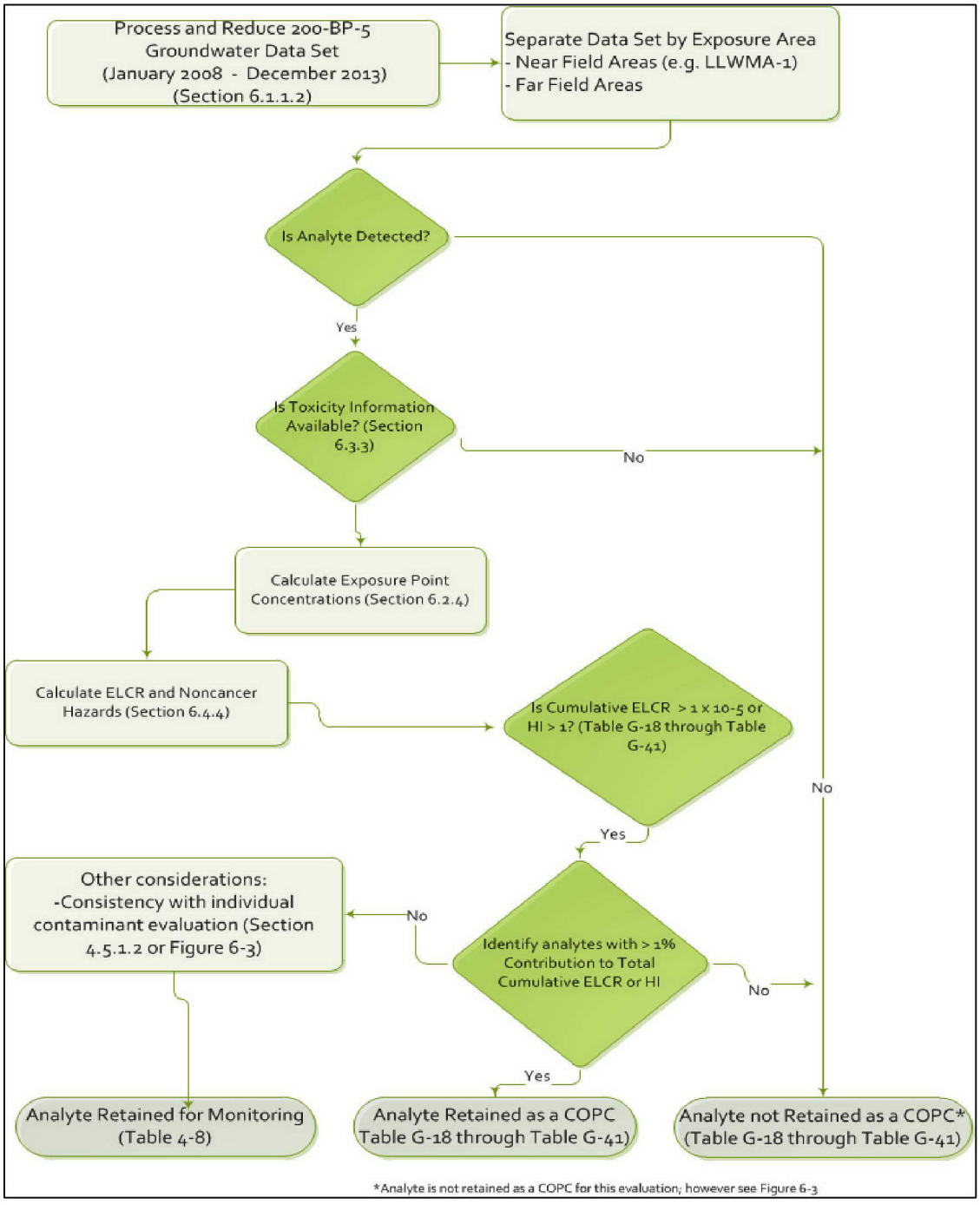

Figure 6-4. EPA Tap Water Scenario Risk Assessment Process

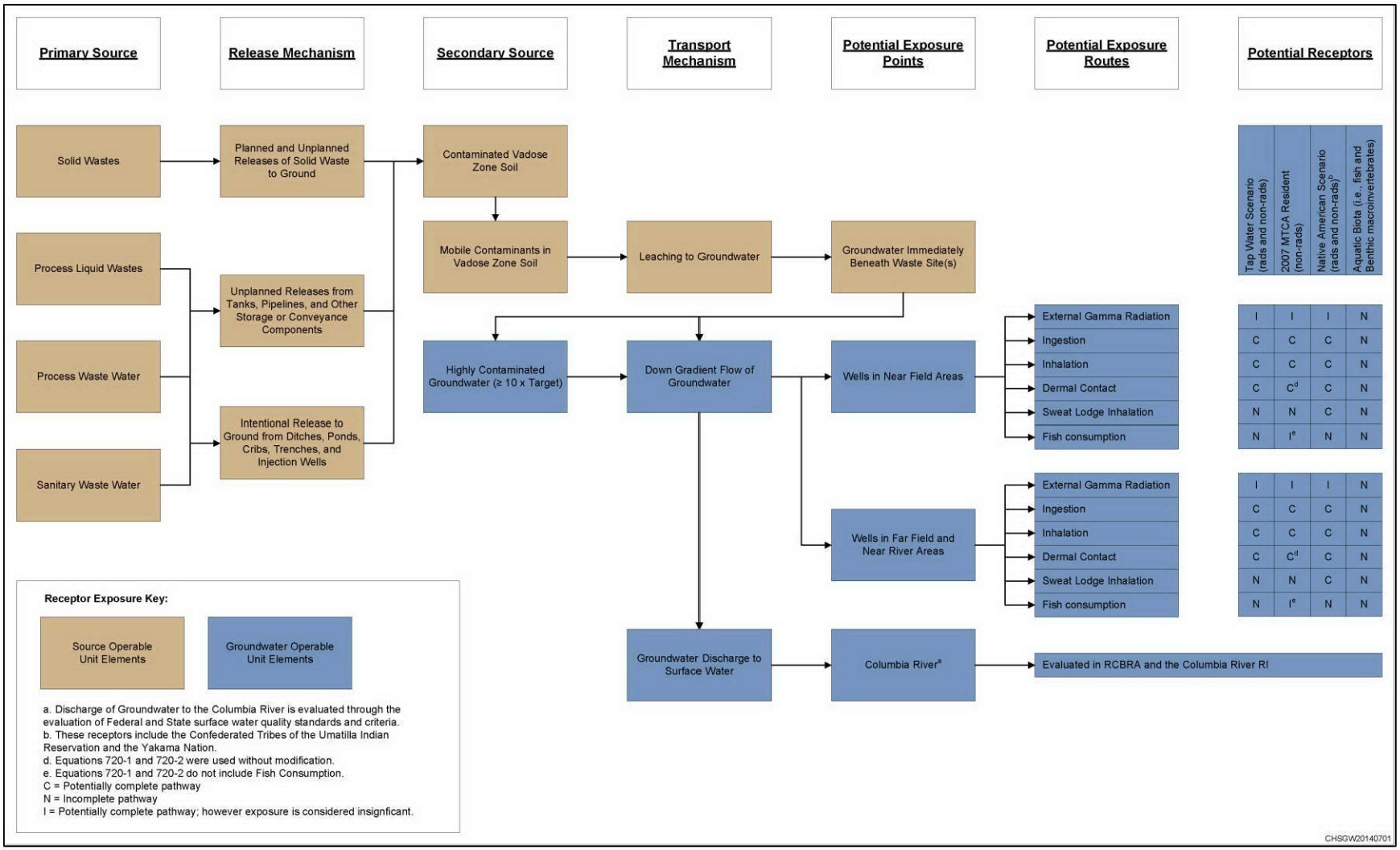

Figure 6-5. CEM for Potential Human Health and Ecological Receptors

6.2.2 Release Mechanisms and Environmental Transport Medium

The primary COPC release mechanisms and transport pathways evaluated include the following:

- Direct contact with groundwater containing COPCs
- Volatilization of COPCs in groundwater from showering or household activities
- Discharge of groundwater to the Columbia River through upwelling and seeps

The contaminants observed in groundwater within the OU resulted from release of process liquid waste and wastewater to the soil via discharge to engineered structures (e.g., cribs, trenches, ditches, ponds, leach fields, or injection wells) in the case of intentional releases. Unintentional (i.e., unplanned) releases typically resulted from inadvertent releases of the same (or similar) waste materials from tanks, pipelines, or other waste storage or conveyance components. Most of the liquid waste and wastewater that contributed to groundwater contamination entered the soil column directly and migrated downward through the soil column by gravity to reach underlying groundwater.

Upon entering the groundwater at the water table, contaminants migrate in a downgradient direction away from the point of entry. Groundwater flow directions within the OU have varied substantially over the period of historical Hanford Site operations, along with observed flow reversals in recent years influenced by Columbia River stage fluctuations. The hydraulic gradients are extremely small in this area, and determining the predominant flow direction is sometimes challenging. As discharge of large volumes of wastewater to surface infiltration ponds within the 200 East Area continued, substantial groundwater mounds developed; groundwater then flowed radially away from these mounds in all directions. When these large-volume discharges ceased in the 1990s, the mounds began to dissipate and flow directions began to return to a more natural condition. The groundwater flow system has not yet returned to a natural state; however, there is little evidence of the historical radial flow associated with the groundwater mounds within the OU. The predominant groundwater flow direction during and after the operational period has generally been northwest and southeast. Section 5.1 provides additional descriptions of the processes that affect contaminant migration within the affected aquifer.

6.2.3 Potentially Complete 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 near-field or far-field areas. Groundwater that discharges to the Columbia River adjacent to the OU is not used as a source of potable water. Discharge of contaminated groundwater does present a potential for exposure pathway of aquatic receptors to groundwater contamination.

The 200-BP-5 OU is divided into two primary areas: the near-field area and the far-field area. The portion of the OU lying to the south of the Gable Butte, Gable Mountain, and Gable Gap area is considered the near-field area because of proximity to contaminant sources. The near-field area was divided into nine separate exposure areas for wells screened in the unconfined aquifer including LLWMA-1, LLWMA-2 and the 216-B-63 Trench, WMA B-BX-BY Tank Farms, WMA C Tank Farm, B Plant, Semiworks, LERF, Gable Mountain Pond, and 200-BP-5 west. These exposure areas represent groundwater located near known or suspected plume sources. The near-field area also has one exposure area for wells screened in the confined aquifer. Note that the confined aquifer exposure area refers to the upper basalt-confined aquifer composed of interbeds in the Columbia River Basalt Group (Section 3.6.1).

The far-field area is divided into two exposure areas, including the far-field exposure area and the near-river exposure area. The far-field area represents downgradient plume conditions north of Gable Gap to the Columbia River. The near-river exposure area is identified by conditions observed in groundwater monitoring wells that are closest to the Columbia River (distances range between 72 and 3,500 m

[236 and 11,500 ft] from the river). Four of the seven wells selected to evaluate near-river conditions are greater than 1,000 m (3,280 ft) from the river. The wells in this exposure area are the closest in proximity to the river and also within the 200-BP-5 OU boundary. The primary objectives for evaluating each exposure area are to provide information necessary to determine the need for remedial action and to use this information to select the best remedy.

Potential human receptors are assumed to be hypothetical future domestic 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.

Potential routes of exposure to human receptors from groundwater contaminants in the near-field and far-field exposure areas 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 from radioactive contaminants in groundwater

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 is provided in Section 6.2.3.1.

The Columbia River, which forms a discharge boundary for groundwater within the 200-BP-5 OU, represents a potentially complete exposure pathway to both human receptors and aquatic ecological receptors. Actual river water contaminant concentrations were not measured as part of this RI; however, measurement of contaminants in river water, as well as in river bottom sediments, has been conducted as part of another characterization effort under the DOE River Corridor contract. To evaluate the potential exposure to groundwater contaminants following discharge of groundwater to the river, the groundwater conditions observed within the OU in the near-river wells (i.e., those within about 1,000 m [3,280 ft] of the river) are assumed to represent water discharged into the Columbia River.

Aquatic receptor protection is determined by comparing the groundwater concentrations at the point of discharge to surface water to the water quality criteria established under Sections 304 or 303 of the CWA, as well as Washington State water quality standards. The point of compliance for surface water cleanup levels is defined in 2007 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 2007 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 Section 6.2.3.2.

6.2.3.1 EPA Tap Water Scenario (Residential)

As described in EPA, 2013, *Regional Screening Levels for Chemical Contaminants at Superfund Sites* (hereafter referred to as EPA Regional Screening Levels), 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)

During September 2014, the EPA, 2015, "Superfund Preliminary Remediation Goals for Radionuclides" download and calculation website published cancer slope factors and equations for immersion for the tap water scenario to address external exposure from gamma and beta emitters. Immersion slope factors and equations were not published at the time that the risk calculations were performed for this groundwater data set. Therefore, radionuclide cancer risk is calculated in this risk assessment only for ingestion and inhalation exposure routes. A summary of the exposure assumptions used for the tap water (residential) scenario is provided in Appendix G, Table G-23. A detailed description of the EPA tap water scenario is provided in ECF-Hanford-13-0035.

6.2.3.2 Federal and State Standards and Criteria Used to Evaluate Protection of Aquatic Receptors

The objectives and methodology for deriving the numerical AWQC are described in PB85-227049, *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*. The AWQC are intended to provide a reasonable level of protection of all except a small fraction (0.05) of the taxa, unless a commercially or recreationally important species is very sensitive. Protection of the following aquatic organisms and their uses are defined in PB85-227049 as prevention of unacceptable long-term and short-term effects:

- Commercially, recreationally, and other important species
- Fish and benthic invertebrate assemblages in rivers and streams
- Fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans

Numeric values are expressed as two numbers, which provide an appropriate degree of protection of aquatic organisms and their uses from acute and chronic toxicity to animals, toxicity to plants, and bioaccumulation by aquatic organisms: (1) criteria maximum concentration (CMC), and (2) criteria continuous concentration (CCC). The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. EPA derives acute criteria from 48- to 96-hour tests of lethality or immobilization. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. EPA derives chronic criteria from longer-term (often greater than 28 days) tests that measure survival, growth, reproduction or, in some cases, bioconcentration. The CMC and the CCC are two of the six parts of the aquatic life criteria. The other four parts include the acute averaging period, chronic averaging period, acute frequency of allowed exceedance, and chronic frequency of allowed exceedance. The lower of the CMC or the CCC is the numeric water quality criteria used as the action level for protection of freshwater species.

6.2.3.3 Identify Exposure Area-Specific Data Sets

Twelve exposure areas have been identified in the 200-BP-5 OU. Eleven exposure areas contain wells screened in the unconfined aquifer, and a single exposure area contains wells screened in the confined aquifer. A list of the wells associated with each exposure area is provided in Table G-8 of Appendix G and in Table 4-5. The 12 exposure areas for the 200-BP-5 OU are as follows:

- LLWMA-1 (218-E-10 Landfill)
- LLWMA-2 and 216-B-63 Trench
- WMA B-BX-BY Tank Farms (B-BX-BY Tank Farms)
- WMA C Tank Farm (C Tank Farm)
- B Plant
- Semiworks
- LERF
- Gable Mountain Pond
- 200-BP-5 west
- Far-field area (north of Gable Gap)
- Near-river area
- 200-BP-5 confined (the only exposure area screened in the confined aquifer)

6.2.4 Exposure Point Concentrations

OSWER Directive 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (hereafter 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 9285.7-08I, *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 percent UCL of the arithmetic mean should be used for this variable." Use of the 95 percent 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.

6.2.4.1 95 Percent Upper Confidence Limit Calculation Methodology

Calculating UCL for EPCs (OSWER Directive 9285.6-10) is the most recent EPA guidance for UCL calculation, and ProUCL 4.00.05 serves as the companion software package for this guidance. ProUCL 4.00.05 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 OSWER Directive 9285.6-10 were used to calculate the UCLs for the 200-BP-5 OU. ProUCL 4.00.05 user guidance is provided in EPA/600/R-07/038, *ProUCL Version 4.00.05 User Guide.*

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 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 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 99 percent UCL may be more appropriate than the 95 percent UCL, because the Chebyshev 95 percent UCL may not provide adequate coverage of the mean. As skewness increases further, the Chebyshev method is not recommended.

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 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 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 less than one 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:** As described previously, EPA suggests the use of the Chebyshev inequality 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 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.

Minimum Data Size Requirements

Some decision statistics computed by ProUCL 4.00.05 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 five results.
- For data sets of at least five results, a UCL is not calculated when there is only one detected result in the data set.
- For data sets of at least five 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 less than 8 to 10) data sets processed, informing the user about potential deficiencies in the data set.

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:

- When a 95 percent UCL cannot be calculated due to small sample size
- When the 95 percent UCL is greater than the maximum detected concentration and the 97.5 percent Chebyshev (mean, Sd) UCL either was not calculated by ProUCL, or the calculated value was 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 percent 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 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). As described above, ProUCL has minimum size requirements to compute decision statistics. For data sets of at least five results, a UCL is not calculated when there is only one detected result in the data set. ProUCL notes that in cases where the number of available detected samples is small (less than five), the estimation of the EPC term is decided on a site-specific basis. 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 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 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, advises 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 evaluation, when the recommended UCL exceeds the maximum detected concentration, a 97.5 percent Chebyshev (mean, Sd) UCL is selected as the EPC, if it is available and its value is less than the maximum detected concentration. If the 97.5 percent Chebyshev (mean, Sd) 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 percent Chebyshev (mean, Sd) as an EPC will be 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.

Develop ProUCL Input Files

Input files that are compatible with ProUCL 4.00.05 are created using the data sets for each exposure area and are written to a Microsoft Excel® file in *.xls format. The *.xls files are then imported directly into ProUCL 4.00.05 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 200-BP-5 OU. The batch processing steps performed for ProUCL processing and data extraction are as follows.

® Microsoft Excel is a registered trademark of Microsoft Corporation, Redmond, Washington.

1. Batch processing of the *.xls files through ProUCL 4.00.05 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):
   - Exposure area
   - Analyte name and Chemical Abstracts Service (CAS) number
   - Total number of sample results, total number of detects, and total number of nondetects
   - 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
   - Recommended UCL value, the UCL basis, and comments and/or warning statements for each analyte

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 valid UCL cannot be calculated, the maximum detected concentration is selected as the EPC.
- If a valid UCL can be calculated, the highest recommended UCL value (if multiple valid UCLs were calculated) is selected.
- If a valid UCL equal to the maximum detected concentration was calculated, this value is selected as the EPC.
- If the selected UCL is greater than the maximum detected concentration, then the following logic is applied:
  - If a 97.5 percent Chebyshev (mean, Sd) UCL was calculated, select the 97.5 percent Chebyshev (mean, Sd) UCL as the EPC if its value is less than or equal to the maximum detected concentration.
  - If the 97.5 percent Chebyshev (mean, Sd) UCL was greater than the maximum detected concentration, select the maximum detected concentration as the EPC.
  - If a 97.5 percent 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 6-6. A summary of the EPCs for each of the exposure areas is provided in Appendix G, Tables G-11 through G-22.

[5] Minimum and maximum detection limits are summarized in the ProUCL output only when a valid UCL can be calculated.

6.3 Toxicity Assessment

This 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.

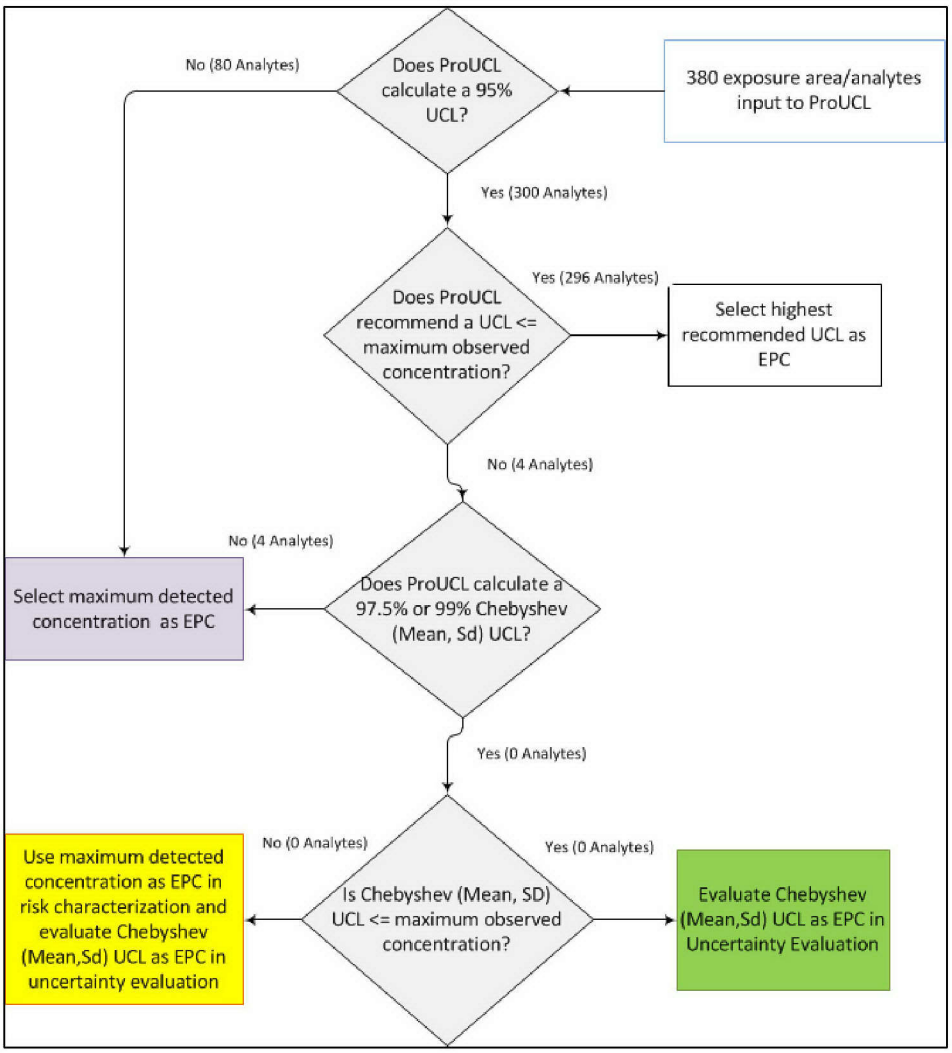

Figure 6-6. EPC Selection Logic

6.3.1 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 based on their effects on human health: noncarcinogens and carcinogens.

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 (e.g., arsenic) 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-03/001F, *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). The COPCs detected at the 200-BP-5 OU that have been identified as having documented systemic effects are listed in Appendix G, Table G-24.

6.3.2 Dose-Response Evaluation

The magnitude of the toxicity of a contaminant depends on the dose to a receptor. Dose refers to exposure to a contaminant concentration over a specified period. Human exposures are generally classified as acute (typically less than 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 subsections.

6.3.2.1 Reference Dose for Noncancer Effects

The toxicity value describing the dose-response relationship for noncancer effects is the reference dose (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, in general, as 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 preliminary remediation goals. 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 200-BP-5 OU are summarized in Appendix G, Table G-24.

6.3.2.2 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 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, then 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 percent 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-24.

6.3.3 Toxicity Values

The analyte-specific toxicity values presented in Appendix G, Table G-24 are determined using the following recommended reference hierarchy, as described in Cook, 2003, "Human Health Toxicity Values in Superfund Risk Assessments":

- Tier 1: EPA Integrated Risk Information System (IRIS) database
- Tier 2: EPA Provisional Peer-Reviewed Toxicity Values
- Tier 3: Other Toxicity Values

6.3.3.1 Tier 1: Integrated Risk Information System Database

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 thorough review and validation both within and outside EPA. If a toxicity value is available in IRIS, that value is preferred to any other value.

6.3.3.2 Tier 2: Provisional Peer-Reviewed Toxicity Values

If a toxicity value is not available in IRIS, the next source is the EPA provisional peer-reviewed toxicity values. 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. This database is not available to the public but is accessible to EPA risk assessors via the EPA intranet. These values are also published in EPA, 2013, "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

6.3.3.3 Tier 3: Other Toxicity Values

Tier 3 includes additional EPA and non-EPA sources of toxicity information, including the following:

- The California Environmental Protection Agency's Toxicity Criteria Database contains toxicity values that are peer-reviewed and address both cancer and noncancer effects.
- Agency for Toxic Substances and Disease Registry database, Minimal Risk Levels for Hazardous Substances, are peer-reviewed estimates of the daily human exposure to hazardous substances that are likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.
- Toxicity values are provided in EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update* (HEAST).

When Tier 1, Tier 2, or Tier 3 toxicity values are not available for a COPC, the toxicity values from the National Center for Environmental Assessment are used. These values can be found in the Risk Assessment Information System (ORNL, 2014).

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 were used to calculate toxicity values for dioxins, furans, and carcinogenic polycyclic aromatic hydrocarbons, as described in 2007 MTCA HHRA Procedures (WAC 173-340-708(8)(D)(iii)(A)).

The analyte-specific toxicity values for radionuclides presented in Appendix G, Table G-24 are determined using the recommended values from the EPA HEAST radionuclide tables (EPA 540-R-97-036).

6.4 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 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 the purpose of 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^{-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) greater than 1 indicates that some potential exists for adverse noncancer health effects associated with exposure to COPCs.

6.4.1 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 (radionuclides only) exposure routes considered, the following equation is used:

$$Risk = CDI \times SF$$

where:

$Risk$ = excess lifetime cancer risk for individual chemical or radioisotope (unitless)

CDI = chronic daily intake averaged over a lifetime (mg/kg-day or pCi)

SF = cancer slope factor (risk/mg/kg-day or risk/pCi)

To estimate the cancer risks from exposure to an individual carcinogen from the inhalation (chemicals only) exposure route, the following equation is used:

$$Risk = CDI \times IUR$$

where:

$Risk$ = excess lifetime cancer risk for individual chemical (unitless)

CDI = chronic daily intake averaged over a lifetime ($\mu g/m^3$)

IUR = inhalation unit risk ($risk/\mu g/m^3$)

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, 1986, *Risk Assessment for Carcinogens*). For estimating the cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used:

$$Risk_T = \sum_1^N Risk_i$$

where:

$Risk_T$ = total cancer risk from route of exposure

$Risk_i$ = cancer risk for the ith chemical

N = number of chemicals

6.4.2 Noncancer Hazard Estimation

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., RfD). The ratio of the chronic daily intake (CDI) divided by RfD is the HQ. To estimate the HQ from the ingestion and dermal contact (chemicals only) and inhalation (radionuclides only) exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = CDI / RfD$$

where:

HQ = hazard quotient for individual chemical (unitless)

CDI = chronic daily intake averaged over a lifetime (mg/kg-day)

RfD = reference dose (mg/kg-day)

To estimate the HQ from an individual hazardous substance from the inhalation (chemicals only) exposure route, the following equation is used:

$$HQ = CDI / RfC$$

where:

HQ = hazard quotient for individual chemical (unitless)

CDI = chronic daily intake averaged over a lifetime (mg/m^3)

RfC = reference concentration (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 less than 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:

$$HI = \sum_1^N E_i / RfD_i$$

where:

HI = hazard index

E_i = daily intake of the ith chemical (mg/kg-day)

RfD_i = reference dose of the ith chemical (mg/kg-day)

N = number of chemicals

6.4.3 Estimating the Sum of Fractions and 4 mrem/yr Dose Equivalent

An annual cumulative dose equivalent of 4 mrem to the total body or internal organ from exposure to beta and photon emitters is considered protective of human health. The sum of fractions 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. The following equation is used to determine if the 4 mrem standard is exceeded when there is a mixture of radioisotopes present:

$$Sum\ of\ fractions = \left(\frac{A\left(\frac{pCi}{L}\right)}{MCL_A\left(\frac{pCi}{L}\right)} + \frac{B\left(\frac{pCi}{L}\right)}{MCL_B\left(\frac{pCi}{L}\right)} + \bullet\bullet\bullet \right)$$

The 4 mrem standard is not exceeded if the sum of fractions is less than or equal to 1. Each fraction is converted to a dose equivalent by multiplying the fraction by 4 mrem/yr.

6.4.4 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 the 2013 EPA Regional Screening Levels, 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 assessment are provided in ECF-Hanford-13-0035. Potential routes of exposure to groundwater include ingestion, dermal contact, and inhalation of volatiles during household activities.

Results from this analysis are used to provide baseline conditions for all analytes with available toxicity information. Summaries of the risk estimates by exposure route are provided in the following subsections for each exposure area. As discussed in Section 6.1.3 and shown in Figure 6-4, all analytes that have reported concentrations and have available toxicity values are included in the calculation of cancer risks and noncancer hazards. Additional details, including analyte-specific cancer risk and noncancer hazard contributions, are provided in Appendix G, Tables G-25 through G-48.

A subset of 44 wells was identified by Ecology for the purpose of identifying COPCs on a well-specific basis. The approach used for the well-specific evaluation is consistent with that described for each exposure area. Additional details, including analyte-specific cancer risk and noncancer hazard contributions for each well, are provided in provided in Appendix H.

6.4.4.1 Low-Level Waste Management Area 1 Exposure Area

Table 6-1 provides a summary of the cancer risks and noncancer hazards by exposure route for the LLWMA-1 exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-25 and G-26.

Table 6-1. Summary of Cancer Risks and Noncancer Hazards for the LLWMA-1 Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.3×10^{-5}	Arsenic (ELCR = 9.3×10^{-5}; 30%) Cobalt-60 (ELCR = 7.8×10^{-6}; 2.5%) Iodine-129 (ELCR = 6.7×10^{-6}; 2.1%) Technetium-99 (ELCR = 1.7×10^{-4}; 53%) Tritium (ELCR = 4.1×10^{-5}; 13%)	13	Antimony (HQ = 3.6; 3.8%) Cyanide (HQ = 90; 94%)
	Dermal contact	5.4×10^{-7}		0.26	
	Inhalation of volatiles	5.3×10^{-7}		84	
	Total risk	**9.4×10^{-5}**		**Total HI**	**96**
Radionuclides	Ingestion	1.9×10^{-4}			
	Inhalation of volatiles	3.4×10^{-5}			
	Total risk	**2.2×10^{-4}**			
Total cumulative risk		**3.2×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the LLWMA-1 exposure area is 3.2×10^{-4}. The total ELCR for nonradiological analytes is 9.4×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) 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 (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cobalt-60 (ELCR = 7.8×10^{-6}; 2.5 percent contribution), iodine-129 (ELCR = 6.7×10^{-6}; 2.1 percent contribution), technetium-99 (ELCR = 1.7×10^{-4}; 53 percent contribution), and tritium (ELCR = 4.1×10^{-5}; 13 percent contribution). Contribution to ELCR is elevated for arsenic (9.3×10^{-5}; 30 percent contribution) where measured concentrations (4.8 µg/L) are within natural background values. The total ELCR for the LLWMA-1 exposure area for nonradiological analytes without contribution from arsenic is 6.0×10^{-7}, which is less than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI for the LLWMA-1 exposure area is 96, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ = 90; 94 percent contribution). Contribution to HI is elevated for antimony (HQ = 3.6; 3.8 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the LLWMA-1 exposure area without contribution from arsenic and antimony is 91, which is greater than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the LLWMA-1 exposure area are shown in Table 6-2. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 26 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-2. Summary of LLWMA-1 EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Cobalt-60	pCi/L	26	100	0.26
Iodine-129	pCi/L	2.4	1	2.4
Technetium-99	pCi/L	3,168	900	3.5
Tritium	pCi/L	7,417	20,000	0.27
			Sum of fractions	**6.6**
			Cumulative annual dose (mrem)	**26**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.2 Low-Level Waste Management Area 2 and 216- B-63 Trench Exposure Area

Table 6-3 provides a summary of the cancer risks and noncancer hazards by exposure route for the LLWMA-2 and 216-B-63 Trench exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-27 and G-28.

Table 6-3. Summary of Cancer Risks and Noncancer Hazards for the LLWMA 2 and 216-B-63 Trench Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.6×10^{-4}	Arsenic (ELCR = 1.6×10^{-4}; 77%)	9.3	Antimony (HQ = 5.1; 12%)
	Dermal contact	9.1×10^{-7}	Iodine-129 (ELCR = 3.9×10^{-6}; 1.8%)	0.29	Arsenic (HQ = 0.85; 1.9%)
	Inhalation of volatiles	--	Technetium-99 (ELCR = 4.2×10^{-5}; 20%)	34	Cyanide (HQ = 37; 85%)
	Total risk	**1.6×10^{-4}**	Tritium (ELCR = 3.1×10^{-6}; 1.5%)	**Total HI**	**44**
Radionuclides	Ingestion	4.7×10^{-5}			
	Inhalation of volatiles	2.6×10^{-6}			
	Total risk	**4.9×10^{-5}**			
Total cumulative risk		**2.1×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the LLWMA-2 and 216-B-63 Trench exposure area is 2.1×10^{-4}. The total ELCR for nonradiological analytes is 1.6×10^{-4}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.9×10^{-5}, which is within the EPA acceptable risk range of 1×10^{-4} to 1×10^{-6}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (ELCR = 3.9×10^{-6}; 1.8 percent contribution), technetium-99 (ELCR = 4.2×10^{-5}; 20 percent contribution), and tritium (ELCR = 3.1×10^{-6}; 1.5 percent contribution). Contribution to ELCR is elevated for arsenic (1.6×10^{-4}; 77 percent contribution) where measured concentrations (8.5 µg/L) are within natural background values. The total ELCR for the LLWMA-2 and 216-B-63 Trench exposure area for nonradiological analytes without contribution from arsenic is 9.1×10^{-7}, which is less than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI for the LLWMA-2 and 216-B-63 Trench exposure area is 44, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ = 37; 85 percent contribution). Contribution to HI is elevated for antimony (HQ = 5.1; 12 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. Contribution to HI is elevated for arsenic (HQ = 0.85; 1.9 percent contribution) where measured concentrations (4.8 µg/L) are within natural background values. The HI for the LLWMA-2 and 216-B-63 Trench exposure area without contribution from arsenic and antimony is 38, which is greater than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the LLWMA-2 and 216-B-63 Trench exposure area are shown in Table 6-4. The cumulative annual dose from drinking water

exposure to all beta- and photon-emitting radioisotopes in groundwater is 9.3 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-4. Summary of LLWMA-2 and 216-B-63 Trench EPCs for Beta/Photon Emitters and Calculated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Iodine-129	pCi/L	1.4	1	1.4
Technetium-99	pCi/L	801	900	0.89
Tritium	pCi/L	572	20,000	0.03
			Sum of fractions	**2.3**
			Cumulative annual dose (mrem)	**9.3**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

Table 6-5 provides a summary of the cancer risks and noncancer hazards by exposure route for the WMA B-BX-BY Tank Farms exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-29 and G-30.

Contribution to ELCR is elevated for arsenic (1.7×10^{-4}; 5.4 percent contribution), where measured concentrations (8.9 µg/L) are within natural background values. As discussed in Section 4.5.1.2, carbon tetrachloride, chloroform, methyl methanesulfonate, and n-nitrosodi-n-dipropylamine were each detected infrequently (in a single sample or two nonconsecutive detections), and their presence did not recur when compared to results collected over the past 10 years. The total ELCR for the WMA B-BX-BY Tank Farms exposure area for nonradiological analytes without contribution from arsenic, carbon tetrachloride, chloroform, methyl methanesulfonate, and n-nitrosodi-n-dipropylamine is 1.0×10^{-6}, which is less than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The HI for the WMA B-BX-BY Tank Farms exposure area is 221, which is greater than the 2007 MTCA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ = 208; 94 percent contribution), uranium, (HQ of 4.2; 1.9 percent contribution), and nitrate (HQ of 2.5; 1.2 percent contribution). Contribution to HI is elevated for antimony (HQ of 3.5; 1.6 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the WMA B-BX-BY Tank Farms exposure area without contribution from arsenic and antimony is 216, which is greater than the target HI of 1. The mechanisms of action (critical effect) for each of the analytes that contribute to HI are as follows:

- Cyanide: thyroid enlargement, altered iodide uptake, and decreased cauda epididymis weight in male rats
- Nitrate: early clinical signs of methemoglobinemia
- Uranium: initial body weight loss and moderate nephrotoxicity

Table 6-5. Summary of Cancer Risks and Noncancer Hazards for the WMA B-BX-BY Tank Farms Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.2×10^{-4}	Arsenic (ELCR = 1.7×10^{-4}; 5.4%) Carbon tetrachloride (ELCR = 7.7×10^{-6}; <1%) Chloroform (ELCR = 6.4×10^{-6}; <1%) Methyl methanesulfonate (ELCR = 4.3×10^{-4}; 14%) n-Nitrosodi-n-dipropylamine (ELCR = 3.2×10^{-4}; 10%) Technetium-99 (ELCR = 6.0×10^{-4}; 19%) Tritium (ELCR = 6.3×10^{-5}; 2.0%) Uranium-234 (ELCR = 8.1×10^{-4}; 25%) Uranium-235 (ELCR = 3.6×10^{-5}; 1.1%) Uranium-238 (ELCR = 7.2×10^{-4}; 22%)	29	Antimony (HQ = 3.5; 1.6%) Cyanide (HQ = 208; 94%) Nitrate (HQ = 2.5; 1.2%) Uranium (HQ = 4.2; 1.9%)
	Dermal contact	1.3×10^{-5}		0.48	
	Inhalation of volatiles	9.5×10^{-6}		192	
	Total risk	**9.4×10^{-4}**		**Total HI**	**221**
Radionuclides	Ingestion	2.2×10^{-3}			
	Inhalation of volatiles	5.2×10^{-5}			
	Total risk	**2.3×10^{-3}**			
Total cumulative risk		**3.2×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

Exposure to each of the analytes that contribute to the HI of 216 results in a different critical effect. As such, it is appropriate to segregate the contributions of each analyte. The critical effects listed are obtained from IRIS database.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the WMA B-BX-BY Tank Farms exposure area are shown in Table 6-6. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 71 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-6. Summary of WMA B-BX-BY Tank Farms EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	57	2,000	0.029
Cobalt-60	pCi/L	40	100	0.40
Iodine-129	pCi/L	3.7	1	3.7
Strontium-90	pCi/L	2.7	8	0.34
Technetium-99	pCi/L	11,390	900	13
Tritium	pCi/L	11,424	20,000	0.57
			Sum of fractions	**18**
			Cumulative annual dose (mrem)	**71**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.4 Waste Management Area C Tank Farm Exposure Area

Table 6-7 provides a summary of the cancer risks and noncancer hazards by exposure route for the WMA C exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-31 and G-32.

The total cumulative ELCR for the WMA C Tank Farm exposure area is 4.6×10^{-4}. The total ELCR for nonradiological analytes is 1.3×10^{-4}, which is greater than the 2007 MTCA (WAC 173-340-720) 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 (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (ELCR = 1.3×10^{-5}; 2.8 percent contribution), technetium-99 (ELCR = 3.1×10^{-4}; 68 percent contribution), and tritium (ELCR = 5.9×10^{-6}; 1.3 percent contribution.

Contribution to ELCR is elevated for arsenic (1.3×10^{-4}; 27 percent contribution) where measured concentrations (6.3 µg/L) are within natural background values. As discussed in Section 4.5.1.2, carbon tetrachloride was detected in a single sample, and its presence did not recur when compared to results collected over the past 10 years. The total ELCR for the WMA C Tank Farm exposure area for nonradiological analytes without contribution from arsenic and carbon tetrachloride is 7.4×10^{-7}, which is less than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The HI for the WMA C Tank Farm exposure area is 10, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ = 4.4; 43 percent contribution). All remaining individual analytes (arsenic, cadmium, cobalt, nitrate, and vanadium) that contribute greater than one percent of the HI also report an HQ less than 1. Contribution to HI is elevated for antimony (HQ = 3.6; 36 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the WMA C Tank Farm exposure area without contribution from arsenic and antimony is 5.9, which is greater than the target HI of 1.

Table 6-7. Summary of Cancer Risks and Noncancer Hazards for the WMA C Tank Farm Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.3×10^{-4}	Arsenic (ELCR = 1.3×10^{-4}; 27%) Carbon tetrachloride (ELCR = 2.9×10^{-6}; <1%) Iodine-129 (ELCR = 1.3×10^{-5}; 2.8%) Technetium-99 (ELCR = 3.1×10^{-4}; 68%) Tritium (ELCR = 5.9×10^{-6}; 1.3%)	5.8	Antimony (HQ = 3.6; 36%) Arsenic (HQ = 0.66; 6.5%) Cadmium (HQ = 0.27; 2.6%) Cobalt (HQ = 0.40; 3.9%) Cyanide (HQ = 4.4; 43%) Fluoride (HQ = 0.068; <1%) Cr(VI) (HQ = 0.077; <1%) Nitrate (HQ = 0.19; 1.9%) Selenium (HQ = 0.065; <1%) Vanadium (HQ = 0.13; 1.2%)
	Dermal contact	1.0×10^{-6}		0.23	
	Inhalation of volatiles	2.0×10^{-6}		4.1	
	Total risk	**1.3×10^{-4}**		**Total HI**	**10**
Radionuclides	Ingestion	3.3×10^{-4}			
	Inhalation of volatiles	4.9×10^{-6}			
	Total risk	**3.3×10^{-4}**			
Total cumulative risk		**4.6×10^{-4}**			

Cr(VI) = hexavalent chromium
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:

- Cadmium: significant proteinuria
- Cobalt: thyroid, decreased iodine uptake
- Cyanide: thyroid enlargement, altered iodide uptake, and decreased cauda epididymis weight in male rats
- Fluoride: objectionable dental fluorosis (a cosmetic effect)
- Cr(VI): nasal septum atrophy

- Nitrate: early clinical signs of methemoglobinemia
- Selenium: clinical selenosis (loss of hair and nails)
- Vanadium: decreased hair cysteine

With the exception of cobalt and cyanide, exposure to each of the analytes that contribute to the HI of 5.9 will result in a different critical effect. As such, it is appropriate to segregate the contributions of each analyte. The critical effects listed are obtained from the IRIS database. Combining the effects for cobalt and cyanide would increase the HQ from 4.4 to 4.8, which remains greater than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the WMA C Tank Farm exposure area are shown in Table 6-8. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 45 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-8. Summary of WMA C Tank Farm EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Iodine-129	pCi/L	4.6	1	4.6
Technetium-99	pCi/L	5,981	900	6.6
Tritium	pCi/L	1,047	20,000	0.054
			Sum of fractions	**11**
			Cumulative annual dose (mrem)	**45**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.5 B Plant Exposure Area

Table 6-9 provides a summary of the cancer risks and noncancer hazards by exposure route for the B Plant exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-33 and G-34.

The total cumulative ELCR for the B Plant exposure area is 2.3×10^{-3}. The total ELCR for nonradiological analytes is 8.8×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.2×10^{-3}, which is greater than the EPA upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cesium-137 (ELCR = 8.1×10^{-4}; 35 percent contribution), plutonium-239/240 (ELCR = 7.8×10^{-5}; 3.4 percent contribution), strontium-90 (ELCR = 1.2×10^{-3}; 52 percent contribution), technetium-99 (ELCR = 7.4×10^{-5}; 3.2 percent contribution), and tritium (ELCR = 2.9×10^{-5}; 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (8.8×10^{-5}; 3.8 percent contribution) where measured concentrations (4.5 µg/L) are within natural background values. A cancer risk is not reported for nonradiological analytes at the B Plant exposure area when contribution from arsenic is not considered.

Table 6-9. Summary of Cancer Risks and Noncancer Hazards for the B Plant Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	8.7×10^{-5}	Arsenic (ELCR = 8.8×10^{-5}; 3.8%) Cesium-137 (ELCR = 8.1×10^{-4}; 35%) Plutonium-239/240 (ELCR = 7.8×10^{-5}; 3.4%) Strontium-90 (ELCR = 1.2×10^{-3}; 52%) Technetium-99 (ELCR = 7.4×10^{-5}; 3.2%) Tritium (ELCR = 2.9×10^{-5}; 1.2%)	8.2	Antimony (HQ = 5.9; 46%) Arsenic (HQ = 0.46; 3.6%) Cadmium (HQ = 0.34; 2.7%) Cyanide (HQ = 4.5; 35%) Fluoride (HQ = 0.45; 3.5%) Nitrate (HQ = 0.37; 2.9%) Uranium (HQ = 0.23; 1.8%) Vanadium (HQ = 0.13; 1.0%)
	Dermal contact	4.9×10^{-7}		0.33	
	Inhalation of volatiles	—		4.1	
	Total risk	**8.8×10^{-5}**		**Total HI**	**13**
Radionuclides	Ingestion	2.2×10^{-3}			
	Inhalation of volatiles	2.4×10^{-5}			
	Total risk	**2.2×10^{-3}**			
Total cumulative risk		**2.3×10^{-3}**			

ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for the B Plant exposure area is 13, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ = 4.5; 35 percent contribution). All of the remaining individual analytes (arsenic, cadmium, fluoride, nitrate, and uranium) that contribute greater than one percent of the HI also report an HQ less than 1. Contribution to HI is elevated for antimony (HQ = 5.9; 46 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the B Plant exposure area without contribution from arsenic and antimony is 6.3, 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:

- Cadmium: significant proteinuria
- Cyanide: thyroid enlargement, altered iodide uptake, and decreased cauda epididymis weight in male rats

- 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
- Vanadium: decreased hair cysteine

Exposure to each of the analytes that contribute to the HI of 6.3 results in a different critical effect. As such, it is appropriate to segregate the contributions of each analyte.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the B Plant exposure area are shown in Table 6-10. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 608 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-10. Summary of B Plant EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	12	2,000	0.0060
Cesium-137	pCi/L	1,390	200	7.0
Europium-154	pCi/L	45	60	0.75
Iodine-129	pCi/L	1.5	1	1.5
Strontium-90	pCi/L	1,127	8	141
Technetium-99	pCi/L	1,415	900	1.6
Tritium	pCi/L	5,272	20,000	0.26
			Sum of fractions	**152**
			Cumulative annual dose (mrem)	**608**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.6 Semiworks Exposure Area

Table 6-11 provides a summary of the cancer risks and noncancer hazards by exposure route for the Semiworks exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-35 and G-36.

The total cumulative ELCR for the Semiworks exposure area is 1.3×10^{-4}. The total ELCR for nonradiological analytes is 7.7×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.3×10^{-5}, which is within the EPA acceptable risk range of 1×10^{-4} to 1×10^{-6}.

Table 6-11. Summary of Cancer Risks and Noncancer Hazards for the Semiworks Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	7.7×10^{-5}	Arsenic (ELCR = 7.7×10^{-5}; 59%) Iodine-129 (ELCR = 5.2×10^{-6}; 4.0%) Strontium-90 (ELCR = 3.0×10^{-6}; 2.3%) Technteium-99 (ELCR = 3.3×10^{-6}; 2.5%) Tritium (ELCR = 4.1×10^{-5}; 32%)	0.99	—
	Dermal contact	4.3×10^{-7}		0.049	
	Inhalation of volatiles	—		—	
	Total risk	**7.7×10^{-5}**		**Total HI**	**1.0**
Radionuclides	Ingestion	1.9×10^{-5}			
	Inhalation of volatiles	3.4×10^{-5}			
	Total risk	**5.3×10^{-5}**			
Total cumulative risk		**1.3×10^{-4}**			

ELCR = excess lifetime cancer risk
HI = hazard index

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (ELCR = 5.2×10^{-6}; 4 percent contribution), strontium-90 (ELCR = 3.0×10^{-6}; 2.3 percent contribution), technetium-99 (ELCR = 3.3×10^{-6}; 2.5 percent contribution), and tritium (ELCR = 4.1×10^{-5}; 32 percent contribution). Contribution to ELCR is elevated for arsenic (7.7×10^{-5}; 59 percent contribution) where measured concentrations (4.0 µg/L) are within natural background values. A cancer risk is not reported for nonradiological analytes at the Semiworks exposure area when contribution from arsenic is not considered.

The HI for the Semiworks exposure area is 1, which is equal to the 2007 MTCA (WAC 173-340-720) target HI of 1. Each of the individual analytes reports an HQ less than 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the Semiworks exposure area are shown in Table 6-12. 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.

6.4.4.7 Liquid Effluent Retention Facility Exposure Area

Table 6-13 provides a summary of the cancer risks and noncancer hazards by exposure route for the LERF exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-37 and G-38.

The total cumulative ELCR for the LERF exposure area is 9.5×10^{-5}. The total ELCR for nonradiological analytes is 9.1×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.4×10^{-6}, which is within the EPA acceptable risk range of 1×10^{-4} to 1×10^{-6}.

Table 6-12. Summary of Semiworks EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Iodine-129	pCi/L	1.8	1	1.8
Strontium-90	pCi/L	2.8	8	0.35
Technetium-99	pCi/L	62	900	0.069
Tritium	pCi/L	7,500	20,000	0.38
			Sum of fractions	**2.6**
			Cumulative annual dose (mrem)	**10**

DWS = drinking water standard
EPC = exposure point concentration

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are carbon tetrachloride (ELCR = 5.1×10^{-6}; 5.3 percent contribution) and tritium (ELCR = 3.5×10^{-6}; 3.6 percent contribution). Contribution to ELCR is elevated for arsenic (8.6×10^{-5}; 90 percent contribution) where measured concentrations (4.4 µg/L) are within natural background values. As discussed in Section 4.5.1.2, carbon tetrachloride was detected once at two separate locations, and its presence did not recur when compared to results collected over the past 10 years. A cancer risk is not reported for nonradiological analytes at the LERF exposure area when contribution from arsenic and carbon tetrachloride are not considered.

The HI for the LERF exposure area is 1.2, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. Each of the individual analytes (antimony, arsenic, carbon tetrachloride, fluoride, Cr(VI), manganese, nickel, nitrate, nitrite, silver, strontium, and vanadium) that contribute greater than one percent of the HI also report an HQ less than 1. The mechanisms of action (critical effect) for each of analyte 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
- Iron: gastrointestinal tract effects
- Manganese: central nervous system effects
- Nickel: decreased body and organ weights
- Nitrate: early clinical signs of methemoglobinemia
- Nitrite: methemoglobinemia
- Silver: argyria (skin effects)
- Strontium: rachitic bone
- Vanadium: decreased hair cysteine

Table 6-13. Summary of Cancer Risks and Noncancer Hazards for the LERF Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	8.8×10^{-5}	Arsenic (ELCR = 8.6×10^{-5}; 90%) Carbon tetrachloride (ELCR = 5.1×10^{-6}; 5.3%) Tritium (ELCR = 3.5×10^{-6}; 3.6%)	1.1	Antimony (HQ = 0.025; 2.1%) Arsenic (HQ = 0.45; 37%) Carbon tetrachloride (HQ = 0.033; 2.8%) Fluoride (HQ = 0.13; 10%) Cr(VI) (HQ = 0.097; 8.1%) Manganese (HQ = 0.014; 1.2%) Nickel (HQ = 0.017; 1.4%) Nitrate (HQ = 0.18; 15%) Nitrite (HQ = 0.032; 2.7%) Silver (HQ = 0.049; 4.1%) Strontium (HQ = 0.029; 2.4%) Vanadium (HQ = 0.13; 11%)
	Dermal contact	1.0×10^{-6}		0.074	
	Inhalation of volatiles	2.5×10^{-6}		0.011	
	Total risk	**9.1×10^{-5}**		**Total HI**	**1.2**
Radionuclides	Ingestion	1.5×10^{-6}			
	Inhalation of volatiles	2.9×10^{-6}			
	Total risk	**4.4×10^{-6}**			
Total cumulative risk		**9.5×10^{-5}**			

Cr(VI) = hexavalent chromium
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

With the exception of nitrate and nitrite, exposure to each of the analytes that contribute to the HI of 1.2 will result in a different critical effect. As such, it is appropriate to segregate the contributions of each analyte. The critical effects listed are obtained from IRIS database. Combining the effects for nitrate and nitrite would result in an HQ of 0.21, which is less than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the LERF exposure area are shown in Table 6-14. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 1.4 mrem/yr, which is less than the 4 mrem/yr DWS.

Table 6-14. Summary of LERF EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Iodine-129	pCi/L	0.32	1	0.32
Tritium	pCi/L	632	20,000	0.032
			Sum of fractions	**0.35**
			Cumulative annual dose (mrem)	**1.4**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.8 Gable Mountain Pond Exposure Area

Table 6-15 provides a summary of the cancer risks and noncancer hazards by exposure route for the Gable Mountain Pond exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-39 and G-40.

The total cumulative ELCR for the Gable Mountain Pond exposure area is 3.4×10^{-4}. The total ELCR for nonradiological analytes is 9.0×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.5×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (ELCR = 2.3×10^{-4}; 68 percent contribution) and tritium (ELCR = 1.8×10^{-5}; 5.2 percent contribution). Contribution to ELCR is elevated for arsenic (9.0×10^{-5}; 27 percent contribution) where measured concentrations (4.7 µg/L) are within natural background values. A cancer risk is not reported for nonradiological analytes at the Gable Mountain Pond exposure area when contribution from arsenic is not considered.

The HI for the Gable Mountain Pond exposure area is 7.0, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. All individual analytes (arsenic, Cr(VI), iron, manganese, and nitrate) that contribute greater than one percent of the HI also report an HQ less than 1. Contribution to HI is elevated for antimony (HQ = 5.6; 79 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the Gable Mountain Pond exposure area without contribution from arsenic and antimony is 0.98, which is less than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the Gable Mountain Pond exposure area are shown in Table 6-16. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 108 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-15. Summary of Cancer Risks and Noncancer Hazards for the Gable Mountain Pond Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	9.0×10^{-5}	Arsenic (ELCR = 9.0×10^{-5}; 27%) Strontium-90 (ELCR = 2.3×10^{-4}; 68%) Tritium (ELCR = 1.8×10^{-5}; 5.2%)	6.8	Antimony (HQ = 5.6; 79%) Arsenic (HQ = 0.47; 6.7%) Cr(VI) (HQ = 0.078; 1.1%); Iron (HQ = 0.13; 1.9%) Manganese (HQ = 0.13; 1.9%) Nitrate (HQ = 0.40; 5.7%)
	Dermal contact	5.0×10^{-7}		0.27	
	Inhalation of volatiles	—		—	
	Total risk	**9.0×10^{-5}**		**Total HI**	**7.0**
Radionuclides	Ingestion	2.3×10^{-4}			
	Inhalation of volatiles	1.4×10^{-5}			
	Total risk	**2.5×10^{-4}**			
Total cumulative risk		**3.4×10^{-4}**			

Cr(VI) = hexavalent chromium
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

1

Table 6-16. Summary of Gable Mountain Pond EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Strontium-90	pCi/L	214	8	27
Tritium	pCi/L	3,200	20,000	0.16
			Sum of fractions	**27**
			Cumulative annual dose (mrem)	**108**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.9 200-BP-5 West Exposure Area

Table 6-17 provides a summary of the cancer risks and noncancer hazards by exposure route for the 200-BP-5 west exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-41 and G-42.

Table 6-17. Summary of Cancer Risks and Noncancer Hazards for the 200-BP-5 West Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	1.2×10^{-4}	Arsenic (ELCR = 1.2×10^{-4}; 34%) BEHP (ELCR = 1.1×10^{-6}; <1%) Carbon tetrachloride (ELCR = 5.6×10^{-6}; 1.6%) Chloroform (ELCR = 3.0×10^{-6}; <1%) Strontium-90 (ELCR = 8.8×10^{-5}; 25%) Technetium-99 (ELCR = 9.0×10^{-5}; 26%) Tritium (ELCR = 3.7×10^{-5}; 11%)	11	Antimony (HQ = 4.6; 8.5%) Arsenic (HQ = 0.61; 1.1%) Cyanide (HQ =46; 86%)
	Dermal contact	2.0×10^{-6}		0.32	
	Inhalation of volatiles	5.4×10^{-6}		43	
	Total risk	**1.3×10^{-4}**		**Total HI**	**54**
Radionuclides	Ingestion	1.9×10^{-4}			
	Inhalation of volatiles	3.0×10^{-5}			
	Total risk	**2.2×10^{-4}**			
Total cumulative risk		**3.5×10^{-4}**			

BEHP = bis(2-ethylhexyl)phthalate
ELCR = excess lifetime cancer risk
HI = hazard index

The total cumulative ELCR for the 200-BP-5 west exposure area is 3.5×10^{-4}. The total ELCR for nonradiological analytes is 1.3×10^{-4}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.2×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are carbon tetrachloride (ELCR = 5.6×10^{-6}; 1.6 percent contribution), strontium-90 (ELCR = 8.8×10^{-5}; 25 percent contribution), technetium-99 (ELCR = 9.0×10^{-5}; 26 percent contribution), and tritium (ELCR = 3.7×10^{-5}; 11 percent contribution). Contribution to ELCR is elevated for arsenic (1.2×10^{-4}; 34 percent contribution) where measured concentrations (6.1 µg/L) are within natural background values. The total ELCR for the 200-BP-5 west exposure area for nonradiological analytes without contribution from arsenic is 9.9×10^{-6}, which is less than the MTCA HHRA Procedures (WAC 173-340-708(5)) cumulative risk threshold of 1×10^{-5}.

The HI for the 200-BP-5 west exposure area is 54, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. The primary contributor to the noncancer HI (those analytes that

contribute greater than 1 percent of total HI) is cyanide (HQ = 46; 86 percent contribution). The remaining individual analyte (arsenic) that contributes greater than 1 percent of the HI also report an HQ less than 1. Contribution to HI is elevated for antimony (HQ = 4.6; 8.5 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the 200-BP-5 west exposure area without contribution from arsenic and antimony is 49, which is greater than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the 200-BP-5 west exposure area are shown in Table 6-18. The cumulative annual dose from drinking water exposure to all of the beta- and photon-emitting radioisotopes in groundwater is 55 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-18. Summary of 200-BP-5 West EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Cobalt-60	pCi/L	6.4	100	0.064
Iodine-129	pCi/L	1.1	1	1.1
Strontium-90	pCi/L	83	8	10
Technetium-99	pCi/L	1,711	900	1.9
Tritium	pCi/L	6,693	20,000	0.33
			Sum of fractions	**14**
			Cumulative annual dose (mrem)	**55**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.10 200-BP-5 Confined Exposure Area

Table 6-19 provides a summary of the cancer risks and noncancer hazards by exposure route for the 200-BP-5 confined exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-43 and G-44.

The total cumulative ELCR for the 200-BP-5 confined exposure area is 1.2×10^{-4}. The total ELCR for nonradiological analytes is 7.8×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.8×10^{-5}, which is within the EPA risk range of 1×10^{-4} to 1×10^{-6}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are benzene (ELCR = 5.5×10^{-6}; 4.8 percent contribution), BEHP (ELCR = 1.7×10^{-6}; 1.5 percent contribution), carbon tetrachloride (ELCR = 5.1×10^{-6}; 4.4 percent contribution), chloroform (ELCR = 5.9×10^{-6}; 5.1 percent contribution), iodine-129 (ELCR = 2.5×10^{-6}; 2.2 percent contribution), strontium-90 (ELCR = 2.5×10^{-6}; 2.1 percent contribution), technetium-99 (ELCR = 1.9×10^{-5}; 16 percent contribution), tritium (ELCR = 9.7×10^{-6}; 8.3 percent contribution), uranium-234 (ELCR = 1.8×10^{-6}; 1.6 percent contribution), and uranium-238 (ELCR = 1.3×10^{-6}; 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (5.9×10^{-5}; 51 percent

contribution) where measured concentrations (3.0 µg/L) are within natural background values. As discussed in Section 4.5.1.2, benzene, carbon tetrachloride, and chloroform were each detected in a single sample from Well 699-52-55B, where their presence did not recur when compared to sample results from the past 10 years. BEHP was detected infrequently (a single detection or two nonconsecutive detections) in three different wells. BEHP is a common laboratory contaminant that is introduced into the sample after it is collected in the field. The total ELCR for the confined exposure area for nonradiological analytes without contribution from arsenic, benzene, BEHP, carbon tetrachloride, and chloroform is 9.7×10^{-7}, which is less than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

Table 6-19. Summary of Cancer Risks and Noncancer Hazards for the 200-BP-5 Confined Aquifer Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	6.5×10^{-5}	Arsenic (ELCR 5.9×10^{-5}; 51%)	4.8	Antimony (HQ = 3.3; 30%)
	Dermal contact	2.2×10^{-6}	Benzene (ELCR 5.5×10^{-6}; 4.8%)	0.22	Arsenic (HQ = 0.31; 2.8%)
	Inhalation of volatiles	1.1×10^{-5}	BEHP (ELCR = 1.7×10^{-6}; 1.5%)	5.8	Cyanide (HQ = 6.2; 58%)
	Total risk	**7.8×10^{-5}**	Carbon tetrachloride (ELCR = 5.1×10^{-6}; 4.4%)	**Total HI**	**11**
Radionuclides	Ingestion	3.0×10^{-5}	Chloroform (ELCR = 5.9×10^{-6}; 5.1%)		
	Inhalation of volatiles	8.0×10^{-6}	Iodine-129 (ELCR = 2.5×10^{-6}; 2.2%)		
	Total risk	**3.8×10^{-5}**	Strontium-90 (ELCR = 2.5×10^{-6}; 2.1%)		
			Technetium-99 (ELCR = 1.9×10^{-5}; 16%)		
			Tritium (ELCR = 9.7×10^{-6}; 8.3%)		
			Uranium-234 (ELCR = 1.8×10^{-6}; 1.6%)		
			Uranium-238 (ELCR = 1.3×10^{-6}; 1.1%)		
Total cumulative risk		**1.2×10^{-4}**			

BHEP = bis(2-ethylhexyl)phthalate
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for the 200-BP-5 confined exposure area is 11, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ = 6.2; 58 percent contribution). The remaining analyte (arsenic) that contribute greater than one percent of the HI also report an HQ less than 1. Contribution to HI is elevated for antimony (HQ = 3.3; 30 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010. The HI for the confined

exposure area without contribution from arsenic and antimony is 7.1, which is greater than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the 200-BP-5 confined exposure area are shown in Table 6-20. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 6.7 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-20. Summary of 200-BP-5 Confined EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	35	2,000	0.018
Iodine-129	pCi/L	0.89	1	0.89
Strontium-90	pCi/L	2.3	8	0.29
Technetium-99	pCi/L	353	900	0.39
Tritium	pCi/L	1,756	20,000	0.088
			Sum of fractions	**1.7**
			Cumulative annual dose (mrem)	**6.7**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.11 200-BP-5 Far-Field Exposure Area

Table 6-21 provides a summary of the cancer risks and noncancer hazards by exposure route for the 200-BP-5 far-field exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-45 and G-46.

The total cumulative ELCR for the 200-BP-5 far-field exposure area is 3.3×10^{-4}. The total ELCR for nonradiological analytes is 2.5×10^{-4}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.0×10^{-5}, which is within the EPA risk range of 1×10^{-4} to 1×10^{-6}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (ELCR = 7.9×10^{-6}; 2.4 percent contribution) and tritium (ELCR = 7.0×10^{-5}; 22 percent contribution). Contribution to ELCR is elevated for arsenic (2.5×10^{-4}; 75 percent contribution) where measured concentrations (13 µg/L) are within natural background values. A cancer risk is not reported for nonradiological analytes at the far-field exposure area when contribution from arsenic is not considered.

Table 6-21. Summary of Cancer Risks and Noncancer Hazards for the 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	2.4×10^{-4}	Arsenic (ELCR = 2.5×10^{-4}; 75%) Technetium-99 (ELCR = 7.9×10^{-6}; 2.4%) Tritium (ELCR = 7.0×10^{-5}; 22%)	2.4	Arsenic (HQ = 1.3; 51%) Copper (HQ = 0.089; 3.6%) Fluoride (HQ = 0.30; 12%) Cr(VI) (HQ = 0.17; 6.8%) Iron (HQ = 0.057; 2.3%) Lithium (HQ = 0.14; 5.7%) Manganese (HQ = 0.058; 2.3%) Molybdenum (HQ = 0.032; 1.3%) Nitrate (HQ = 0.089; 3.6%) Uranium (HQ = 0.042; 1.7%) Vanadium (HQ = 0.14; 5.7%) Zinc (HQ = 0.037; 1.5%)
	Dermal contact	1.4×10^{-6}		0.10	
	Inhalation of volatiles	—		—	
	Total risk	**2.5×10^{-4}**		**Total HI**	**2.5**
Radionuclides	Ingestion	2.2×10^{-5}			
	Inhalation of volatiles	5.8×10^{-5}			
	Total risk	**8.0×10^{-5}**			
Total cumulative risk		**3.3×10^{-4}**			

Cr(VI) = hexavalent chromium
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The HI for the 200-BP-5 far-field exposure area is 2.5, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. All individual analytes (fluoride, Cr(VI), lithium, molybdenum, nitrate, and vanadium) that contribute greater than one percent of the HI also report an HQ less than 1. Contribution to HI is elevated for arsenic (HQ = 1.3; 51 percent contribution) where measured concentrations (13 µg/L) are within natural background values. The HI for the 200-BP-5 far-field

exposure area without contribution from arsenic is 1.2, which is greater than the target HI of 1. The mechanisms of action (critical effect) for each analyte that contribute to the HI are as follows:

- Copper: significant proteinuria
- Fluoride: objectionable dental fluorosis (a cosmetic effect)
- Cr(VI): nasal septum atrophy
- Iron: gastrointestinal tract effects
- Lithium: nervous system and kidney effects
- Manganese: central nervous system effects
- Molybdenum: increased uric acid levels
- Nitrate: early clinical signs of methemoglobinemia
- Nitrite: methemoglobinemia
- Uranium: initial body weight loss and moderate nephrotoxicity
- Vanadium: decreased hair cysteine
- Zinc: decreased erythrocyte copper, zinc-superoxide dismutase (blood effects)

With the exception of nitrate and nitrite and copper, lithium, molybdenum, and uranium, exposure to each of the analytes that contribute to the HI of 1.2 result in a different critical effect. As such, it is appropriate to segregate the contributions of each analyte. The critical effects listed are obtained from IRIS, and the critical effect for lithium was obtained from the Provisional Peer-Reviewed Toxicity Values derived by the EPA Superfund Health Risk Technical Supper Center for the EPA Superfund program. Combining the effects for nitrate and nitrite would result in an HQ of 0.11, which is less than the target HI of 1. Combining the effects for copper, lithium, molybdenum, and uranium would result in an HQ of 0.30, which is also less than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the 200-BP-5 far-field exposure area are shown in Table 6-22. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 5.9 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-22. Summary of 200-BP-5 Far-Field Exposure Area EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Iodine-129	pCi/L	0.68	1	0.68
Technetium-99	pCi/L	150	900	0.17
Tritium	pCi/L	12,770	20,000	0.64
			Sum of fractions	**1.5**
			Cumulative annual dose (mrem)	**5.9**

DWS = drinking water standard
EPC = exposure point concentration

6.4.4.12 200-BP-5 Near-River Exposure Area

Table 6-23 provides a summary of the cancer risks and noncancer hazards by exposure route for the 200-BP-5 near-river exposure area. Additional details, including analyte-specific risk contributions, are provided in Appendix G, Tables G-47 and G-48.

Table 6-23. Summary of Cancer Risks and Noncancer Hazards for the 200-BP-5 Near-River Exposure Area

Analyte Group	Exposure Route	ELCR	% Risk Contribution	HI	% HI Contribution
Nonradionuclides	Ingestion	6.2×10^{-5}	Arsenic (ELCR 6.1×10^{-5}; 41%) Trichloroethene (ELCR = 2.6×10^{-6}; 1.8%) Carbon-14 (ELCR = 8.7×10^{-6}; 5.9%) Technetium-99 (ELCR = 3.2×10^{-6}; 2.2%) Tritium (ELCR = 6.9×10^{-5}; 47%)	1.1	Arsenic (HQ = 0.32; 20%) Fluoride (HQ = 0.12; 7.4%) Cr(VI) (HQ = 0.090; 5.5%) Lithium (HQ = 0.15; 9.4%) Manganese (HQ = 0.021; 1.3%) Molybdenum (HQ = 0.027; 1.7%) Nitrate (HQ = 0.10; 6.2%) Nitrite (HQ = 0.022; 1.4%) Trichloroethene (HQ = 0.57; 35%) Uranium (HQ = 0.024; 1.5%) Vanadium (HQ = 0.11; 6.5%)
	Dermal contact	5.3×10^{-7}		0.077	
	Inhalation of volatiles	2.1×10^{-6}		0.44	
	Total risk	**6.4×10^{-5}**		**Total HI**	**1.6**
Radionuclides	Ingestion	2.7×10^{-5}			
	Inhalation of volatiles	5.7×10^{-5}			
	Total risk	**8.4×10^{-5}**			
Total cumulative risk		**1.5×10^{-4}**			

Cr(VI) = hexavalent chromium
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient

The total cumulative ELCR for the 200-BP-5 near-river exposure area is 1.5×10^{-4}. The total ELCR for nonradiological analytes is 6.4×10^{-5}, which is greater than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 8.4×10^{-5}, which is within the EPA risk range of 1×10^{-4} to 1×10^{-6}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are TCE (ELCR = 2.6×10^{-6}; 1.8 percent contribution), carbon-14 (ELCR = 8.7×10^{-6}; 5.9 percent contribution), technetium-99 (ELCR = 3.2×10^{-6}; 2.2 percent contribution), and tritium (ELCR = 6.9×10^{-5}; 47 percent contribution). Contribution to ELCR is elevated for arsenic (6.1×10^{-5}; 41 percent contribution) where measured concentrations (3.2 µg/L) are within natural background values. The total ELCR for the 200-BP-5 near-river exposure area for nonradiological analytes without contribution from arsenic is 3.5×10^{-6}, which is less than the 2007 MTCA (WAC 173-340-720) cumulative risk threshold of 1×10^{-5}.

The HI for the 200-BP-5 near-river exposure area is 1.6, which is greater than the 2007 MTCA (WAC 173-340-720) target HI of 1. All individual analytes (arsenic, fluoride, Cr(VI), lithium, molybdenum, nitrate, nitrite, selenium, uranium, and vanadium) that contribute greater than one percent of the HI also report an HQ less than 1. The HI for the 200-BP-5 near-river exposure area without contribution from arsenic is 1.3, which is greater than the target HI of 1. The mechanisms of action (critical effect) for each analyte 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
- Lithium: nervous system and kidney effects
- Manganese: central nervous system effects
- Molybdenum: increased uric acid levels
- Nitrate: early clinical signs of methemoglobinemia
- Nitrite: methemoglobinemia
- TCE: adult immunological effects, development immunotoxicity, and heart malformations
- Uranium: initial body weight loss and moderate nephrotoxicity
- Vanadium: decreased hair cysteine
- Zinc: decreased erythrocyte copper, zinc-superoxide dismutase (blood effects)

With the exception of nitrate, nitrite, lithium, molybdenum, and uranium, exposure to each of the analytes that contribute to the HI of 1.3 result in a different critical effect. As such, it is appropriate to segregate the contributions of each analyte. The critical effects listed are obtained from IRIS database, and the critical effect for lithium was obtained from the provisional peer-reviewed toxicity values derived by the EPA Superfund Health Risk Technical Supper Center for the EPA Superfund program. Combining the effects for nitrate and nitrite would result in an HQ of 0.12, which is less than the target HI of 1. Combining the effects for lithium, molybdenum, and uranium would result in an HQ of 0.20, which is also less than the target HI of 1.

The EPCs and DWSs for all beta- and photon-emitting radioisotopes detected in the 200-BP-5 near-river exposure area are shown in Table 6-24. The cumulative annual dose from drinking water exposure to all beta- and photon-emitting radioisotopes in groundwater is 4.4 mrem/yr, which is greater than the 4 mrem/yr DWS.

Table 6-24. Summary of 200-BP-5 Near-River Exposure Area EPCs for Beta/Photon Emitters and Associated Cumulative Annual Dose

Beta/Photon Emitter	Units	EPC	DWS	Individual Fraction
Carbon-14	pCi/L	293	2,000	0.15
Iodine-129	pCi/L	0.25	1	0.25
Technetium-99	pCi/L	61	900	0.068
Tritium	pCi/L	12,568	20,000	0.63
			Sum of fractions	**1.1**
			Cumulative annual dose (mrem)	**4.4**

DWS = drinking water standard
EPC = exposure point concentration

6.5 Uncertainties in Risk Assessment

The purpose of this 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 are related 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.

6.5.1 Uncertainties Associated with Sampling and Analysis Data

Current baseline conditions are represented by groundwater data collected over the past 6 years from 161 monitoring wells within the 200-BP-5 OU. The groundwater data set for the COPCs has more than 1,800 samples available from 161 wells that were routinely sampled over a period of many years. Therefore, the groundwater data set is considered adequate for risk assessment.

Groundwater data from the 200-BP-5 OU are collected in accordance with nine different SAPs. One SAP addresses the requirements of the characterization work plan (DOE/RL-2007-18), two SAPs address the requirements under CERCLA and the AEA (DOE/RL-2001-49; DOE/RL-2006-55), and six SAPs address RCRA requirements (DOE/RL-2008-60; DOE/RL-2009-75; DOE/RL-2009-76; DOE/RL-2009-77; DOE/RL-2012-35; DOE/RL-2012-53).

New wells are generally sampled quarterly the first year after installation, semiannually the second year after installation, and annually thereafter. Biennial sampling is used for existing perimeter wells that have shown stable concentrations for several years. If irregular, decreasing, or increasing trends appear, the sampling frequencies are adjusted accordingly. Samples collected under the SAPs cited in this chapter are generally collected annually and tri-annually.

Sampling and analysis results from these programs comprehensively define the suite of contaminants associated with existing source area plumes. However, differences in sampling frequencies (annually

or triennially) 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.

6.5.1.1 Uncertainties Associated with Antimony Results

For the purposes of this risk assessment, an analyte is identified as a COPC when the groundwater concentration is greater than the published DWS. The DWS for antimony is 6 µg/L and the 90th percentile Hanford Site background level is 55 µg/L.

The 200-BP-5 OU data set contains antimony results that are reported by two different analytical methods. The majority of antimony results that are available in the HEIS database are reported using EPA Method 6010. The MDLs reported using EPA Method 6010 range between 3.5 and 237 µg/L. (Note that greater than 99 percent of the MDLs are above the DWS of 6 µg/L.) Consequently, detected antimony concentrations less than the MDL are considered estimated results and are assigned a "B" flag by the laboratory.

Antimony was also analyzed in a subset of 18 groundwater wells using EPA Method 200.8 or Method 6020. The MDLs reported using Method 200.8/6020 range between 0.1 and 1.7 µg/L. All detected antimony concentrations reported by Method 200.8/6020 were less than 1 µg/L. Chapter 4 provides the time-series plots of antimony concentrations reported by EPA Methods 6010 and 200.8 over the last 10 years. The purpose of these plots is to demonstrate the differences in analytical method sensitivity (see Appendix E).

The results of the comparisons show that analytical sensitivity associated with EPA Method 6010 is not adequate for determining the presence or absence of antimony at the DWS or the Hanford Site background level. Although antimony results using EPA Method 6010 are included in the groundwater evaluation presented in Chapter 4 and the risk assessment, these results represent false-positive results. When antimony is analyzed using EPA Method 200.8/6020, the results show that antimony is not present at levels above the DWS.

6.5.1.2 Uncertainties Associated with Hexavalent Chromium Results

The data set for total chromium is in general much more robust than the data set for Cr(VI). It is documented that filtered total chromium concentrations effectively represent Cr(VI) concentrations (WHC-SD-EN-TI-302). As such, filtered total chromium results were used as a surrogate for Cr(VI) to compute EPCs and perform comparisons to relevant standards and criteria. Summary statistics for filtered total chromium and Cr(VI) results from each exposure areas are shown in Table 6-25.

As shown in Table 6-25, the data sets for filtered total chromium are more robust than what is available for Cr(VI). There were no samples analyzed for Cr(VI) at the LERF and Gable Mountain Pond exposure areas. EPCs for filtered total chromium and Cr(VI) concentrations do not differ more than three times their concentration.

6.5.2 Uncertainties Associated with Exposure Point Concentrations

Calculating UCL for EPCs (OSWER Directive 9285.6-10) recommends using a 95 percent UCL on the mean for estimating EPCs. Section 6.2.4 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 percent UCL cannot be calculated due to small sample size
- When the 95 percent UCL is greater than the maximum detected concentration and the 97.5 percent 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 6.2.4, and the EPC logic was shown in Figure 6-6. The steps that are shown in Figure 6-6 are consistent with and follow ProUCL software and guidance. Table 6-26 provides a summary of the number of individual records considered in the UCL selection steps for the 200-BP-5 OU. A limited number of instances occurred when ProUCL calculated a 95 percent UCL that was greater than the maximum detected concentration. As shown in Table 6-26, four 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 percent Chebyshev (mean, Sd) UCL was calculated for all four analytes; these values were greater than or equal to the maximum concentration. As shown in Table 6-27, the outcome of this evaluation does not impact the groundwater risk assessment because the concentrations are considerably below their respective DWSs.

6.5.3 Uncertainties Associated with Exposure Assumptions

The exposure assumptions used for the EPA tap water exposure scenario represent an RME. For estimating the RME, 95th 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 (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 overestimate of the true risk or hazard.

6.5.3.1 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 $\mu g/m^3$, which was measured over 24 hours of use. The air concentrations of 0.087 to 0.324 $\mu g/m^3$ 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 not identified as a COPC for any of the exposure areas within the 200-BP-5 OU. The concentrations of Cr(VI) in groundwater are well below the concentration range of 2 to 10 mg/L evaluated in these studies.

Table 6-25. Summary Statistics for Cr(VI) and Filtered Total Chromium within 200-BP-5 OU Exposure Areas

Analyte Name	Filtered?	Total Samples	Total Detects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	EPC
LLWMA-1										
Chromium	Yes	226	80	35	µg/L	4.0	14	3.1	70	7.7
Cr(VI)	No	24	5	21	µg/L	2.0	2.0	4.6	14	8.2
LLWMA-2 and 216-B-63 Trench										
Chromium	Yes	153	63	41	µg/L	3.1	14	3.2	54	8.9
Cr(VI)	No	30	9	30	µg/L	2.0	2.0	2.3	8.5	3.2
WMA B-BX-BY Tank Farm										
Chromium	Yes	616	468	76	µg/L	3.1	14	3.6	114	27
Cr(VI)	No	114	100	88	µg/L	2.0	3.7	2.0	80	33
WMA C Tank Farm										
Chromium	Yes	271	62	23	µg/L	3.1	14	2.4	18	5.2
Cr(VI)	No	10	10	100	µg/L	—	—	2.4	6.9	5.5
B Plant										
Chromium	Yes	23	2	8.7	µg/L	5.0	14	5.1	5.4	5.4
Cr(VI)	No	6	3	50	µg/L	2.0	2.0	2.6	3.1	3.1
Semiworks										
Chromium	Yes	1	1	100	µg/L	—	—	5.4	5.4	5.4
Cr(VI)	No	1	1	100	µg/L	—	—	3.1	3.1	3.1

Table 6-25. Summary Statistics for Cr(VI) and Filtered Total Chromium within 200-BP-5 OU Exposure Areas

Analyte Name	Filtered?	Total Samples	Total Detects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	EPC
Liquid Effluent Retention Facility										
Chromium	Yes	39	5	13	µg/L	4.0	14	5.5	8.0	6.6
Cr(VI)	No	Not analyzed								
Gable Mountain Pond										
Chromium	Yes	8	1	13	µg/L	3.1	13	5.3	5.3	5.3
Cr(VI)	No	Not analyzed								
200-BP-5 West										
Chromium	Yes	62	16	26	µg/L	1.0	14	2.0	27	5.5
Cr(VI)	No	27	6	22	µg/L	2.0	3.7	2.3	9.3	4.0
200-BP-5 Confined										
Chromium	Yes	72	5	6.9	µg/L	3.1	14	0.20	17	6.2
Cr(VI)	No	32	1	3.1	µg/L	2.0	3.7	3.9	3.9	3.9
200-BP-5 Far-Field Area										
Chromium	Yes	36	16	44	µg/L	0.50	14	1.7	19	11
Cr(VI)	No	14	6	43	µg/L	2.0	3.7	8.3	13	11
200-BP-5 Near-River Area										
Chromium	Yes	40	34	85	µg/L	2.8	13	0.68	14	6.1
Cr(VI)	No	31	16	52	µg/L	2.0	3.7	2.4	9.7	4.7

Cr(VI) = hexavalent chromium
EPC = exposure point concentration
LLWMA = low-level waste management area
WMA = waste management area

Table 6-26. Records in EPC Selection Steps for 200-BP-5 OU

Number of Records	200-BP-5
Total analytes input to ProUCL from 200-BP-5 OU data set	380
Number of instances where highest recommended UCL was used as EPC	296
Number of instances that a UCL was not calculated and maximum detection was used as EPC	80
Number of instances that a UCL was greater than the maximum detection and maximum detection was used as EPC	4

EPC = exposure point concentration
OU = operable unit
UCL = upper confidence limit

1

Table 6-27. Comparison of 97.5% Chebyshev (Mean, Sd) UCL to DWS

Exposure Area	Analyte	No. of Samples	Maximum Detection (pCi/L)	97.5% Chebyshev (Mean, Sd) UCL (pCi/L)	DWS (pCi/L)
200-BP-5 west	Neptunium-237	12	0.57	0.67	15
Far-field area (north of Gable Gap)	Technetium-99	32	150	180	900
Near-river area	Americium-241 Iodine-129	6 12	0.13 0.25	0.18 0.25	15 1

DWS = drinking water standard
UCL = upper confidence limit

2 ### 6.5.4 Uncertainties Associated with Toxicity Assessment

3 The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of
4 uncertainty as defined in the risk assessment guide (EPA/540/1-89/002) and in the human health toxicity
5 values (Cook, 2003). These sources may include or result from the extrapolation from high to low doses
6 and from animals to humans. This is contingent on the species, gender, age, and strain differences in the
7 uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The variability of the
8 human population' with regard to diet, environment, activity patterns, and cultural factors are also sources
9 of uncertainty.

10 Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens
11 are nonthreshold contaminants. However, EPA recently has published revised cancer guidelines
12 (EPA/630/P-03/001F) in which they have modified their former position of assuming nonthreshold action
13 for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action
14 that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States
15 will be developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or
16 where the mode of action is not known. However, currently available EPA toxicity criteria for
17 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, International Toxicity Estimates for Risk database). Specifically for genotoxic contaminants, the cancer dose response model is based on high-dose to low-dose extrapolation and assumes 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.

6.5.4.1 Slope Factors for Hexavalent Chromium

The oral RfD of 0.003 mg/kg-day published by IRIS is used to develop the 2007 MTCA (WAC 173-340-720) level for Cr(VI). An oral carcinogenic potency factor has recently been published, which is derived as 0.5 $(mg/kg\text{-}day)^{-1}$ (NJDEP, 2009). If this value was used to calculate the 2007 MTCA (WAC 173-340-720) level, the groundwater concentration would decrease from 48 to 0.18 µg/L.

6.5.4.2 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. In addition, human evidence of carcinogenicity from epidemiologic studies of TCE exposure is strong for non-Hodgkin's lymphoma and more limited for liver and biliary tract cancer. The adult-based oral cancer potency factor of 0.046 mg/kg-day is for total cancer incidence based on the route-to-route extrapolation of the inhalation unit risk estimate for kidney cancer with a factor of 5 applied to include non-Hodgkin's lymphoma and liver cancer risks combined. The adult-based oral cancer potency factor estimates for separate cancer types are 0.009 mg/kg-day for renal cell carcinoma, 0.02 mg/k-day for non-Hodgkin's lymphoma, and 0.02 mg/kg-day for liver cancer. If the IRIS value of 0.046 mg/kg-day were used to calculate the 2007 MTCA (WAC 173-340-720) level, the groundwater concentration would equal 0.95 µg/L.

Ecology's CLARC data tables published a 2007 MTCA Method B groundwater cleanup level of 0.54 µg/L for TCE.[6] Contrary to the oral cancer potency factor published by IRIS, the CLARC guidance for TCE acknowledges early-life susceptibility for kidney cancer only, and age-dependent adjustment factors are applied when calculating the associated Method B formula cleanup values for this cancer potency factor. For the MTCA Method B groundwater cleanup level, the formula-based values for the three types of cancer are calculated separately, and then the harmonic mean of these three values is determined to derive the final formula-based cleanup level. Table 4 of the CLARC guidance (footnote b in the table) provides the equations used to calculate the 2007 MTCA Method B groundwater cleanup level.

[6] The basis for the MTCA Method B groundwater cleanup level value can be found in Ecology guidance available at: https://fortress.wa.gov/ecy/clarc/FocusSheets/CLARC%20guidance%20TCE%20PCE.pdf.

There were no differences identified between the oral reference dose and the inhalation reference concentrations published by Ecology's CLARC data tables and IRIS website.

6.5.5 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. In accordance with EPA guidance, this approach did not account for the possibility that constituents act synergistically or antagonistically.

6.5.5.1 Uncertainties Associated with the Native American Risk Assessments

As discussed in the introduction of this chapter, the CTUIR (Harris and Harper, 2004) and the Yakama Nation (Ridolfi, 2007) have provided exposure scenarios. These scenarios represent their traditional activities related to rural land-use patterns involving exposure assumptions that represented subsistence use. Although groundwater within the 200-BP-5 OU is not anticipated to become a source of drinking water, contaminants in groundwater were assessed using the two Native American scenarios to provide estimates of human health risks under the assumption of full-time occupancy in the future. The risks calculated using the Native American scenarios were compared with risks estimated using the EPA standard default assumptions for residential tap water use (i.e., the tap water scenario). A summary of the risk characterization results of the Native American risk assessments is provided in Appendix G, Section G1. The following discussion addresses 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 groundwater risk assessment are presented in Table 6-28. The risks and hazards can be summed to obtain a cumulative estimate of risk and hazard for all groundwater exposure pathways included in the CTUIR and Yakama Nation exposure scenarios.

Exposure parameters for drinking water ingestion, VOC inhalation, and dermal absorption differ between the Native American 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/d (1 gal/d); EPA tap water, 2.5 L/d (0.66 gal/d)
- **Inhalation rate:** CTUIR, 25 m^3/d (883 ft^3/d), Yakama Nation, 26 m^3/d (918 ft^3/d); EPA tap water, 20 m^3/d (706 ft^3/d)

Table 6-28. Summary of Cancer Risks and Noncancer Hazards for Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios

Environmental Medium/ Exposure Pathway	CTUIR Total ELCR	CTUIR Risk Drivers (Contributes > 1×10^{-6})	CTUIR HI	CTUIR Hazard Drivers	Yakama Nation Total ELCR	Yakama Nation Risk Drivers (Contributes > 1×10^{-6})	Yakama Nation HI	Yakama Nation Hazard Drivers
LLWMA-1								
Groundwater as a potential drinking water source	1.5×10^{-3}	Cobalt-60, iodine-129, technetium-99, tritium	111	Cyanide, nitrate	1.6×10^{-3}	Cobalt-60, iodine-129, technetium-99, tritium	111	Cyanide. Nitrate
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	5.8×10^{-3}	Cr(VI), technetium-99	22	Cyanide, uranium, vanadium, barium	4.3×10^{-2}	Cr(VI), technetium-99	158	Cyanide, uranium, vanadium, barium, Cr(VI), nickel, cobalt, cadmium, manganese
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	9.1×10^{-5}	Tritium	65	Cyanide
LLWMA-2 and 216-B-63 Trench								
Groundwater as a potential drinking water source	9.8×10^{-4}	Iodine-129, technetium-99, tritium	54	Cyanide	1.1×10^{-3}	Iodine-129, technetium-99, tritium	54	Cyanide
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	6.6×10^{-3}	Cr(VI)	16	Cyanide, vanadium, nickel	4.8×10^{-2}	Cr(VI)	114	Cyanide, vanadium, nickel, barium, manganese, Cr(VI), uranium
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	2.9×10^{-5}	Tritium	29	Cyanide
WMA B-BX-BY Tank Farms								
Groundwater as a potential drinking water source	1.5×10^{-2}	Technetium-99, tritium, uranium-234, uranium-235, uranium-238	255	Cyanide, nitrate, uranium	1.6×10^{-2}	Technetium-99, tritium, uranium-234, uranium-235, uranium-238	255	Cyanide, nitrate, uranium
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	7.3×10^{-2}	Cr(VI), uranium-234, uranium-235, uranium-238	141	Uranium, cyanide, cobalt, cadmium, nickel, manganese, Cr(VI), barium	5.1×10^{-1}	Cr(VI), uranium-234, uranium-235, uranium-238	1,027	Uranium, cyanide, cobalt, cadmium, nickel, manganese, Cr(VI), barium
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	2.7×10^{-4}	Tritium	158	Cyanide, cadmium

Table 6-28. Summary of Cancer Risks and Noncancer Hazards for Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios

Environmental Medium/ Exposure Pathway	CTUIR Total ELCR	CTUIR Risk Drivers (Contributes > 1×10^{-6})	CTUIR HI	CTUIR Hazard Drivers	Yakama Nation Total ELCR	Yakama Nation Risk Drivers (Contributes > 1×10^{-6})	Yakama Nation HI	Yakama Nation Hazard Drivers
WMA C Tank Farm								
Groundwater as a potential drinking water source	2.2×10^{-3}	Iodine-129, technetium-99, tritium	16	Cyanide	2.3×10^{-3}	Iodine-129, technetium-99, tritium	16	Cyanide
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	4.6×10^{-3}	Cr(VI), cobalt, cadmium, technetium-99	20	Cobalt, cadmium, vanadium	3.4×10^{-2}	Cr(VI), cobalt, cadmium, technetium-99	142	Cobalt, cadmium, vanadium, nickel, barium, uranium, manganese, Cr(VI), cyanide
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	3.3×10^{-5}	Carbon tetrachloride, chloroform, tributyl phosphate, tritium	6.6	Cyanide
B Plant								
Groundwater as a potential drinking water source	1.2×10^{-2}	Cesium-137, plutonium-239/240, strontium-90, technetium-99, tritium	20	Cyanide	1.2×10^{-2}	Cesium-137, plutonium-239/240, strontium-90, technetium-99, tritium	20	Cyanide
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	1.0×10^{-2}	Cr(VI), plutonium-239/240, strontium-90, uranium-233/234, uranium-238	19	Uranium, cadmium, manganese, vanadium, barium	7.7×10^{-2}	Cr(VI), plutonium-239/240, strontium-90, uranium-233/234, uranium-238	138	Uranium, cadmium, manganese, vanadium, barium, nickel, fluoride, Cr(VI), cyanide
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	6.7×10^{-5}	Tritium	6.1	Cyanide
Semiworks								
Groundwater as a potential drinking water source	5.7×10^{-4}	Iodine-129, strontium-90, technetium-99, tritium	1.9	None	6.1×10^{-4}	Iodine-129, strontium-90, technetium-99, tritium	1.9	None
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	3.9×10^{-3}	Cr(VI)	6.9	Barium, uranium, vanadium	2.9×10^{-2}	Cr(VI)	50	Barium, uranium, vanadium, Cr(VI)
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	8.9×10^{-5}	Tritium	0.5	None

Table 6-28. Summary of Cancer Risks and Noncancer Hazards for Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios

Environmental Medium/ Exposure Pathway	CTUIR Total ELCR	CTUIR Risk Drivers (Contributes > 1×10^{-6})	CTUIR HI	CTUIR Hazard Drivers	Yakama Nation Total ELCR	Yakama Nation Risk Drivers (Contributes > 1×10^{-6})	Yakama Nation HI	Yakama Nation Hazard Drivers
Liquid Effluent Retention Facility								
Groundwater as a potential drinking water source	4.2×10^{-4}	Tritium	2.2	None	4.6×10^{-4}	Tritium	2.2	None
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	4.8×10^{-3}	Cr(VI)	8.7	Manganese, vanadium, barium	3.5×10^{-2}	Cr(VI)	63	Manganese, vanadium, barium, nickel, Cr(VI), fluoride
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	2.4×10^{-5}	Tritium	0.7	None
Gable Mountain Pond								
Groundwater as a potential drinking water source	1.6×10^{-3}	Strontium-90, tritium	13	None	1.7×10^{-3}	Strontium-90, tritium	13	None
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	4.0×10^{-3}	Cr(VI), nickel, strontium-90	23	Manganese, barium, vanadium	3.0×10^{-2}	Cr(VI), nickel, strontium-90	165	Manganese, nickel, barium, vanadium, Cr(VI)
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	4.6×10^{-5}	Tritium	2.8	None
200-BP-5 West								
Groundwater as a potential drinking water source	1.6×10^{-3}	Strontium-90, technetium-99, tritium	66	Cyanide	1.7×10^{-3}	Strontium-90, technetium-99, tritium	66	Cyanide
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	4.6×10^{-3}	Cr(VI), cobalt, technetium-99	57	Manganese, aluminum, cobalt, cyanide, cadmium, uranium, vanadium, nickel, barium	3.4×10^{-2}	Cr(VI), cobalt, technetium-99	412	Manganese, aluminum, cobalt, cyanide, cadmium, uranium, vanadium, nickel, barium
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	9.9×10^{-5}	Tritium	35	Cyanide

Table 6-28. Summary of Cancer Risks and Noncancer Hazards for Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios

Environmental Medium/ Exposure Pathway	CTUIR Total ELCR	CTUIR Risk Drivers (Contributes > 1×10^{-6})	CTUIR HI	CTUIR Hazard Drivers	Yakama Nation Total ELCR	Yakama Nation Risk Drivers (Contributes > 1×10^{-6})	Yakama Nation HI	Yakama Nation Hazard Drivers
200-BP-5 Confined								
Groundwater as a potential drinking water source	5.1×10^{-4}	Iodine-129, strontium-90, technetium-99, tritium, 6-62ranium-234, uranium-238	15	Cyanide	5.4×10^{-4}	Iodine-129, strontium-90, technetium-99, tritium, uraium-234, uranium-238	15	Cyanide
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	4.6×10^{-3}	Cr(VI), cobalt, uranium-234	20	Manganese, barium, cobalt	3.4×10^{-2}	Cr(VI), cobalt, uranium-234	142	Manganese, barium, cobalt, vanadium, nickel, uranium, cyanide, Cr(VI)
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	5.5×10^{-5}	Tributyl phosphate, tritium	6.4	Cyanide, Cr(VI), vanadium, manganese, silver
200-BP-5 Far-Field Area								
Groundwater as a potential drinking water source	1.4×10^{-3}	Technetium-99, tritium	4.7	None	1.5×10^{-3}	Technetium-99, tritium	4.7	None
Groundwater as a potential source of steam from sweat lodge use (includes vaporized nonvolatiles)	8.4×10^{-3}	Cr(VI)	19	Manganese, vanadium, Cr(VI)	6.2×10^{-2}	Cr(VI)	139	Manganese, vanadium, Cr(VI), uranium, nickel, barium, fluoride
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	1.7×10^{-4}	Tritium	1.0	None
200-BP-5 Near-River Area								
Groundwater as a potential drinking water source	6.4×10^{-4}	Carbon-14, technetium-99, tritium	2.7	None	6.7×10^{-4}	Carbon-14, technetium-99, tritium	2.7	None
Groundwater as a potential source of steam from sweat lodge (includes vaporized nonvolatiles)	4.5×10^{-3}	Cr(VI)	7.6	Manganese, vanadium	3.3×10^{-2}	Cr(VI)	56	Manganese, vanadium, Cr(VI), uranium, barium, cobalt, fluoride
Groundwater as a potential source of steam from sweat lodge use (excludes vaporized nonvolatiles)	--	--	--	--	1.4×10^{-4}	Tritium	0.9	None

Cr(VI) = hexavalent chromium
CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index
LLWMA = low-level waste management area
WMA = waste management area

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 ELCRs and His for the Native American scenarios may be four- to five-fold greater than for the tap water scenario, drinking water ingestion, VOC inhalation, and dermal absorption exposure pathways. The COPCs are the same between each of the 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 and Yakama Nation resident scenarios. Appendix 4 of the CTUIR exposure scenario (Harris and Harper, 2004) provides equations for estimating air-phase contaminant concentrations for volatile and semivolatile COPCs in the water used to create steam in the lodge, as well as separate equations for 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 200-BP-5 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.

6.6 Ecological Risk Assessment Conclusions of the Near-Shore and River Environments

Currently, several ecological risk assessments have been conducted at groundwater OUs where the groundwater discharges to the river. The 200-BP-5 OU borders the Columbia River, between the 100-B/C OU and the 100-KR-4 OU.

Additionally, the CRC (DOE/RL-2010-117) included an ecological risk assessment that combines both screening and baseline elements. Abiotic media were compared to screening benchmarks for surface water, sediment, and pore water to identify contaminants of potential ecological concern. 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 (DOE/RL-2010-117) concluded that seven COECs were within sediment, pore water, island soil, and shoreline sediment (aluminum, chromium, Cr(VI), lead, manganese, nickel,

and nitrate). The evaluation included distinct conclusions for the Hanford Reach adjacent to the 100 Areas versus those for the Hanford Reach adjacent to a specific source OU (e.g., 100-B/C or 100-K OUs).

Seven wells that are located closest to the Columbia River (distances range between 72 m [236 ft] and 3,500 m [11,500 ft] from the river) are screened in the unconfined aquifer. Four of the seven wells selected to evaluate near-river conditions are greater than 1,000 m [3,280 ft] from the river. These wells are the closest in proximity to the river and within the 200-BP-5 OU boundaries. To determine if groundwater concentrations within the OU have the potential to impact aquatic receptors, individual measurements from the near-river wells were compared to following federal and Washington State standards and criteria:

- Nationally recommended water quality criteria, AWQC established under Section 304 of the CWA
- 40 CFR 131,"Water Quality Standards," for states not complying with Section 304 of the CWA
- WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"

A discussion of each of the seven COECs relative to 200-BP-5 OU monitoring wells closest to the river is provided below.

- Aluminum was analyzed in six of the seven wells. Aluminum was detected in 7 of 34 unfiltered groundwater samples (21 percent frequency) and was detected in one of 3 filtered groundwater samples (2.9 percent frequency). The single detection of aluminum was measured at Well 199-K-31 during November 2012. Although the filtered result was greater than the AWQC, the corresponding unfiltered aluminum result (27 µg/L) was less than the AWQC. Appendix E, Figure E-77 shows the time-series plots for filtered aluminum in Well 199-K-31 over the past 10 years (note that this figure shows two nonconsecutive detections above the AWQC). Aluminum is not retained as a COEC for the 200-BP-5 OU.

- Cr(VI) was analyzed in six of seven wells. Cr(VI) was detected in 16 of 31 unfiltered groundwater samples (52 percent frequency) with concentrations ranging between 2.4 and 9.7 µg/L. All of the Cr(VI) results (detected concentrations and minimum detection limits) were less than the state surface water quality standard (WAC 173-201A) of 10 µg/L. Cr(VI) is not retained as a COEC for the 200-BP-5 OU.

- Dissolved total chromium was analyzed in six of seven wells. Dissolved total chromium was detected in 34 of 40 filtered groundwater samples (85 percent frequency) with concentrations ranging between 0.68 and 14 µg/L. A single measurement of dissolved total chromium (14 µg/L) was reported above the state surface water quality standard (WAC 173-201A) of 10 µg/L at Well 199-K-31. The single measurement above the standard was reported on October 27, 2008, and 11 subsequent rounds of sampling reported concentrations (2.6 to 8.6 µg/L) were less than the standard. Dissolved total chromium is not retained as a COEC for the 200-BP-5 OU.

- Total chromium was analyzed in six of seven wells. Total chromium was detected in 34 of 40 filtered groundwater samples (85 percent frequency) with concentrations ranging between 0.83 and 9.7 µg/L. All total chromium results (detected concentrations and minimum detection limits) are less than the AWQC of 65 µg/L. Total chromium is not retained as a COEC for the 200-BP-5 OU.

- Lead was analyzed in six of seven wells. Lead was detected in 7 of 34 filtered groundwater samples (21 percent frequency) with concentrations ranging between 0.19 and 2.3 µg/L in filtered samples. Lead was measured (2.3 µg/L) in one of six filtered samples above the state water quality standard (WAC 173-201A) at Well 699-73-61. Lead concentrations from five previous sampling rounds

(concentrations ranging from 0.19 to 1.2 µg/L) were less than the standard of 2.1 µg/L. Lead is not retained as a COEC for the 200-BP-5 OU.

- Manganese was analyzed in six of seven wells. Manganese was detected in 16 of 34 filtered groundwater samples (47 percent frequency) with concentrations ranging between 0.22 and 66 µg/L. Manganese was detected in 20 of 34 unfiltered samples (59 percent frequency), with concentrations ranging 0.34 and 70 µg/L. All filtered and unfiltered results (detected concentrations and MDLs) are less than the 2007 MTCA (WAC 173-340-720) risk-based value of 384 µg/L. Manganese is not retained as a COEC for the 200-BP-5 OU.

- Nickel was analyzed in six of seven wells. Nickel was detected in 8 of 34 filtered groundwater samples (24 percent frequency) with concentrations ranging between 0.22 and 4 µg/L. All filtered nickel results (detected concentrations and minimum detection limits) are less than the AWQC of 52 µg/L. Nickel is not retained as a COEC for the 200-BP-5 OU.

- Nitrate was analyzed in each of the seven wells. Nitrate was detected in all of the 49 groundwater samples (100 percent frequency) with concentrations ranging between 28,200 and 26,871 µg/L. All nitrate results (detected concentrations and minimum detection limits) are less than the DWS of 45,000 µg/L. Nitrate is not retained as a COEC for the 200-BP-5 OU.

6.7 Summary and Conclusions

The following subsections provide the conclusions for the human health and ecological risk evaluations.

6.7.1 Conclusions of the Human Health 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 2007 MTCA (WAC 173-340-720) criteria to determine if individual measurements are greater than cleanup levels based on a target HI greater than or equal to 1 (see Section 4.5 for the results of the comparison).

- Individual measurements are also compared to the 2007 MTCA (WAC 173-340-720) criteria to determine if individual measurements are greater than cleanup levels based on a target risk level of 1 in 1,000,000 (1×10^{-6}) (see Section 4.5 for the results of the comparison).

- Individual groundwater measurements were compared to DWSs to identify concentrations greater than these standards (see Section 4.5 for the results of this comparison).

- Individual groundwater measurements within the 200-BP-5 near-river exposure area were also compared to AWQC and state surface water quality standards to determine if groundwater located approximately 1,000 m (3,280 ft) inland has the potential to impact aquatic organisms (see Section 4.5 for the results of this comparison).

- Cumulative cancer risks 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 6.4 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}) for cumulative

carcinogenic site risk to an individual based on RME (see Section 6.4 for the risk characterization results).

- Sums of fractions 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 6.4 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 and Section 6.5.5 for a discussion of these results).

The 200-BP-5 OU is divided into two primary areas: the near-field area and the far-field area. The portion of the OU lying to the south of the line described by Gable Butte, Gable Mountain, and Gable Gap is considered the near-field area because of its proximity to contaminant sources. The near-field area was divided into nine separate exposure areas: LLWMA-1, LLWMA-2 and the 216-B-63 Trench, WMA B-BX-BY Tank Farms, WMA C Tank Farm, B Plant, Semiworks, LERF, Gable Mountain Pond, and 200-BP-5 west. These exposure areas represent groundwater concentrations located near known or suspected plume sources.

The far-field area represents downgradient plume conditions north of Gable Gap to the Columbia River and includes the far-field exposure area and the near-river exposure area. The near-river exposure area is identified by conditions observed in groundwater monitoring wells that are generally closest to the west bank of the Columbia River and within the boundaries of the 200-BP-5 OU.

A separate confined aquifer exposure area refers to the upper basalt-confined aquifer composed of interbeds in the Columbia River Basalt Group.

As previously described, the 200-BP-5 OU was evaluated as 12 separate exposure areas. The contaminants in groundwater that are the largest contributors to calculated risks, dose, and hazards are summarized in Table 6-29. Summaries of the results for each exposure area are provided in the following subsections.

Table 6-29. Summary of Groundwater COPCs for the 200-BP-5 OU

Exposure Area	Individual Groundwater Evaluation Results (Comparison to DWS)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards	Cumulative Annual Dose (4 mrem/yr)
LLWMA-1	Cyanide Gross alpha Iodine-129 Nitrate Technetium-99 Tritium Uranium	Technetium-99 Cyanide	Iodine-129 Technetium-99
LLWMA-2 and 216-B-63 Trench	Cyanide Iodine-129 Nitrate Sulfate* Technetium-99 Uranium	Cyanide	Iodine-129 Technetium-99 Tritium

Table 6-29. Summary of Groundwater COPCs for the 200-BP-5 OU

Exposure Area	Individual Groundwater Evaluation Results (Comparison to DWS)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards	Cumulative Annual Dose (4 mrem/yr)
WMA B-BX-BY Tank Farms	Arsenic Cobalt-60 Cyanide Gross alpha Hexavalent chromium Iodine-129 Nitrate Sulfate* Technetium-99 Tritium Uranium	Technetium-99 Uranium-234 Uranium-238 Cyanide Nitrate Uranium	Cobalt-60 Iodine-129 Technetium-99 Tritium
WMA C Tank Farm	Cyanide Iodine-129 Nitrate Technetium-99 Sulfate*	Technetium-99 Cyanide	Iodine-129 Technetium-99
B Plant	Cesium-137 Cyanide Fluoride Gross alpha Iodine-129 Nitrate Plutonium-239/240 Strontium-90 Technetium-99 Uranium	Cesium-137 Strontium-90 Cyanide	Cesium-137 Iodine-129 Strontium-90 Technetium-99
Semiworks	Iodine-129	None	Iodine-129
Liquid Effluent Retention Facility	Nitrate Sulfate*	None	None
Gable Mountain Pond	Nitrate Strontium-90 Sulfate*	Strontium-90	Strontium-90
200-BP-5 west	Cyanide Iodine-129 Nitrate Strontium-90 Technetium-99	Cyanide	Iodine-129 Strontium-90 Technetium-99
Confined	Iodine-129 Technetium-99 Cyanide	Cyanide	Iodine-129 Technetium-99

Table 6-29. Summary of Groundwater COPCs for the 200-BP-5 OU

Exposure Area	Individual Groundwater Evaluation Results (Comparison to DWS)	Tap Water Scenario Primary Contributors to Cancer Risk and Noncancer Hazards	Cumulative Annual Dose (4 mrem/yr)
Far-field area (north of Gable Gap)	None identified	None identified	Iodine-129 Technetium-99 Tritium
Near-river area	None identified	None identified	Iodine-129 Tritium

* Sulfate concentrations were greater than the secondary DWS; therefore, this analyte was retained as a COPC.

COPC = contaminant of potential concern
DWS = drinking water standard
LLWMA = low-level waste management area
WMA = waste management area

6.7.1.1 Low-Level Waste Management Area 1 Exposure Area

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cyanide, iodine-129, nitrate, technetium-99, tritium, and uranium. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of iodine-129 and technetium-99 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.

Gross-alpha concentrations were also greater than the DWS; therefore, this analyte is retained as a COPC. Gross alpha is an indicator of uranium.

Based on the results of the EPA tap water (residential) risk assessment, cyanide and technetium-99 are the primary contributors to cancer risks and noncancer hazards and are, therefore, retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.1 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.2 Low-Level Waste Management Area 2 and 216-B-63 Trench Exposure Area

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cyanide, iodine-129, nitrate, technetium-99, tritium, and uranium. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of iodine-129 and technetium-99 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.

Sulfate concentrations were also greater than the secondary DWS; therefore, this analyte is retained as a COPC.

Based on the results of the EPA tap water (residential) risk assessment, cyanide is the primary contributor to noncancer hazards and is retained as a COPC, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.2 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cyanide, Cr(VI), iodine-129, nitrate, technetium-99, tritium, and uranium. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of cobalt-60, iodine-129, technetium-99, and tritium results in an annual dose equivalent of 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.

Arsenic and cobalt-60 were greater than the DWS or state groundwater cleanup levels in localized areas; these analytes are retained as COPCs. Cobalt-60 was measured above the DWS at Wells 299-E33-4 and 299-E33-7, and arsenic was measured above the DWS at Well 299-E33-16. Additionally, gross-alpha concentrations were greater than the DWS; therefore, this analyte is retained as a COPC. Gross alpha is an indicator of uranium. Sulfate concentrations were greater than the secondary DWS; therefore, this analyte is retained as a COPC.

Based on the results of the EPA tap water (residential) risk assessment, technetium-99, uranium-234, uranium-238, cyanide, nitrate, and uranium are the primary contributors to cancer risks and noncancer hazards and are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.3 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.4 Waste Management Area C Tank Farm

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cyanide, iodine-129, nitrate, and technetium-99. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of iodine-129 and technetium-99 results in an annual dose equivalent of 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.

Sulfate concentrations were greater than the secondary DWS; therefore, this analyte is retained as a COPC.

Based on the results of the EPA tap water (residential) risk assessment, technetium-99 and cyanide are the primary contributors to cancer risks and noncancer hazards and are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.4 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.5 B Plant

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cesium-137, cyanide, iodine-129, nitrate, plutonium-239/240, strontium-90, technetium-99, and uranium. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of cesium-137, iodine-129, strontium-90, and technetium-99 results in an annual dose equivalent of 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.

Fluoride concentrations were greater than the state groundwater cleanup levels in a localized area; therefore, this analyte is retained as a COPC. Fluoride was measured above the state groundwater cleanup level at Well 299-E28-24. Gross-alpha concentrations were greater than the DWS; therefore, this analyte is retained as a COPC. Gross alpha is an indicator of uranium.

Based on the results of the EPA tap water (residential) risk assessment, cesium-137, strontium, and cyanide are the primary contributors to cancer risks and noncancer hazards and are retained as COPCs, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.5 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.6 Semiworks

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, iodine-129 is retained as a COPC. The results of this evaluation indicate the need to evaluate iodine-129 for potential remedial technologies in the FS. The presence of iodine-129 results in an annual dose equivalent of 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 the results of the EPA tap water (residential) risk assessment, none of the analytes were identified as primary contributors to cancer risks or noncancer hazards. Section 6.4.4.6 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.7 Liquid Effluent Retention Facility

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, nitrate is retained as a COPC. The results of this evaluation indicate the need to evaluate nitrate for potential remedial technologies in the FS. No radiological analytes were retained as COPCs through this evaluation process.

Sulfate concentrations were greater than the secondary DWS; therefore, this analyte is retained as a COPC.

Based on the results of the EPA tap water (residential) risk assessment, none of the analytes were identified as primary contributors to cancer risks or noncancer hazards. Section 6.4.4.7 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.8 Gable Mountain Pond

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: nitrate and strontium-90. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The presence of strontium-90 results in an annual dose equivalent of 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.

Sulfate concentrations were greater than the secondary DWS; therefore, this analyte is retained as a COPC.

Based on the results of the EPA tap water (residential) risk assessment, strontium-90 is the primary contributor to cancer risks and is retained as a COPC, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.8 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.9 200-BP-5 West

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cyanide, iodine-129, nitrate, and technetium-99. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of iodine-129, strontium-90, and technetium-99 results in an annual dose equivalent of 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.

Strontium-90 was greater than the DWS in a localized area; therefore, this analyte is retained as a COPC. Strontium-90 was measured above the DWS at Well 699-50-56.

Based on the results of the EPA tap water (residential) risk assessment, cyanide is the primary contributor to noncancer hazards and is retained as a COPC, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.9 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.10 200-BP-5 Confined

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, the following analytes are retained as COPCs: cyanide, iodine-129, and technetium-99. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS. The combination of iodine-129 and technetium-99 results in an annual dose equivalent of 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 the results of the EPA tap water (residential) risk assessment, cyanide is the primary contributor to noncancer hazards and is retained as a COPC, indicating the need to evaluate potential remedial technologies in the FS. Section 6.4.4.10 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.11 200-BP-5 Far-Field Area (North of Gable Gap)

Based on the comparison of individual groundwater measurements to DWSs or state groundwater cleanup levels, no COPCs are retained. However, the combined presence of iodine-129, technetium-99, and tritium result in an annual dose equivalent of greater than 4 mrem to the total body or any internal organ. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS.

Based on the results of the EPA tap water (residential) risk assessment, none of the analytes were identified as primary contributors to cancer risks or noncancer hazards. Section 6.4.4.11 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.1.12 200-BP-5 Near-River Area

Based on the comparison of individual groundwater measurements to DWSs, state groundwater cleanup levels, AWQC, and state surface water quality standards, no COPCs are retained. However, the combined presence of iodine-129 and tritium result in an annual dose equivalent of greater than 4 mrem to the total body or any internal organ. The results of this evaluation indicate the need to evaluate these analytes for potential remedial technologies in the FS.

Based on the results of the EPA tap water (residential) risk assessment, none of the analytes were identified as primary contributors to cancer risks or noncancer hazards. Section 6.4.4.12 provides a detailed discussion of the cancer risks and noncancer hazards for this scenario.

6.7.2 Conclusions of Ecological Risk Evaluation

As stated previously, one of the purposes of this BRA is to determine whether a groundwater remedial action may be required under CERCLA to protect ecological receptors. The primary objective of the groundwater risk assessment is to identify the COECs in groundwater that require further evaluation in the FS.

As described in Section 6.6, the CRC (DOE/RL-2010-117) included an ecological risk assessment that combines both screening and baseline elements and concluded that seven COECs were present within

sediment, pore water, island soil, and shoreline sediment: aluminum, chromium, Cr(VI), lead, manganese, nickel, and nitrate.

Individual groundwater measurements from the seven wells located closest to the Columbia River (distances range between 72 and 3,500 m [236 and 11,500 ft] from the river) were compared to the following federal and Washington State standards and criteria:

- Nationally recommended water quality criteria, AWQC established under Section 304 of the CWA
- 40 CFR 131, "Water Quality Standards," for states not complying with Section 304 of the CWA
- WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"

All groundwater measurements in these seven wells were less than the standards and criteria listed above. These wells were also evaluated to determine if the seven COECs identified by the CRC (DOE/RL-2010-117) were detected at concentrations above criteria or standards. No groundwater COECs were identified for the 200-BP-5 OU based on comparison to AWQC or state surface water quality standards.

Monitoring wells from inland locations of the OU report concentrations of two of the seven COECs identified by the CRC (DOE/RL-2010-117); however, the COECs are not predicted to arrive at the river above the AWQC or state water quality standards (see Table 4-6). Cr(VI) and nitrate are identified as COPCs for inland locations because concentrations are greater than DWS. Surface water quality criteria or standards are not published for nitrate; however, modeling results presented in Chapter 5 indicate that nitrate concentrations will attenuate to less than the DWS of 45,000 μg/L within 600 years and are not predicted to be transported to the Columbia River.

As a result of limited Cr(VI) data, dissolved chromium concentrations are considered equivalent. Measured concentrations of dissolved chromium were evaluated in Section 4.5.1.2. Dissolved chromium was analyzed in six of seven near-river wells, and all but a single result was less than the state surface water quality standard of 10 μg/L. Of the 14 results from Well 199-K-31, 1 was above the state surface water quality standard of 10 μg/L; this result (13.7 μg/L) was based on Method 6010 and was reported on October 27, 2008. When dissolved total chromium was analyzed using Method 200.8, it was reported at concentrations less than the standard of 10 μg/L.

Cr(VI) was identified as a COPC in the WMA B-BX-BY Tank Farms exposure area, where concentrations ranged between 2.9 and 356 μg/L. Modeling results presented in Chapter 5 indicate that Cr(VI) concentrations will attenuate to concentrations less than the 2007 MTCA (WAC 173-340-720) level of 48 μg/L within 25 years. Cr(VI) is not predicted to arrive at the river above the state surface water quality standard.

7 Summary and Conclusions

This chapter provides a summary discussion of the 200-BP-5 OU RI activities and conclusions regarding the nature and extent of contamination present in the groundwater, the potential for migration of the contamination associated with the OU, and the potential adverse HHE risks if no action is taken to remediate the groundwater.

7.1 Summary

The completed 200-BP-5 OU RI activities, conducted as described in the 200-BP-5 RI/FS work plan (DOE/RL-2007-18) and presented in this RI report, included the following major tasks:

- **Drilling and construction of new wells:** Sixteen new monitoring wells were constructed in the 200-BP-5 OU near-field area to characterize the nature and extent of groundwater contamination and to provide further refinement of the CSM. In accordance with the RI/FS work plan, 12 wells were constructed to monitor the unconfined aquifer, and 3 wells were constructed to monitor the confined aquifer. One additional well was constructed to monitor a perched water zone near WMA B-BX-BY Section 2.1).

- **Sediment sampling (vadose zone and saturated zone):** Soil samples were collected during the drilling of the new monitoring wells. These samples were analyzed for contaminants and physical properties to define the nature and extent of contamination further; to provide additional information to support groundwater flow and transport modeling; and to provide data for the 200-DV-1, 200-EA-1, and 200-IS-1 Source OUs (Section 2.1.9).

- **Hydrologic testing:** Short-term pumping was conducted at all wells installed in the unconfined and confined aquifers to provide data (e.g., hydraulic conductivity) for calculations of flow velocity and for input to groundwater flow and transport modeling to aid in estimating aquifer transmissivity and evaluating well-specific capacity (Section 2.1.10).

- **Geophysical investigations (surface and borehole methods):** Geophysical investigations included both surface and subsurface methods. Geophysical logging of all 16 wells installed for the RI was completed using spectral gamma and neutron moisture methods. The borehole geophysical logging information was used to identify geologic features and contaminant distribution. Surface geophysical investigations using high-resolution resistivity were completed in the vicinity of WMA B-BX-BY and WMA C; seismic reflection surveys, check-shot surveys, and high-resolution seismic reflection surveys were conducted within the 200 East Area for the 200-PO-1 OU (study area overlapped a portion of the 200-BP-5 OU). The surface geophysical information was used to refine geological features further within the 200 East Area (Section 2.1.8).

- **Groundwater monitoring of new and existing wells:** Groundwater sampling was conducted during the drilling of nine wells for the 200-BP-5 OU RI. Depth-discrete samples were also collected from 14 existing wells and 4 new RCRA wells installed in the OU. The analytical results from the samples collected were used to evaluate the nature and extent (both vertically and laterally) of groundwater contaminants (Section 2.1.10).

In addition, the following tasks for the RI were completed:

- **Supplemental investigations:** Groundwater monitoring data available from January 2008 through January 2014 represented 161 groundwater monitoring wells. Of the 161 wells, 145 wells monitor the unconfined aquifer and 16 wells monitor confined aquifers. The data were used for COPC development, risk assessment, and refinement of the CSM (Chapters 4 and 6). Geophysical survey

data obtained during the 200-PO-1 OU RI and by the CTUIR from within the 200-BP-5 OU (Section 2.1.8 and Chapter 3) were used to refine the CSM and the geologic understanding of the OU. The results of aquifer tube sampling along the Columbia River segment of the OU were used as supplemental information. These aquifer tubes are used to acquire contaminant data from locations as close as logistically practical to the point where groundwater discharges into the riverbed substrate. Beginning in 2005, work has been performed to evaluate hydraulic gradients in the 200 East Area at select RCRA sites. The data are used to calculate the magnitude of the hydraulic gradients and the direction of groundwater flow in the 200 East Area.

- **Contaminant F&T modeling:** Numerical modeling was used to predict the F&T of selected COPCs present in the unconfined aquifer within the 200-BP-5 OU. These predictions were then used as a basis for evaluating potential future contaminant migration and attenuation (Chapter 5).

- **Risk evaluation:** A BRA was completed for the 200-BP-5 OU to evaluate potential HHE risks posed by the site, including an EPA tap water (residential) scenario to calculate cumulative cancer risks and noncancer hazards. An ecological risk evaluation was also performed to evaluate potential risk to aquatic receptors from exposure to OU contaminants along the Columbia River shoreline. In addition, two Native American exposure scenario evaluations were completed for comparison and informational purposes (Chapters 4 and 6).

7.1.1 Nature and Extent of Contamination

The RI sampling activities confirmed the presence of cyanide, uranium, nitrate, technetium-99, and iodine-129 as the most widely distributed contaminants in the OU unconfined aquifer at concentrations above DWSs or MTCA cleanup levels. Nitrate, technetium-99, cyanide, and uranium are associated with sources from the B Complex in the northeastern portion of the 200 East Area. Drilling of the RI boreholes revealed two notable conditions that were not previously observed in the OU:

- Concentrations of nitrate deep in the unconfined aquifer were detected in the B Plant area.

- A perched water zone was encountered that contains high concentrations of nitrate and uranium. Contamination within this perched zone is currently being remediated by the 200-DV-1 OU (DOE/RL-2014-34).

Technetium-99 is associated with the B Complex and WMA C. Arsenic, cesium-137, cobalt-60, fluoride, Cr(VI), gross alpha, plutonium-239/240, strontium-90, sulfate, and tritium were detected at concentrations in excess of DWSs; however, these contaminants are found in more localized areas within the OU. These localized areas include the following:

- Arsenic is detected at single well, 299-E33-16, at elevated concentrations in the aquifer. The elevated arsenic in this well was the result of mobilization of naturally occurring arsenic in soils after acid was added to the nearby 216-B-8 Crib (Figure 1-4).

- Cesium-137 and plutonium-239/240 are associated with the 216-B-5 Reverse Well (Figure 4-3). These two contaminants have not migrated from the vicinity of the reverse well since their disposal in the 1940s.

- Elevated groundwater Cr(VI) concentrations are found near the B Complex.

- Gross-alpha groundwater concentrations in excess of the 15 pCi/L MCL have been detected at the 216-B-62 Crib and the 216-B-5 Reverse Well. Gross alpha is an indicator for uranium and/or plutonium.

- Cobalt-60 has been detected in two wells (299-E33-4 and 299-E33-7) near the BY Cribs. The BY Cribs are located north of the WMA B-BX-BY within the B Complex.
- Sulfate above the secondary DWS of 250 mg/L is limited to three locations: the BY Cribs, the east side of WMA C, and the southeast corner of LLWMA-2.
- Elevated concentrations of fluoride are detected at one well, 299-E28-24, near the 216-B-5 Reverse Well.
- Strontium-90 is detected above the DWS at two locations: beneath the former Gable Mountain Pond, and at the 216-B-5 Reverse Well.
- Tritium is detected above the DWS in four areas: beneath the 216-B-50 and 216-B-57 Cribs (in the B Complex), beneath the B Tank Farm, and beneath the former B Pond.

Tritium and iodine-129 contamination has been intermittently detected above DWSs in the near-field area confined aquifer near B Pond. The detections were likely the result of relatively high hydraulic heads in the unconfined aquifer during Hanford Site operations and the interconnection of the unconfined and confined aquifers in this area.

7.1.2 Contaminant Fate and Transport

The simulation of contaminant F&T was completed for cyanide, Cr(VI), iodine-129, nitrate, strontium-90, technetium-99, tritium, and uranium to provide estimates of future contaminant concentrations. These contaminants were selected for transport evaluation because they occur in well-defined distributions, at high concentrations, or both, and they have the potential for future migration.

The MODFLOW and MT3DMS software programs were used to simulate groundwater flow and contaminant transport, respectively. The model domain incorporated the entire Central Plateau area, including both the 200 East and 200 West Areas and a large, contiguous surrounding area extending east to the Columbia River. The base case model simulations did not include continuing source contributions for contaminants from the vadose zone. Additional scenarios were evaluated to assess impacts from continuing sources of nitrate, technetium-99, and uranium from the vadose zone to groundwater at the B Complex and technetium-99 at WMA C, as well as the effects of continuing TEDF discharges on plume migration for the OU contaminants.

As discussed in Section 5.3, simulated time to reach DWSs using initial average concentrations (assuming no continuing sources or TEDF discharges), ranged from 0.2 years for Cr(VI) to 800 years for technetium-99. Cyanide, iodine-129, nitrate, and technetium-99 were predicted to take 450 years or more to attenuate naturally below the DWSs. Cr(VI), iodine-129, tritium, and uranium attenuate within the Central Plateau area. Cyanide, nitrate, strontium-90, and technetium-99 take longer to attenuate in the Gable Gap area (due to potentially stagnant groundwater flow conditions) than to the south in the 200 East Area.

The addition of TEDF discharges does not change the time to reach DWSs for Cr(VI), strontium-90, and tritium, and it increases the time to reach DWSs for technetium-99 and uranium by 50 years and 10 years, respectively. The addition of TEDF decreased the time to reach the DWS for cyanide by 150 years due to dispersion caused by the hydraulic influence of TEDF discharges.

The addition of the continuing source, with or without the TEDF, adds greatly to the cleanup times for nitrate, technetium-99, and uranium. Simulated time to reach the DWS increased by hundreds of years in all cases, except for the scenario including both TEDF and a continuing source for technetium-99, in

which the addition of the continuing source decreased cleanup time by 50 years (from 850 years to 800 years).

7.1.3 Risk Assessment

The BRA was prepared to identify COPCs for the OU. The risk evaluations performed for this RI were limited to assessing the contaminants currently in groundwater within the 200-BP-5 OU. This evaluation is presented in Chapter 6. For the BRA, the near-field area was divided into nine exposure areas (LLWMA-1, LLWMA-2 and the 216-B-63 Trench, WMA B-BX-BY, WMA C, B Plant, Semiworks, LERF, Gable Mountain Pond, and 200-BP-5 west), and the far-field area was divided into two exposure areas (far-field and near-river). The near-river area is identified by conditions observed in groundwater monitoring wells that are located generally within about 1,000 m (3,280 ft) of the Columbia River, adjacent to the OU. A separate confined aquifer exposure area refers to the upper basal-confined aquifer that is composed of interbeds in the Columbia River Basalt Group.

Data reduction and analysis, which included an evaluation of the results of the last 6 years of groundwater sampling and analysis, were used to identify a final data set that was used in the BRA. The BRA used the EPA tap water (residential) scenario to calculate cumulative cancer risks for radionuclides and chemicals and cumulative noncancer hazards for chemicals. The COPCs that require evaluation in the FS were identified when the following risk and hazard thresholds were met:

- When the cumulative cancer risk for chemicals was greater than 1 in 100,000 (1×10^{-5}), or when the HI for chemicals was greater than 1, as described in 2007 MTCA HHRA Procedures (WAC 173-340-708(5)(a))
- When the cumulative cancer risk for radiological analytes was greater than 1 in 10,000 (1×10^{-4}), which is described as the upper end of the NCP (40 CFR 300) risk range

In addition to the groundwater BRA, all individual groundwater measurements were compared to DWSs and 2007 MTCA (WAC 173-340-720) groundwater cleanup levels based on a target risk level of 1 in 1,000,000 (1×10^{-6}) or an HQ of 1.

The BRA and individual groundwater measurement evaluation identified 15 groundwater contaminants within the OU that met the criteria to be determined as COPCs. Table 7-1 presents the results of this evaluation, and Table 7-2 presents the results by contaminant type. The COPCs are arsenic, cesium-137, cobalt-60, cyanide, Cr(VI), fluoride, gross alpha, iodine-129, nitrate, plutonium-239/240, strontium-90, sulfate, technetium-99, tritium, and uranium. Each of the 15 of the COPCs was identified in the near-field unconfined exposure area. Three of the COPCs (cyanide, iodine-129, and technetium-99) were identified in the near-field confined aquifer and far-field exposure areas. Two of the 15 COPCs (iodine-129 and technetium-99) were identified in the near-river exposure area.

The ecological risk evaluation (Section 6.6) considered groundwater beneath the Central Plateau and areas leading to the Columbia River. Several ecological risk assessments have been conducted at groundwater OUs where the groundwater discharges to the river. The 200-BP-5 OU borders the Columbia River, between the 100-B/C OU and 100-KR-4 OU. Additionally, a separate risk assessment, the CRC (DOE/RL-2010-117), was conducted related to the Columbia River, which included an ecological risk assessment combining both screening and baseline elements. The CRC concluded that seven COECs were within sediment, pore water, island soil, and shoreline sediment (aluminum, chromium, Cr(VI), lead, manganese, nickel, and nitrate). Based on analytical results from the 200-BP-5 OU wells, none of these seven COECs were retained in the near-river area. Monitoring wells from inland locations of the OU report concentrations of two of the seven COECs (Cr(VI) and nitrate) identified by the CRC. Cr(VI) is not predicted to arrive at the river above the AWQC or state water

quality standards. Nitrate is not predicted to arrive at the river above the DWS (AWQC and state water quality standards are not published for nitrate).

Table 7-1. Summary of COPCs for the 200-BP-5 OU BRA by Exposure Area

Near-Field Area
LLWMA-1: Cyanide, gross alpha,[a] iodine-129, nitrate, technetium-99, tritium, and uranium
LLWMA-2 and 216-B-63 Trench: Cyanide, iodine-129, nitrate, sulfate,[b] technetium-99, tritium, and uranium
WMA B-BX-BY Tank Farms: Arsenic,[c] cobalt-60,[c] cyanide, Cr(VI), gross alpha,[a] iodine-129, nitrate, sulfate,[b] technetium-99, tritium, and uranium
WMA C Tank Farm: Cyanide, iodine-129, nitrate, sulfate,[b] and technetium-99
B Plant: Cesium-137, cyanide, fluoride,[c] gross alpha,[a] iodine-129, nitrate, plutonium-239/240, strontium-90, technetium-99, and uranium
Semiworks: Iodine-129
Liquid Effluent Retention Facility: Nitrate and sulfate[b]
Gable Mountain Pond: Nitrate, sulfate,[b] and strontium-90
200-BP-5 West: Cyanide, iodine-129, nitrate, strontium-90,[c] and technetium-99
200-BP-5 Confined: Cyanide, iodine-129, and technetium-99
Far-Field Area
Far-Field Exposure Area: Iodine-129, technetium-99, and tritium
Near-River: Iodine-129 and tritium

a. Gross alpha is an indicator of the presence of uranium.

b. Groundwater concentrations exceed secondary drinking water standard.

c. Retained as a COPC due to localized contamination.

COPC = contaminant of potential concern
Cr(VI) = hexavalent chromium
LLWMA = low-level waste management area
WMA = waste management area

Table 7-2. Groundwater COPCs for the 200-BP-5 OU by Contaminant Type

Metals	Radionuclides	Anions
Arsenic Hexavalent Chromium Uranium	Cesium-137 Cobalt-60 Gross alpha Iodine-129 Plutonium-239 Strontium-90 Technetium-99 Tritium	Cyanide Fluoride Nitrate Sulfate

A Native American risk assessment was performed using two exposure scenarios provided by the CTUIR (Harris and Harper, 2004) and the Yakama Nation (Ridolfi, 2007) for informational purposes. These scenarios reflect exposure conditions that assume groundwater from the OU is restored to its highest beneficial use, used as a drinking water source, and used to make steam in a sweat lodge. The potential routes of exposure to groundwater evaluated in these scenarios include ingestion of drinking water, dermal contact, and inhalation of volatiles and semivolatiles during household and sweat lodge activities. For comparison, the risks posed from exposure to groundwater used as a drinking water source were evaluated using the EPA tap water scenario equations. The results of the Native American risk and EPA tap water evaluations demonstrate that the risks associated with the scenarios exceed applicable WAC 173-340-707 and EPA thresholds for cumulative risk. Additional analytes contributing to risk in the CTUIR scenarios include aluminum, barium, cadmium, cobalt, manganese, nickel, and vanadium in the near-field area; manganese, barium, and cobalt in the confined aquifer exposure area; and manganese and vanadium in the far-field and near-river exposure areas. Additional analytes contributing to risk in the Yakama Nation scenarios included barium, cadmium, carbon tetrachloride, chloroform, cobalt, nickel, manganese, uranium-234, uranium-235, uranium-238, and vanadium in the near-field area; barium, cobalt, manganese, nickel, uranium-234, and vanadium in the near-field confined aquifer exposure area; barium, nickel, and vanadium in the far-field exposure area; and barium, cobalt, manganese, and vanadium in the near-river exposure area, with many of these analyte concentrations within Hanford Site groundwater background values (DOE/RL-96-61).

7.2 Conclusions

The data and information collected during the RI were of sufficient quantity and quality to support the following determinations:

- The RI activities, which included drilling, groundwater sampling, and geophysical investigations, were sufficient to support a BRA and an evaluation of the nature and extent of contamination.
- The observed groundwater contamination conditions and groundwater F&T modeling, including the refinement of the CSM and CEM, confirm a basis for the FS, and sufficient data have been collected to support the preparation of the FS.
- Fifteen COPCs were identified for the OU: arsenic, cesium-137, cobalt-60, cyanide, Cr(VI), fluoride, gross alpha, iodine-129, nitrate, plutonium-239/240, strontium-90, sulfate, technetium-99, tritium, and uranium.
- Groundwater within the near-field area of the OU is contaminated above applicable DWSs for all 15 COPCs. Groundwater within the near-field confined aquifer area is contaminated above applicable standards for three COPCs: cyanide, iodine-129, and technetium-99. Three of the 15 COPCs (iodine-129, technetium-99, and tritium) were identified as COPCs in the far-field exposure area, and 2 of the 15 COPCs (iodine-129 and tritium) were identified as COPCs in the near-river exposure area.
- The ecological portion of the risk assessment did not identify any COECs.
- Modeling simulations predict that under a no action scenario, cyanide, nitrate, technetium-99, and iodine-129 will take more than 400 years to attenuate below DWSs, and that current groundwater plumes will not migrate northward through the Gable Gap and toward the Columbia River.

Based on the evaluations and analysis conducted for this FS, the following conclusions are made:

- The observed groundwater contamination confirm the basis for an FS.

- An FS is warranted.
- Sufficient data have been collected to support the preparation of the FS.

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Appendix A

Annotated Bibliography

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A1 Introduction A-1

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Terms

AEA	*Atomic Energy Act of 1954*
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
COPC	contaminant of potential concern
CSM	conceptual site model
CY	calendar year
D2EPHA	di-2-ethylhexyl phosphoric acid
DCG	derived concentration guideline
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EDTA	ethylenediamine tetra acetic acid
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ETF	Effluent Treatment Facility
FS	feasibility study
FY	fiscal year
gpm	gallons per minute
H_2	Hanford formation sand-dominated facies
H_3	Hanford formation gravel-dominated facies
HDW	Hanford Defined Waste (model)
HEIS	Hanford Environmental Information System
HPCP	Hanford Pathline Calculation Program
K_d	distribution coefficient
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
LWDF	Liquid Waste Disposal Facility

MCL	maximum contaminant level
MMT-DPRW	Multicomponent Mass Transport Discrete-Parcel-Random-Walk
ORP	DOE, Office of River Protection
OU	operable unit
PCB	polychlorinated biphenyl
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion
PUREX	Plutonium-Uranium Extraction (Plant)
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	reduction-oxidation
RESRAD	RESidual RADioactivity (dose model)
RI	remedial investigation
RL	DOE, Richland Operations Office
SAC	System Assessment Capability
SAP	sampling and analysis plan
SIM	Soil Inventory Model
TBP	tributyl phosphate
TLM	Tank Layer Model
TSD	treatment, storage, and disposal
UPR	unplanned release
WIDS	Waste Information Data System
WMA	waste management area
WSTRS	Waste Status and Transaction Record Summary

A1 Introduction

An annotated bibliography is provided in this appendix that identifies the technical documents that describe the process chemistry for the various liquid effluent wastes discharges (Table A-1), waste inventory-related documents (Table A-2), information on the vadose zone overlying the 200-BP-5 Groundwater Operable Unit (OU) (Table A-3), and information on the groundwater within the OU (Table A-4). This annotated bibliography (Tables A-1 through A-4) was the result of an extensive review of historical information that was conducted as part of the data quality objective (DQO) process for the 200-BP-5 OU, which is documented in *Data Quality Objective Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process* (WMP-28945), which was published as Rev. 0 in 2004, and Rev. 1 was issued in 2008. These documents were provided in Appendices A through D of WMP-28945.

Since the completion of WMP-28945 in 2004, many additional reports (e.g., U.S. Department of Energy [DOE], Richland Operations Office [RL] and Pacific Northwest National Laboratory [PNNL] documents) have been issued that contain information relevant to the 200-BP-5 OU. Table A-5 includes a list of the major documents published since 2004.

Table A-1. Process Chemistry Bibliography

Document	Summary
Hanford Engineer Works Technical Manual, Sections A, B, and C, HW-10475	This document discusses the various separation processes that were completed for the refinement of plutonium. The 221-B Building (B Plant) created the following separation wastes: coating removal waste, metal waste, and first- and second-cycle wastes. All are explained in the following text. The coating waste is a combination of the aluminum silicate jackets with trace amounts of tin, copper, and other heavy metals dissolved by sodium hydroxide and washwater containing nitric acid. The resulting solution was sufficiently alkaline for transfer to the 241 Building (e.g., B-BX-BY Tank Farms). Several radioactive contaminants were associated with this waste based on cooling requirements, which included strontium, yttrium, zirconium, cadmium, ruthenium, tellurium, iodine, cesium, barium, lanthanum, cerium, and praseodymium. In addition, several other fission products were contained in the waste based on fission yield. The uranium in this process was described as uranyl nitrate [$UO_2(NO_3)_2$]. The metal waste is a combination of mixed fission products, uranyl nitrate hexahydrate ([$UO_2(NO_3)_2$ + 6H2O] or UNH), various metals, some plutonium, and various solutions (e.g., HNO_3, H_2SO_4, H_3PO_4, $BiPO_4$, $NaNO_2$, $NaNO_3$, NaOH, Na_2CO_3, and H_2O). There was discussion as to whether the plutonium may be oxidized to the hexavalent state; however, this document concluded that no appreciable amount of hexavalent plutonium would be formed based on pilot and plant operations. The addition of sodium nitrite and sulfuric acid ensured that plutonium was reduced to the four-valence state. The sulfate also was used to complex the uranium and prevent precipitation with phosphate. The metal waste was nearly neutralized with carbonate caustic (e.g., Na_2CO_3). This produced an almost completely soluble waste at minimum total volume. As a cost savings, it was preferred that the neutralization be held short of neutral (e.g., pH of 7) so difficult-to-dissolve precipitates would not form. Later, because of tank corrosivity, the pH was raised to 10.5. This waste stream was temperature sensitive; above 75°C (167°F), one-half to three-quarters of the metal waste would precipitate in 5 days. This waste was later found to complex uranium as a carbonate and phosphate. The first and second decontamination cycles were completed to reduce the fission products in the bismuth-phosphate cake from approximately 3 Ci to less than 0.001 percent of the total fission activity. Two steps were employed during the decontamination process. The first step was the addition of a sodium bismuthate ($NaBiO_3$) and sodium dichromate ($Na_2Cr_2O_7$) to oxidize the plutonium. After plutonium oxidation, bismuth-subnitrite solution was added to precipitate bismuth phosphate and insoluble fission products. In addition, ceric and zirconium phosphate [e.g., $CePO_4$ and $Zr_3(PO_4)_4$] were added as scavengers. As a final step, phosphoric acid was added to complete precipitation. The precipitate was dissolved in nitric acid and sent for waste disposal. The second step was to remove the phosphate-soluble fission products. This was completed by jetting the oxidized product solution to a precipitator and reducing with ferrous ammonium sulfate [$FeSO_4{\cdot}(NH_4)_2SO_4{\cdot}6H_2O$] in the presence of ammonium silicofluoride. Then bismuth subnitrite in nitric acid was added, followed by addition of phosphoric acid to complete the precipitation.

Table A-1. Process Chemistry Bibliography

Document	Summary
Hanford Engineer Works Technical Manual, Sections A, B, and C, HW-10475 (cont'd.)	The precipitate was washed with water twice in the centrifuge to remove soluble fission products. The remaining solution was combined with the dissolved precipitate from the first step, neutralized to a pH of 7 with sodium hydroxide, and sent to the tank farms. The neutralized waste contains a quantity of suspended solids of phosphate and bismuth hydroxides, scavenger metals, chromium, iron, and silicofluoride. It was believed that the 90 percent of the activity would be precipitated during storage. The second-cycle waste was similar to the first-cycle waste, except that the scavengers were not added. The 224 Building was used as the concentrator building for the lanthanum-fluoride/bismuth-phosphate cross-over cycle. According to the plutonium flow sheet, the bismuth-phosphate cake was sent to this facility in a nitric acid solution with approximately 3 Ci of fission products. Phosphoric acid is added to aid in the solubility of bismuth phosphate. To ensure plutonium in an oxidized state, potassium permanganate is added. Hydrofluoric acid is added with a lanthanum salt solution consisting of lanthanum, water, and nitric acid to precipitate the insoluble fluoride radionuclides. The precipitate was dissolved with water and sent for neutralization. The waste slurry contained lanthanum fluoride, nitric acid, hydrofluoric acid, manganese oxide, and water. The product solution then was reduced with the addition of oxalic acid, lanthanum salt solution, hydrofluoric acid, and potassium permanganate. The solution was decanted and sent for neutralization. The waste solution contained various nitrates (i.e., sodium, potassium, chromium, manganese, and ammonium), and acids (i.e., hydrofluoric, nitric, and phosphoric). The product precipitate then was dissolved with potassium hydroxide and water. After the waste solutions were neutralized, it was considered safe to send to the ground because it contained less than 0.001 percent of the total fission activity and about 4 percent of the product. Waste was first directed to the 241-B-361 Settling Tank and later to the 216-B-7A&B Cribs. The 231 Isolation Building's active wastes were associated with laboratory sinks, washings from process cells, and water from water aspirators. This waste was neutralized with sodium hydroxide and sent to the 216-Z-10 Injection/Reverse Well in the 200 West Area and, therefore, is not considered in the remainder of this document. The 241-B-361 Settling Tank was used to settle out solids before overflowing to the 216-B-5 Injection/Reverse Well. It was overfilled with jetted waste solution and then allowed to drain to the overflow pipe connecting to the reverse well. The 216-B-5 Injection/Reverse Well received waste overflow from the 241-B-361 Settling Tank. Cooling water from the jacket process vessels and metal storage was sent to the 216-2-1 Ditch (e.g., 216-B-2-1). The ditch was never lined and received up to 1,892,000 L (500,000 gal) per shift during full operations. A subsequent swamp/pond was created, which was more than 243.8 m (800 ft) long. The location of the ditch was approximately 243.8 m (800 ft) southeast of the B Tank Farm, which drained to the swamp/pond (e.g., later known as the 216-B Pond [B Pond]). The activities from these sources were considered innocuous. Powerhouse (284B) and water treatment effluents were sent to an open drainage ditch approximately 152.4 m (500 ft) south of the Hot Semiworks Plant (i.e., central portion of the 200 East Area). The drainage ditch is estimated to be more than 914.4 m (3,000 ft) long. Hot laboratory sink waste is disposed to a dry well (e.g., 216-B-6 Injection/Reverse Well) near the northwest corner of the 222 Building.

Table A-1. Process Chemistry Bibliography

Document	Summary
REDOX Technical Manual, HW-18700-DEL	This document not only provided the process chemistry for the REDOX process, but also provided the first criteria for effluent waste disposal to the ground, known as cribbing. The REDOX waste stream was determined to produce 476 g/L of uranium. It also was expected that the plutonium concentration would be approximately 10 ppb of uranium concentration (e.g., 0.476 µg/L). Cribbing was determined to be necessary, because it was not practical to store large volumes of waste with low concentrations of radioactivity. The cribbing criteria for radionuclide wastes to the soil column are explained in this document. The criteria were based on the adsorption of a large fraction of the radionuclides to soils in the soil column, decay of the short-lived radionuclides before they reach the river (e.g., 10 to 20 years), and dilution of the waste by the groundwater. The maximum concentrations quoted in this document were the following: plutonium was limited to 0.5 µg/L, beta emitters were to be less than 4 µCi/L, and pH was to be greater than 5. However, these levels were being reviewed for groundwater quality measures, and more conservative targets were being implemented, with plutonium at 0.024 µg/L and beta emitters at 0.1 µCi/L. The Health Instrument Division postulated that 90 percent of the plutonium and fission products are retained on the Hanford sediments by ion exchange or adsorption. In addition, the thought was that plutonium was best retained at a pH of 5 to 7, while fission products were best retained at a pH of 8. However, a pH greater than 5 was sought so alkaline soils would not be leached and a preferential pathway would not form in the soil column. The cribs from the REDOX process received redistilled condensate, building drainage, and hexone washes. The condensate carried over small concentrations of radioactive constituents in the vapor because of the vapor velocity exceeding the rate of settling. Therefore, the condensate was sent through de-entrainment columns for partial removal of entrained droplets.
Uranium Recovery Technical Manual, HW-19140	To employ the uranium recovery process, a phased construction approach was established. Phase II and Phase III included addition to the 200 East Area tank farms (e.g., slurry pits, blending tanks, and acidification tanks) and piping connections from the 200 East Area tank farms and 221-U Plant (U Plant), respectively. The feed for the Uranium Recovery Plant consisted of metal waste from the bismuth phosphate and REDOX processes. The bismuth-phosphate metal waste stored in the BX, BY, and C Tank Farms was dissolved and sent to the TBP Plant (221-U Building). The metal waste consisted of the following: mixed fission products, uranyl nitrate hexahydrate ($[UO_2(NO_3)_2 + 6H2O]$ or UNH), various metals, some plutonium, and various solutions (HNO_3, H_2SO_4, H_3PO_4, $BiPO_4$, $NaNO_2$, $NaNO_3$, NaOH, Na_2CO_3, and H_2O). The uranyl-nitrate solution was calculated to contain 59.2 g/L of uranium.

Table A-1. Process Chemistry Bibliography

Document	Summary
Uranium Recovery Technical Manual, HW-19140 (cont'd.)	The first step consisted of dissolving the sludge metal waste materials precipitated in the underground storage tanks (e.g., B, BX, BY, and, C). The sludge from the metal waste was determined to be primarily uranyl sodium carbonate [$Na_4UO_2(CO)_3$] and uranyl sodium phosphate [$NaUO_2PO_4$]. The solubility of $Na_4UO_2(CO)_3$ is reported to be very soluble in water (e.g., 143.8 g/L) at low temperatures (30°C [86°F]). The $NaUO_2PO_4$ is reported as insoluble (e.g., less than 1 g/L) in low concentrations of $Na_4UO_2(CO)_3$ and even low solubility in water. These sludge heels were sluiced by supernatant and pumped with a sludge pump to a slurry accumulator (241-WR Vault). The supernatant solution contained more $Na_4UO_2(CO)_3$ in the second and third tanks of the cascading tanks than in the first tank as a result of cascading before the precipitation was complete in the first tank. Possible difficulties associated with transfer of the slurry included plugged lines and erosion and corrosion of pipelines. It was concluded that the penetration rate for the velocity of the solution was low (e.g., 30 mL/yr in 90-degree elbows and almost no erosion in straight runs) and that the pipes could handle the cascading of any sluicing action. The next steps were the preparation step (adding feed to nitric acid), and the solvent extraction step (TBP in a paraffin hydrocarbon is floated up through a column to extract the uranium at the same time a nitric acid scrub containing ferrous ammonium sulfate [$(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$] and sulfamic acid [$H_3NO_3S$] sinks through the column). The TBP complexes and separates the uranium from an acid scrub solution, which retains the fission products and plutonium. The acid scrub solution is drained and combined with portions of nonrecyclable TBP solvent and neutralized with sodium hydroxide. Occasionally, excessive amounts of uranium were reported in the pooled waste; this was reprocessed at times, and other times, it was sent to the neutralization tank. The neutralization process used sodium hydroxide to raise the pH to 9.5 or higher to minimize corrosion of the mild steel tank liners. The neutralized waste solutions then were sent to the evaporator to be concentrated to about half the original volume and then returned to the underground storage tanks. Four waste streams (e.g., high-activity liquids, low-activity liquids, cooling water and steam condensate, and gaseous waste) were produced from the uranium recovery process. High-activity liquid wastes from the acid scrub and TBP solvent waste were neutralized and sent to the tank farms, which included the B-BX-BY Tank Farms. The low-activity wastes were sent to the 216-ER and 216-WR Cribs. The process cooling water and steam condensate were sent to ponds in the 200 West Area, and gaseous waste was sent to stacks. The high-activity wastes that are sent to the tank farms are decontamination column waste and solvent recovery column waste that has been neutralized and concentrated and contained the following: H_3PO_4, Na_3PO_4, HNO_3, $NaNO_3$, $NaHSO_4$, Na_2SO_4, $Fe(NH_4)_2(SO_4)_2$, $Fe(OH)_3$, NH_2SO_3H, NH_4OH, uranium or UNH, plutonium, mixed fission products, water, and trace amounts of NaCl and TBP. The specific gravity of the concentrated waste was 1.4.

Table A-1. Process Chemistry Bibliography

Document	Summary
Uranium Recovery Technical Manual, HW-19140 (cont'd.)	The low-activity waste sent to the 216-ER (e.g., 216-B-12 Crib) and 216-WR Cribs (e.g., 200 West Area cribs) was condensate from the waste concentrator. Two concentrators delivered condensate to the waste concentrator: the feed concentrator and the product concentrator. The feed concentrator received dilute uranium solution [e.g., HNO_3, Na_2SO_4, Na_2HPO_4, $NaNO_3$, $UO_2(NO_3)_2$ or UNH, plutonium, and mixed fission products] from the feed receiver. As the solution was heated, vapors were routed to a bubble-cap stripping column where nitric acid was scrubbed from the vapor by a water reflux and the acid-free vapors were condensed and routed to the condensate receiver tank and waste concentrator tank. The product concentrator received uranium separated solution [e.g., UNH, H_3PO_4, NA_3PO_4, HNO_3, $NaNO_3$, NaHSO4, $NaHSO_4$, Na_2SO_4, $Fe(NH_4)_2(SO_4)_2$, $Fe(OH)_3$, NH_2SO_3H, NH_4OH, plutonium, mixed fission products, water, and trace amounts of TBP] from the feed preheater. Briefly, the dilute uranium solution (entering the evaporator, mixes with more concentrated solution upon heating vapors) rises into the vapor space of the evaporator. Liquid de-entrainment is accomplished by interception on an impingement plate and lowered vapor velocity. The total amount of de-entrained water vapor contains approximately 1.5 to 2 weight-percent nitric acid; this was then routed to the nitric acid fractionator and then to the waste concentrator. The waste concentrator sent the waste to the 241-WR Diversion Station Vault to determine if cribbing criteria had been met. The 216-ER Crib received up to 100 gpm for up to 8 hr/d. The pH of the waste stream was monitored, and a limestone tank was installed to ensure that the waste stream was greater than pH of 5. Several tests were made to ensure that the waste did not cool appreciably during transport and that the limestone would not be degraded causing clogging of the crib.
Routine UR Plant Strontium Scavenging with $Ca(NO_3)_2$, HW-36293	This document, written in April 1955, reported findings from using an additional scavenging process, calcium nitrate, to scavenge strontium in the Uranium Recovery Plant. Laboratory studies reported that the addition of calcium nitrate after the nickel sulfate addition, provided the pH of the waste is controlled between 8 and 10, provided between four- to six-fold decontamination of strontium based on the temperature.
Waste Management Technical Manual, ISO-100	This manual describes, in detail, most of the steps in the waste fractionization process conducted at the 221-B Facility from 1967 to approximately 1992. Several key sections, most notably waste handling, are missing and may not have been prepared. The waste fractionization process was designed to remove select long-lived fission products that were capable of posing long-term environmental hazards but also were capable of being used for beneficial purposes. The primary radionuclides of interest were strontium-90, cesium-137, cesium-144, promethium-147, and rare earths, with technetium-99, americium-241, rhodium/palladium, antimony-125, neptunium-237, and plutonium-239 as secondary interests. The primary feedstock for waste fractionization was the acid waste from the REDOX and PUREX processes. Additional sources were the acid waste sludge material associated with each plant where the waste stream had been stored in the 241-A/S series tank farms, and the associated acid waste sludge supernatants. Three processes were developed for the feedstock and were carried out in different parts of the 221-B Facility. All wastes required pre-treatment to remove solids.

Table A-1. Process Chemistry Bibliography

Document	Summary
Waste Management Technical Manual, ISO-100 (cont'd.)	The tank farm supernatant wastes were treated by passing the stream through a series of ion-exchange columns with resins designed to remove cesium-137. In the course of operations, the resins slowly lost the ability to attract cesium-137, and isotope breakthrough would be detected. At that point, water or dilute NaOH was washed through the column, followed by ammonia-based solutions to ready the resins for isotope removal. A heated ammonia solution removed (eluted) the cesium-137 and was followed by water or dilute NaOH rinses to remove residual ammonia. The cesium-137-rich solution was concentrated and then packed in containers and stored in pools. Ammonia driven off in the concentration process was recovered and used to augment the ammonia washes. PUREX acidic waste was received directly from the plant or following only several weeks of storage in tank farms. The wastes were targeted for strontium-90, cesium-137, cesium-144, promethium-147, and rare earth recovery and used a solvent-extraction process with D2EHPA as the extractant in a TBP diluent. The first process step was centrifugation to separate particulate matter from the liquid. The solids were washed out with a strong NaOH solution, centrifuged again, and sent to the tank farms for storage. The fission-product-rich solution was passed through a four-column separations process, which in the first (extraction) column, separated cesium-137 from the remainder of the constituents. This stream was sent to underground storage for later recovery of cesium-137. In the second, or scrub column, NaOH was added to adjust pH levels. Strontium-90 was removed from the stream in the third (partitioning) column with the addition of nitric acid. The remaining cesium-144, promethium-147, and rare earth stream was treated with a D2EPHA/TBP organic in a fourth column to separate out cesium-144. The remaining material was sent to a batch contactor and, following another pH adjustment, NaOH was added as a chelating agent. After this step, organic D2EPHA/TBP was added to remove the promethium-147 and rare earths. As a final step, the organic solutions were treated with NaOH and citrate and could then be reused. The third process addressed the acid waste sludge material in the A and S Tank Farms. It started with slicing of sludge wastes out of the tanks and transporting it to the 221-B Facility. This process actually prepared the feed for the acidic waste process described in the previous text. The source material consisted of aluminum-, iron-, and sodium-nitrates with minor concentrations of rare earths, promethium-147, and strontium-90. A nitric acid addition acidified the waste stream and was followed by sequential additions of sodium sulfate, hydroxyacetate, sodium hydroxide, and lead nitrate in a precipitation tank. Lead sulfate was formed and carried the strontium-90, promethium-147, and rare earths through the sequence. The solution was next sent to a centrifuge where the aluminum, iron, and sodium were removed with successive washes of sodium sulfate and sodium nitrate solutions. In this step, the lead sulfate was converted to lead carbonate and was next sent to the extraction column for the stepwise recovery of cesium-137, strontium-90, cesium-144, promethium-147, and rare earths. When strontium-90 was separated from the solvent extraction process, it was treated to a similar volume-reduction process used for cesium-137. The solution was sent to a concentrator, which boiled off a large fraction of the liquids. The residual material then was packaged in high-integrity containers and placed in storage pools.

Table A-1. Process Chemistry Bibliography

Document	Summary
Waste Management Technical Manual, ISO-100 (cont'd.)	The three processes generated eight relatively low-level waste streams, which required storage in tank farms. To lower that volume, a continuously operating waste concentrator boiled off excess water, which carried with it radionuclides, volatiles, and organics. This material was condensed off-line and was sent to the 216-B-62 Crib. The residual concentrated waste material was sent to the B-BX-BY Tank Farms for storage. Steam condensate associated with 221-B Facility operations was sent to the 216-B-55 Crib. The 216-B-2/-3 Ditches and 216-B-3 Pond system received cooling water waste, while chemical sewer waste was discharged to the 216-B-63 Ditch. With the added waste, water volume in the tanks was driven off with two in-tank solidification units, large heaters placed into several 241-BY underground tanks. Heated air was injected into the liquid and generated water vapor from the waste. Vapors were condensed offline and sent to either the 216-B-50 or the 216-B-57 Cribs, which received 54.8 million L (14.5 million gal) and 84.4 million L (22.3 million gal), respectively.
Hot Semiworks Manual Part I, HW-22955	This document provides a detailed description of the 201-C Facility (Hot Semiworks Plant) and equipment, plus supporting facilities, all of which were designed to provide a large-scale test bed for the REDOX process under realistic radiological conditions. REDOX testing ran in the 1952 to 1953 time frame and yielded improved process understanding. Additional facilities included the aqueous chemical makeup and control (271-C), solvent handling (276-C), gas preparation (215-C), waste storage (241-C), and ventilation (291-C) buildings, plus basic support functions such as change houses, offices, and shops. Three soil-column disposal sites were initially constructed for the plant: the 216-C-1 Crib, which received process condensates and process wastes; the 216-C-2 Injection/Reverse Well, which received ventilation system condensates; and the 216-C-3 Leaching Pit, which received wastes from the 276-C Solvent Handling Building. In addition, the foundation excavation for a planned 221-C bismuth-phosphate plant was used as a pond for cooling water discharges. In addition, a large holding tank (241-CX-70) was constructed to hold high-level wastes. The 201-C Facility consisted of three cells (A, B, and C) with equipment representative of that in the REDOX Facility. Fuel rods were loaded into the A cell, dissolved, and the charged solutions readied for testing. The liquid was pumped into simple or compound liquid solvent extraction or scrubbing columns located in the B cell. The liquids generated by the columns either were passed along to the next column in the treatment train in the B cell or were collected in tanks in the C cell where the aqueous and solvent liquids were treated, concentrated, and collected for disposal.
Hot Semiworks REDOX Studies, HW-31767	Twelve separate REDOX runs were made at the Hot Semiworks Plant before the plant was decontaminated and modified for PUREX process testing. Each run was discussed in a separate report but is summarized in this document. The 216-C-1 Crib received 13.9 million L (3.7 million gal) of water with 16.5 kg of uranium, 1.5 g of plutonium, and 328 Ci of beta-emitting fission products through June 1954. This includes wastewater from REDOX processing and cleanout water used in preparation for PUREX testing.

Table A-1. Process Chemistry Bibliography

Document	Summary
Standby Status Report Hot Semiworks Facility, HW-52860	This report summarizes the plant's status following 10 months (May 1955 to March 1956) of PUREX testing in which 18 separate process studies were completed. Specifically, the document notes that the 216-C-1 Crib had received approximately 4.4 million L (1.2 million gal) of water during the studies, in which 1,419 kg of uranium, 7 g of plutonium, and 10,400 Ci of beta emitters had been discharged to the soil column. The 216-C-2 Injection/Reverse Well, 216-C-3 Crib, 216-C-4 Crib, 216-C-5 Crib, and 216-C-6 Crib were used during this testing campaign, and most received minor amounts of liquid and radionuclides.
Hot Semiworks Strontium-90 Recovery Program, HW-72666	A production program was conducted at the Hot Semiworks Plant in 1960 through 1961 to separate mega-curie quantities of strontium-90 for thermoelectric power supplies. The program was a developmental test bed for a solvent-extraction process using an organic solvent D2EPHA-extraction process flowing through an inorganic, strontium-90-rich PUREX waste stream. Reported process development included cold and hot runs of material. Waste generation was reported as 416,400 L (110,001 gal) of process condensates through the duration of this report. The process ran through 1967, generating an unknown quantity of waste and disposing it to unidentified waste sites.
WIDS (queried in 2006)	The WIDS database indicates that 23.4 million L (6.2 million gal) of high-salt, neutral/basic waste was discharged to the 216-C-1 Crib. Most of this waste was discharged before the start of the PUREX test processing. The 216-C-3 Crib received 5 million L (1.3 million gal) of acidic waste.
The Fate of Organics from Hot Semiworks in CR Vault, HNF-4869	This document discusses 25 organic wastes received from the 201-C Facility (Hot Semiworks Plant). Although no process descriptions are provided, it may be assumed the waste sites have received at least small quantities of each organic and would form the basis for Semiworks-specific potential COCs. The compounds included hexone, citric acid, normal paraffin hydrocarbon (e.g., kerosene), TBP, EDTA, and D2EPHA.
PUREX Technical Manual – Chemical Processing, Volume I & II, HW-31000, RHO-MA-116, and WHC-SP-0479	These documents present detailed descriptions of the plutonium-uranium extraction process and together provide insight as to how the process changed over time. Most waste sites associated with PUREX are in the 200-PO-1 OU. Interest in PUREX processes for the 200-BP-5 OU is centered around the nitric acid recovery step, which was processed at the E-F11 and E-F6 Waste Concentrators. The residual waste from this process step became three of the five feedstocks used by the waste fractionization process at B Plant. The major change affecting the material process by the waste concentrator appears to be related to changes in fuel rod cladding material.

Table A-1. Process Chemistry Bibliography

Document	Summary
PUREX Technical Manual – Chemical Processing, Volume I & II, HW-31000, RHO-MA-116, and WHC-SP-0479 (cont'd.)	In all variations of the PUREX process, following dissolution of the fuel rods in boiling nitric acid and removal of the cladding material, the dissolved uranium/plutonium/fission product/nitric acid solution was introduced at the middle of the carboxylic acid solvent extraction column, where plutonium and uranium were removed from the descending inorganic solution by a rising organic extractant and diluent. The residual inorganic was highly radioactive with fission products and highly acidic. The waste stream was collected out of the bottom of the carboxylic acid column and, following chemical manipulations in a feed tank, was sent to either the E-F11 or the E-F6 Waste Concentrator, depending on the date of the process. In either of the processes, the waste concentrators boiled off about 80 percent of the nitric acid, which was collected and liquefied in a condenser and prepared for reuse. The residual material was discharged to a holding tank in preparation for treatment to protect underground storage tanks. For the first decades of PUREX operations, a 50 percent NaOH solution was mixed, along with sodium carbonate, to neutralize the residual nitric acid. In the second phase, nitric acid was neutralized by the addition of sucrose sugar, which denitrified the solution by conversion of HNO_3 to NHO_3. After this step, the highly radioactive, fission-product-rich stream was sent to the boiling waste A and AX Tank Farms. The high fission product load ensured that the waste would boil for about 5 years before the major heat-generating radionuclides decayed and were not able to sustain boiling. With cooling, precipitates containing significant quantities of fission products formed and sludge was generated. At the same time, a supernatant with reduced particulate or precipitable matter was generated and also was identified for use at the 221-B Facility.

Note: Surfer™ is a trademark of Golden Software, Inc., Golden, Colorado.

Table A-2. Waste Inventory Bibliography

Document	Summary
Tabulation of Radioactive Liquid Waste Disposal Facilities, HW-43121	This document details the LWDF and the associated waste source site with dates of release up to early 1956. The following bismuth-phosphate waste streams were described: • **216-B-2 Ditch:** 221-B cooling water and 284B water, April 1945 • **216-B-3 Pond:** 221-B cooling water and 284B water, April 1945 • **216-B-4 Injection/Reverse Well:** 291-B stack drainage, April 1945 to August 1947 • **216-B-5 Injection/Reverse Well:** 224-B 5-6 and cell drain, April 1945 to October 1947 • **216-B-6 Injection/Reverse Well:** 222-B sinks, April 1945 to November 1949 • **216-B-7 Crib:** 224-B, 221-B 5-6, and 201-4 tank overflow, October 1946 to present • **216-B-8 Crib:** 221-B 2 cycle and 5-6, March 1945 to May 1954 • **216-B-9 Crib:** 221-B 5-6, August 1948 to July 1951 • **216-B-10 Crib:** 222-B and 292 sinks, December 1949 to June 1952 • **216-B-11 Crib:** 242-B evaporator condensate, December 1951 to November 1954
200 Area Disposal Sites for Radioactive Liquid Wastes, HW-83718	This document details the LWDF and the associated waste source site with dates of release up to early 1964. The following bismuth-phosphate waste streams were described: • **216-B-7 Crib:** 224-B, 221-B 5-6, and 201-4 tank overflow, October 1946 to 1958 • **216-B-11 Crib:** 242-B evaporator condensate, December 1951 to November 1954 • **216-B-35 Trench:** first-cycle supernatant, February 1954 • **216-B-36 Trench:** first-cycle supernatant, April 1954 • **216-B-37 Trench:** evaporator bottoms, August 1954 to September 1954 • **216-B-38 Trench:** first-cycle supernatant, July 1954 • **216-B-39 Trench:** first-cycle supernatant, December 1953 to November 1954 • **216-B-40 Trench:** first-cycle supernatant, April 1954 to August 1954 • **216-B-41 Trench:** first-cycle supernatant, November 1954.

Table A-2. Waste Inventory Bibliography

Document	Summary
Flow Sheets and Flow Diagrams of Precipitation Separations Process, HW-23043	This report describes the precipitation separations process in effect on October 1, 1951, for the bismuth-phosphate process. The neutralized metal waste solution composition was described as 132 g/L or 10.5 percent uranyl sodium carbonate and uranyl sodium phosphate, 9.7 g/L or 0.8 percent nitrate, 24.4 g/L or 1.9 percent sulfate, 25.5 g/L or 2.0 percent phosphate, 83.2 g/L or 6.6 percent sodium, and 78.2 percent water with a specific gravity of 1.25. The neutralized first-cycle waste solution composition was described as 2.59 g/L or 0.24 percent bismuth, 0.030 g/L or 0.003 percent cerium, 0.030 g/L or 0.003 percent zirconium, 1.37 g/L or 0.13 percent ferric, 0.16 g/L or 0.02 percent chromium, 1.98 g/L or 0.18 percent ammonium, 47.3 g/L or 4.3 percent sodium, 4.35 g/L or 0.40 percent silicon fluoride, 26.2 g/L or 2.4 percent phosphate, 93.1 g/L or 8.5 percent nitrate, 4.73 g/L or 0.44 percent sulfate, and 83.4 percent water with a specific gravity of 1.09. The neutralized second-cycle waste solution composition was described as 1.31 g/L or 0.12 percent bismuth, 1.82 g/L or 0.17 percent ferric, 0.06 g/L or 0.006 percent chromium, 1.71 g/L or 0.16 percent ammonium, 36.7 g/L or 3.5 percent sodium, 3.67 g/L or 0.35 percent silicon fluoride, 23.0 g/L or 2.2 percent phosphate, 61.3 g/L or 5.8 percent nitrate, 3.61 g/L or 0.34 percent sulfate, and 87.3 percent water with a specific gravity of 1.05. The neutralization of the bismuth-phosphate precipitate waste solution composition (e.g., 224 Building) was described as 1.18 g/L or 0.11 percent bismuth, 0.17 g/L or 0.016 percent chromium, 0.33 g/L or 0.031 percent manganese, 1.29 g/L or 0.11 percent oxalate, 0.12 g/L or 0.011 percent ammonium, 0.49 g/L or 0.045 percent lanthanum, 36.8 g/L or 3.4 percent sodium, 8.53 g/L or 0.79 percent potassium, 5.6 g/L or 0.5 percent fluoride, 3.05 g/L or 2.8 percent phosphate, 42.4 g/L or 3.9 percent nitrate, 0.35 g/L or 0.032 percent sulfate, and 90.75 percent water with a specific gravity of 1.08.
Summary of Liquid Radioactive Wastes Discharged to the Ground – 200 Areas, July 1952 through June 1954, HW-33591; and *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Through June 1955*, HW-38562	This document reports the effluent disposal volume, major radionuclide concentrations, date of disposal, source of the effluent waste (e.g., Tank 241-BX-110), pH of effluent, and trench name. The first-cycle supernatant for the 216-B-35 through 216-B-41 Trenches is as follows: • 216-B-35 received 962,933 L (254,380 gal) from Tank 241-BX-110 with a pH of 7.6. The concentrations for uranium, cesium, strontium, and plutonium were as follows: 920 pCi/L, 580 µCi/L, 1.9 µCi/L, and 0.028 µCi/L, respectively. The total activity for each is 8.86E-4 Ci, 558 Ci, 1.83 Ci, and 0.27 Ci, respectively. • 216-B-36 received 1,769,000 L (467,500 gal) from Tank 241-BX-111 with a pH of 9.9. The concentrations for uranium, cesium, strontium, and plutonium were as follows: 480 pCi/L, 570 µCi/L, 3.5 µCi/L, and 0.011 µCi/L, respectively. The total activity for each is 8.5E-4 Ci, 1,008.6 Ci, 6.2 Ci, and 0.2 Ci, respectively. • 216-B-37 received 4,294,076 L (1,134,375 gal) from Tanks 241-B-107, 241-B-108, and 241-B-109 with a pH of 8.0. The concentrations for uranium, cesium, strontium, and plutonium varied for each of the tanks. The total activity for each is 3.2E-3 Ci, 3,078 Ci, 7.7 Ci, and 0.056 Ci, respectively. • 216-B-38 received 1,504,228 L (397,375 gal) from either Tank 241-BY-106 or Tank 241-BY-110 with a pH of 7.2. The concentrations for cesium and strontium were as follows: 4.2 µCi/L and 1,230 µCi/L, respectively. The total activity for each is 6.3 Ci and 1,850 Ci, respectively.

Table A-2. Waste Inventory Bibliography

Document	Summary
Summary of Liquid Radioactive Wastes Discharged to the Ground – 200 Areas, July 1952 through June 1954, HW-33591; and *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Through June 1955*, HW-38562 (cont'd.)	• 216-B-39 received 780,741 L (206,250 gal) from Tank 241-BX-112 with a pH of 8.7. The concentrations for uranium, cesium, strontium, and plutonium were as follows: 1.9E-3 µCi/L, 550 µCi/L, 15 µCi/L, and 0.11 µCi/L, respectively. The total activity for each is 1.5E-3 Ci, 429 Ci, 11.7 Ci, and 0.086 Ci, respectively. • 216-B-40 received 1,129,472 L (298,375 gal) from Tank 241-BY-106 or Tank 241-BY-110 with a pH of 7.4. The concentrations for cesium and strontium were as follows: 2.1 µCi/L and 250 µCi/L, respectively. The total activity for each is 2.37 Ci and 282 Ci, respectively. The data are contradictory of Atlantic Richfield Hanford Company documents (e.g., ARH-231), which provided different inventories with no explanation for the difference. In addition, it appears that RHO-CD-673 made additional changes without explanation for the inventories listed previously. Therefore, these inventories are chosen to best represent the waste streams to the BX Trenches.
Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Through June 1955, HW-38562; and *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Through June 1956*, HW-44784	These documents report the effluent disposal volume, major radionuclide concentrations, date of disposal, source of the effluent waste (e.g., 241-BY-110), pH of effluent, and crib name. The scavenged TBP supernatant for 216-B-43 through 216-B-49 are as follows: • 216-B-43 received 2,110,231 L (557,464 gal) from Tank 241-BY-110 with a pH of 9.7. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 5.9 mg/L or approximately 1.9E-3 µCi/L, 21.7 µCi/L, 635.07 µCi/L, 9.00 µCi/L, and 0.1 µg/L or approximately 0.12 µCi/L, respectively. The total activity for each is approximately 4.175E-3 Ci, 45.9 Ci, 1340 Ci, 19 Ci, and 2.47 Ci, respectively. • 216-B-44 received 5,620,610 L (1,484,808 gal) from Tanks 241-BY-107, 241-BY-108, and 241-BY-109, with an average pH of 9.3. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 0.42 mg/L or approximately 1.408E-4 µCi/L, 116 µCi/L, 500 µCi/L, 182 µCi/L, and 1.97 µg/L, or approximately 0.12 µCi/L, respectively. The total activity for each is 7.9E-4 Ci, 651.9 Ci, 2,812 Ci, 1,024 Ci, and 0.6843 Ci, respectively. • 216-B-45 received 4,910,535 L (1,297,226 gal) from Tanks 241-BY-106 and 241-BY-108, with an average pH of 9.3. The concentrations for uranium, cesium, strontium, antimony, and plutonium varied for each of the tanks. The total activity for each is 1.79E-3 Ci, 1,490 Ci, 2,792 Ci, 2,870 Ci, and 0.649 Ci, respectively. • 216-B-46 received 6,730,462 L (1,778,000 gal) from Tanks 241-BY-107 and 241-BY-108, with an average pH of 9.7. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 0.02g/L or approximately 9.0E-3 µCi/L, 20.39 µCi/L, 218.3 µCi/L, 601.3 µCi/L, and 2.47 µg/L or approximately 0.152 µCi/L, respectively. The total activity for each is 1.025 Ci, 137.2 Ci, 1,468.8 Ci, 4,047 Ci, and 1.025 Ci, respectively. • 216-B-47 received 3649137 L (964,000 gal) from Tanks 241-BY-108 and 241-BY-110, with an average pH of 9.7. The concentrations were slightly to significantly less than 216-B-46. The total activity for uranium, cesium, strontium, antimony, and plutonium were as follows: 1.89E-3 Ci, 130 Ci, 613 Ci, 2,664 Ci, and 0.345 Ci, respectively.

Table A-2. Waste Inventory Bibliography

Document	Summary
Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Through June 1955, HW-38562; and *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Through June 1956*, HW-44784 (cont'd.)	• 216-B-48 received 4,100,358 L (1,083,200 gal) from Tanks 241-BY-106 and 241-BY-108, with an average pH of 9.4. The concentrations were slightly to significantly less than 216-B-46. The total activity for uranium, cesium, strontium, antimony, and plutonium were as follows: 6.4E-7 Ci, 437.9 Ci, 1,227 Ci, 1,996 Ci, and 0.29 Ci, respectively. • 216-B-49 received 6,700,728 L (1,770,145 gal) from Tanks 241-BY-104, 241-BY-107, and 241-BY-110, with an average pH of 9.8. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 0.047 g/L or approximately 1.0E-3 µCi/L, 59.85 µCi/L, 392.6 µCi/L, 586 µCi/L, and 1.79 µg/L or approximately 0.11 µCi/L, respectively. The total activity for each is 0.0105 Ci, 401 Ci, 2,631 Ci, 3,926 Ci, and 0.741 Ci, respectively. The data are altered in Atlantic Richfield Hanford Company documents (e.g., ARH-231), which provided different inventories with no explanation for the difference. In addition, it appears that RHO-CD-673 made additional changes without explanation for the inventories listed previously.
TBP Waste Disposal Project Criteria for Cribbing Scavenged RAW, HW-30652	This document, published in January 1954, discusses the criteria and recommendations for cribbing nickel ferrocyanide scavenging liquid waste based on test cribbing of approximately 984,000 L (260,000 gal) of scavenged raw supernatant. Waste site selection was based on proximity to a tank farm containing metal waste and the lithology of the underlying soils. The 200 East Area was preferred over the 200 West Area because of the more permeable soils, causing less horizontal migration. Waste site spacing (15.2 m [50 ft] between centers in the north-south direction and 22.9 m [75 ft] between centers in the east-west direction) was based on routine discharge rates of up to 379 L/min (100 gpm). Larger spacing requirements were proposed for higher discharge rate. Total release volume and liquid waste concentration were based on per square foot of subsurface ground area for sorption of contaminants. Maximum volumes and cesium and strontium concentrations were limited to 22,712 L/ft^2 (6,000 gal/ft^2) and 100 µCi/L with a ceiling of 2,000 Ci of each, respectively. Sampling requirements consisted of analysis of liquid waste from the discharge line at a frequency of at least one sample from each 189,271 L (50,000 gal) cribbed. Each sample was to be analyzed for pH, cesium-137, and strontium-90. In addition, a combined aliquot from a specific tank was to be analyzed for pH, cesium-137, strontium-90, total beta, rare earths, yttrium, plutonium, and uranium. Finally, combined aliquot from every fifth specific tank was to be analyzed for pH, cesium-137, strontium-90, total beta, rare earths, yttrium, plutonium, uranium, ruthenium-106, cesium-144, and antimony-125.

Table A-2. Waste Inventory Bibliography

Document	Summary
Sampling of Scavenged Waste, HW-37478	This document, published in June 1955, superseded HW-30652 and provided revised sampling requirements before disposal of scavenged liquid effluent to cribs. Increased requirements consisted of a sample of the unneutralized waste before addition of scavenging chemicals could be analyzed for alpha, beta, cesium, strontium, and phosphate ion. The phosphate ion was necessary for adequate adsorption of strontium in soil. Also, a sample of the neutralized waste with scavenging chemicals added was requested before the waste left the separations plant. The sample was to be collected after centrifuging and analyzed for the same constituents as before the scavenging chemical addition. In addition, 5 to 7 days after scavenging, addition of a detailed tank analysis was requested for crib disposal acceptance. Samples were to be collected of the supernatant from 1.5 m (5 ft) intervals throughout the tank. Samples containing sludge were allowed to be returned to the tank after noting the depth of the sludge. The analysis consisted of pH, total beta, cesium-137, and strontium-90. In addition, aliquots of each sample (for a specific tank) were to be combined and analyzed for pH, cesium-137, strontium-90, total beta, rare earths, yttrium, plutonium, uranium, ruthenium-106, antimony-125, zirconium-niobium, curium, phosphate ion, nitrate ion, and dissolved salts. Waste line samples were considered to be sufficient every 378,541 L (100,000 gal) for scavenged first-cycle or TBP supernatant discharged to the cribs. Each sample was to be analyzed for pH, cesium-137, and strontium-90. In addition, aliquots of each sample (for a specific tank) were to be combined and analyzed for pH, cesium-137, strontium-90, total beta, rare earths, yttrium, plutonium, uranium, ruthenium-106, antimony-125, phosphate ion, nitrate ion, and dissolved salts. Another requirement included that the effluent being pumped be gamma-monitored to decrease the amount of precipitates discharged to the soil column. The pump was suspended in the supernatant with a floating intake as well. By this process, sludge buildup in the crib would be minimized, and the early abandonment of the crib would be prevented. It appears that these requirements began in March 1955.
Decontamination of Uranium Recovery Process Stored Wastes – Interim Report, HW-36717	This report, written in May 1955, discusses the results of various initial tests required by HW-37478 to evaluate the decontamination of cesium and strontium in Uranium Recovery Plant wastes using potassium ferrocyanide and calcium nitrate. Samples were collected from six tanks (241-C-106, 241-C-109, 241-C-111, 241-C-112, 241-BX-108, and 241-BX-109). Results indicated that the cribbing criteria were met for all wastes. It was noted that only 500 mL of supernatant was collected from each of the tanks and that this volume was not representative of the tank because of stratification. Precipitate formation also was studied to determine if line plugging may occur from the scavenged wastes being transported by line. Analysis indicated that sodium, aluminum, and iron phosphate were precipitated as a phosphate at varying temperatures. Furthermore, it was found that when aluminum was present, settling took longer for the precipitates. Based on analysis, it was determined that 2 to 3 weeks of settling were sufficient using nickel ferrocyanide scavenging of stored wastes for a 2,839,000 L (750,000 gal) tank.

Table A-2. Waste Inventory Bibliography

Document	Summary
In-Farm Scavenging Operating Procedure and Control Data, HW-38955	This document was published in September 1955 and details the "in-farm scavenging" process at the C Tank Farm. This document provided the due diligence of the initial sampling required by HW-37478. In addition, it provides a process flow sheet of the various scavengers. Thirteen of the 200 East Area tanks on which scavenging studies were completed varied considerably in composition because they were produced under significantly different waste treatment conditions in the TBP Plant. Ten of the tanks were produced during the early period of TBP Plant operations before scavenging was employed. Five of these tanks (241-C-106, 241-C-109, 241-C-110, 241-C-111, and 241-B-112) contain significant amounts of cesium and strontium and, therefore, required nickel ferrocyanide (e.g., sodium ferrocyanide and nickel sulfate) scavenging and, in some cases, supplemental calcium nitrate scavenging (e.g., 241-C-106 and 241-C-109). Five of the tanks (241-BX-108, 241-BX-109, 241-C-106, 241-C-108, and 241-C-112) were filled during periods when nickel ferrocyanide scavenging process used a lower pH of 8 to 10 and contain strontium concentrations greater than cribbing criteria (1 μCi/mL). These wastes possibly required scavenging with both nickel ferrocyanide and calcium nitrate. Three of the tanks (241-BY-101, 241-BY-102, and 241-BY-103) were filled during periods when nickel ferrocyanide scavenging was employed in the TBP Plant. Although the cesium concentration in these supernatants was low enough to permit cribbing, the strontium concentrations were too high. Therefore, these supernatants only required calcium addition to reduce the strontium concentration to acceptable cribbing concentrations. In addition, this document also discussed the tanks that still required sampling.
History: Metal Recovery Waste Scavenging Program, HW-43066	This document summarizes the scavenging process changes for cesium and strontium that occurred from September 1954 to May 1956 for acceptable crib disposal of stored TBP waste. According to this document, the scavenging began September 29, 1954. The purpose was to chemically treat cesium and strontium so bismuth-phosphate metal waste without most of the uranium from the TBP process could be cribbed. The scavenging process initially consisted of the addition of potassium ferrocyanide [$K_4Fe(CN)_6$ $3H_2O$], NaOH, and nickel sulfate ($NiSO_4$). Laboratory soil column studies were completed to determine the retention capacity and cribbing criteria for scavenged effluent. The criteria initially restricted cesium and strontium concentrations that exceeded 100 μCi/L in accordance with HW-30652. In addition, the volume of disposal could not exceed 6,000 gal/ft^2 of ground surface in the crib (e.g., 5.4 million gal). The final criterion was that the total curies per crib of cesium and or strontium could not exceed 4,100 Ci (e.g., 200 μCi/L multiplied by 20.4 million L [5.4 million gal]). These criteria were to ensure that cesium and strontium would not exceed the 0.1 maximum groundwater permissible limits (e.g., 1.5E5 and 80 pCi/L, respectively). In June 1955, the inline discharge sampling was relaxed to one sample every 378541 L (100,000 gal) cribbed, as reported in HW-37478.

Table A-2. Waste Inventory Bibliography

Document	Summary
History: Metal Recovery Waste Scavenging Program, HW-43066 (cont'd.)	One of the most important parts of the scavenging process was control of the pH. The optimum pH was 9, with an acceptable range from 8 to 10. Soil column studies reported a large drop in scavenged cesium for pH above 10 and a corresponding drop for scavenged strontium for pH below 8. The transfer data for each tank are provided in a table in the back of this document. The table provides the tank number, transfer date, associated crib number, tank sample results, and crib line results. The report also discusses the changes that occurred during the disposal process and the findings that terminated the disposal of effluent waste to the 216-B-43 through 216-B-49 Cribs. The basis for stopping the process was the detection of beta activity in the groundwater and confirmation of cesium-137 in December 1955.
Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4, LA-UR-96-3860	The HDW model uses various process and transaction reports to define the various waste streams generated during active separations. The process part provided chemical and radionuclide concentrations defined by three distinct methods: (1) knowledge of the processes, (2) chemicals used and waste volumes produced, and (3) analyses of characteristic wastes. Methods 1 and 2 focused mainly on technical manuals, process flow sheets, and radionuclide source-term reports. Results from models of fuel generation were then combined with the various processes to determine radionuclide and chemical partitioning. The transaction reports mainly consisted of the following: waste status and transaction record summaries, Hanford Site high-level defense waste characterization report, supplementary information for the preliminary estimation of waste tank inventories in Hanford tanks through 1980, a history of the 200 Area tank farms, and Hanford tank logbook data set. The information from these reports provided a data set that was transferred into a balanced tank-by-tank quarterly summary transaction spreadsheet called the WSTRS. Some uncertainty exists with the chronology because early recorded data did not specify exact dates of transactions. In addition, the volume reductions and continuous transfers of condensates from the evaporator campaigns were not well represented. Perhaps as much as 60 to 80 percent of the evaporator campaign transactions are missing. While these methods provide the necessary information to define the waste stream, two critical pieces of information (i.e., the total solid volume percent and the solubility of each component in the supernatant) were needed to calculate the actual compositions of the supernatant and solids. To derive estimates of the type of solids that reside within the tanks, fill records from the tank farm surveillance and waste status and summary report and other estimation reports were collected and fed into the TLM. These estimates are made from three categories: additions from process plants directly into waste tanks, solid accumulated as a result of evaporation, and accumulations from tank-to-tank transfers. The solids that precipitate are set by evaluating component solubility and supernatant analytical results from tank and evaporator operations and adjusting the fraction precipitated. The reported supernatant concentrations of a species suggest a limiting solubility of that species. These values provide the method by which partitions of supernatant and sludge fractions are generated. The TLM reconciles this information against the reported solid levels from WSTRS for each tank. Note that not all of the transactions that occurred in the past are recorded in the WSTRS data set. However, the two critical pieces of information that are used in the TLM analysis are the primary waste additions and the solid level measurements, both of which are well represented in WSTRS.

Table A-2. Waste Inventory Bibliography

Document	Summary
Hanford Tank Chemical and Radionuclide Inventories: HDW Model, Rev. 4, LA-UR-96-3860 (cont'd.)	The supernatant mixing model uses information from both WSTRS and TLM. The supernatant mixing model module reads transaction information from WSTRS, sorts it to an absolute chronological order, and performs a transaction-by-transaction accounting of all the tank waste supernatant for the history of the Hanford Site. A fundamental assumption within the supernatant mixing model is the ideal and complete mixing of each tank's supernatant. In this approach, the volume of TLM solid layers within each tank is excluded from mixing with any supernatant additions. The mass balances are limited by difference among water, oxide, and hydroxide with the various solids. The supernatant concentration is equal to or less than the target solubility. Thus, each waste is kept in ion and mass balance according to the oxidation states assumed for that species. Results of this work provide partitioning estimates of radionuclides released during historical waste disposal. These results indicate differences from historical references for various disposal inventories. An example is that the cesium and strontium inventory for the bismuth-phosphate campaign was somewhat different than historical references. This program defined cesium and strontium inventories as 35 percent in metal waste streams, 58.4 percent in the first-cycle waste, 6 percent in the second-cycle waste, and 0.6 percent in the 224 Building waste, as opposed to 88.9, 10, 1, and 0.1 percent, respectively. The remaining radionuclides were partitioned as 88.9 percent metal waste, 10 percent as first cycle, 1 percent as second cycle, and 0.1 percent as 224. In addition, partitioning estimates for the uranium recovery process indicate that there is uncertainty in the uranium inventory tied up in the sludge. Some sources indicate that 75 percent of the uranium was present in the sludge while solubility calculations indicate that only 35 percent of the uranium was present in the sludge. The results of this document were based on several prior documents attempting to better constrain the inventory of each constituent sent to specific waste sites. However, because of the uncertainty associated with the lack of records before 1970, specific site inventories were considered to have large uncertainty. Thus, more refinements of these inventories have occurred and are shown in Rev. 5 of this document.
Review of Generation and Flow of Recycled Uranium at Hanford, DOE/RL-2000-43	This document describes the assessment completed to address the extent of potential exposure to recycled uranium completed in the Uranium-Trioxide Plant. Before the startup of the Uranium-Trioxide Plant, requirements were set to permit essentially direct physical handling of the final product. This measure drove decontamination processes with respect to plutonium, gross beta, and gamma radiation. It was recognized that subsequent processing at other plants might result in fractionation or concentration of either fission products or plutonium. A letter was provided with the requirements in 1951 and later revised in 1953; however, during this time, technetium was not considered. Analytical measurements from 1959 onward from receiving plants reported technetium values in the range from 3 to 12 ppm/g of uranium. The technetium was determined to be co-processed with the recovered uranium because of the solvent extraction process used to recover the uranium and the distribution coefficient (organic/aqueous phase) for technetium. Other contaminants discussed in this report included neptunium and plutonium.

Table A-2. Waste Inventory Bibliography

Document	Summary
Hanford Defined Waste Model – Revision 5.0, RPP-19822	This version of HDW was required to provide more accurate information for the best-basis inventory, the official database for waste inventory estimates for tank farms, which uses estimates from the HDW model when direct sample data are not available. Because the best-basis inventory does not use individual tank inventory estimates but instead interfaces with waste type composition estimates calculated by the HDW workbook, it was determined that the HDW model be revised in three areas: fuel activity estimates, chemical process simulations, and error correction. The main updates included the following: • Relaxing conservative assumptions that all of the radionuclides in the fuel, except uranium and plutonium, remained in the tank farm system. Thus, several radionuclides (e.g., tritium, carbon-14, technetium-99, and iodine-129) were evaluated to have chemical properties that allowed them to escape or be removed from the process (i.e., partitioning of tritium to cribs via evaporator condensates, carbon-14 and iodine-129 to the atmosphere, and technetium-99 with the uranium product shipped offsite). • Using site-specific solubility changes as opposed to global solubility factors used in Rev. 4. This increased uranium solubility by a factor of 30 in the bismuth-phosphate metal waste because of complexing of uranium with carbonate. Strontium and cesium solubility concentrations also were revised for the ferrocyanide waste stream in accordance with historical laboratory results (e.g., in the 1950s). The solubility of calcium carbonate was increased to reflect lower ionic strength because it was not part of a separations waste stream. • Including 224 Building waste generated before 1952. • Providing chemical process percentage breakdown of fission products in the various waste components of the bismuth-phosphate process is now based on process flow sheets, plant test data, and a laboratory simulation of the plutonium-product extraction step. The new process splits reduced the activity estimated for the first-cycle, second-cycle, and 224 Building waste streams. The new information on the bismuth-phosphate process is documented in Appendix C (Interoffice Memorandum 7G300-02-NWK-024) of RPP-19822. • Correcting errors pertaining to the calculations of the uranium recovery and scavenging streams. The activity in the metal waste was used rather than all the bismuth phosphate activity. • Correcting errors representing the Hot Semiworks and the B Plant waste fractionization. • Incorporating new Oak Ridge Isotope GENeration and depletion code (ORIGEN2) fuel activity estimates for improved chemical process models (ORNL-5621). • Resolving issues and limitations identified in the best-basis inventory and HDW model.

Table A-2. Waste Inventory Bibliography

Document	Summary
Hanford Defined Waste Model – Revision 5.0, RPP-19822 (cont'd.)	• Some remaining problems exist with the program, which include the following: (1) HDW model predicts that $NiFe(CN)_6^-$ is insoluble and stable, (2) pH for various waste streams was varied over a significant range while the model holds the waste to a specific pH, (3) several of the chemical constituents do not reconcile with process flow sheets, (4) uncertainty in accumulated sludge or salt cake, (5) carbon dioxide adsorption and resulting formation of $NaCO_3$, (6) special recovery processes (e.g., B Plant fractionization and Hot Semiworks) are incompletely modeled or neglected by the HDW model, and (7) the HDW model does not maintain mass balances throughout the waste stream or tank inventory (e.g., frequently, waste streams chemical composition are calculated independently rather than from the waste stream upon which they are dependent).

Note: KINEPAK™ is a trademark of Slurry Explosive Corporation, Oklahoma City, Oklahoma.

Table A-3. Vadose Zone Bibliography

Document	Summary
Waste Site Grouping for 200 Areas Soil Investigations, DOE/RL-96-81, Rev. 0	This document describes the logic for grouping liquid effluent release sites for streamlining the RI/FS and facility investigation/corrective measures study processes. The waste sites are source disposal sites located within and adjacent to the 200 East Area and overlying the 200-BP-5 OU. The document presents the final waste site groups (e.g., 200-TW-1 Scavenged Waste Group OU and 200-TW-2 Tank Waste Group OU), selection of representative site(s) that best represent typical and worst-case conditions for each waste group, and development of a conceptual model for each waste group. A generalized conceptual leaching transport model is provided in this document (Figure 4-1). In addition, various conceptual leaching transport models are presented for the selected representative waste sites for each OU. Figures 4-9, 4-10, 4-13, and 4-15 provide the conceptual models for the 200-TW-1, 200-TW-2, 200-CS-1, and 200-CW-1 OUs, respectively. The conceptual model considered lateral spreading and decided that 15 to 30 m (49.2 to 98.4 ft) beyond the facility centerline was sufficient unless a significant impermeable zone beneath the waste site creates a perched water condition. Lateral spreading was known to occur at the 216-B-7A/216-B-7B, 216-B-57, and 216-B-43/47 Cribs overlying the 200-BP-5 OU.
200-TW-1 Scavenged Waste Group Operable Unit and 200-TW-2 Tank Waste Group Operable Unit RI/FS Work Plan, DOE/RL-2000-38, Rev. 0	This document describes the waste sent to 200-TW-1 and 200-TW-2 OU waste sites (e.g., scavenged and tank waste, respectively). The following waste sites were identified as representative sites overlying the 200-BP-5 OU: 216-B-5 Reverse Well, 216-B-7A Crib, 216-B-38 Trench, and 216-B-46 Crib. This document also provides a final list of COCs for the 200-TW-1 and 200-TW-2 OUs. The following is the final list for these OUs: americium-241, carbon-14, cesium-137, cobalt-60, europium-152, europium-154, europium-155, tritium, neptunium-237, nickel-63, plutonium-238, plutonium-239/240, radium-226, radium-228, strontium-90, technetium-99, thorium-232, uranium-234, uranium-235, uranium-238, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, ammonia/ammonium, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, normal paraffins, TBP, and total organic carbon.

Table A-3. Vadose Zone Bibliography

Document	Summary
200-TW-1 Scavenged Waste Group Operable Unit and 200-TW-2 Tank Waste Group Operable Unit RI/FS Work Plan, DOE/RL-2000-38, Rev. 0 (cont'd.)	The 216-B-5 Reverse Well, 216-B-7A Crib, 216-B-38 Trench, and 216-B-46 Crib waste sites were selected as the representative waste sites for the following analogous waste sites overlying the 200-BP-5 OU: • **216-B-5 Reverse Well:** none • **216-B-7A Crib:** 216-B-7B Crib, 216-B-8 Crib and Tile Field, 216-B-9 Crib, UPR-200-E-7, 200-E-45 Health Instrument Shaft, and 241-B-361 Settling Tank • **216-B-38 Trench:** 216-B-35 through 216-B-41 Trenches • **216-B-46 Crib:** 216-B-42 through 216-B-49 Cribs, 216-BY-201 Settling Tank, UPR-200-E-9, UPR-200-E-144, and 216-B-51 French Drain Note that the 216-B-46 Crib was not actually characterized; instead, the 216-B-43 and 216-B-49 Cribs were selected to represent the 216-B-46 Crib. In addition, the 216-B-49 Crib actually had a larger uranium concentration and nearly the same effluent to pore-space ratio as the 216-B-46 Crib. The 216-B-38 Trench and the 216-B-46 Crib waste sites effluent to pore-space ratios were less than one, which was characteristic of all the analogous sites they represented. Conceptual contaminant distribution models were provided for the representative waste sites in this document. The 216-B-5 Reverse Well, 216-B-46 Crib, 216-B-7A Crib, and 216-B-38 Trench models are provided in Figures 3-16, 3-14, 3-17, and 3-18, respectively. This document also describes the planned borehole investigations within these representative sites.
Uranium-Rich/General Process Condensate and Process Waste Group Operable Units RI/FS Work Plan and RCRA TSD Unit Sampling Plan; Includes 200-PW-2 and 200-PW-4 Operable Units, DOE/RL-2000-60, Rev. 0	This document describes the waste (uranium-rich process waste) sent to 200-PW-2 OU waste sites. The 216-B-12 Crib waste site was the only identified representative waste site overlying the 200-BP-5 OU. Analogous sites overlying the 200-BP-5 OU included the 216-B-60 Crib, 216-C-1 Crib, 270-E-1 Condensate Neutralization Tank, and UPR-200-E-64. This document provides a final list of COCs for uranium-rich process waste streams (e.g., 200-PW-2 OU) as follows: americium-241, carbon-14, cesium-137, cobalt-60, europium-152, europium-154, europium-155, tritium, neptunium-237, nickel-63, plutonium-238, plutonium-239/240, radium-226, radium-228, strontium-90, technetium-99, thorium-232, uranium-234, uranium-235, uranium-238, antimony, arsenic, barium, beryllium, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, selenium, ammonia/ammonium, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, normal paraffins, TBP, and total organic carbon.

Table A-3. Vadose Zone Bibliography

Document	Summary
Uranium-Rich/General Process Condensate and Process Waste Group Operable Units RI/FS Work Plan and RCRA TSD Unit Sampling Plan; Includes 200-PW-2 and 200-PW-4 Operable Units, DOE/RL-2000-60, Rev. 0 (cont'd.)	The 216-B-12 Crib waste site was selected as one of the representative waste sites because it had some of the largest waste inventories for uranium (21,000 kg), plutonium (374 g), and cesium (716 Ci), and the effluent to pore-space ratio was calculated at 28.4 with 520 million L (137 gal) of effluent disposed during the operating period 1952 to 1973. A conceptual contaminant distribution model was provided for the 216-B-12 Crib representative waste site in this document. This document also describes the planned borehole investigation within this crib. Note that some of the following waste site descriptions were also provided by the WIDS database. The 216-B-60 Crib waste site is located west of the 221-B Building (B Plant) under a portion of the 225 Building and was the source of 221-B Cell drain header during 1967. The waste inventory indicates that this waste site received 18,900 L (4,993 gal) of low-salt, neutral-to-basic liquid containing uranium, plutonium, cerium, cesium, and europium. Waste inventories were estimated at 720 kg of uranium and 8 g of plutonium during the operating period. This waste site is preliminarily analogous of the 216-B-12 Crib according to early drafts of the 200-PW-2 OU FS. The 216-C-1 Crib waste site is located south of 7th Street and east of the 209-E Building and was the source of cold-run waste and process condensate from 201-C from 1953 to 1957. The waste inventory indicates that this waste site received 23,400,000 L (6,182,000 gal) of high-salt waste, cold-run waste, process condensate of experimental REDOX, and PUREX effluent. Waste inventories for uranium, plutonium, and strontium were estimated at 300 kg, 8 g, and 85.5 Ci, respectively. The effluent to pore-space ratio was calculated at 29.8 during the operating period. This waste site is preliminarily analogous of the 216-A-10 Crib according to early drafts of the 200-PW-2 OU FS. The 216-E-1 neutralization tank was used to neutralize acidic process condensate from the 221-B (B Plant) and 224-B concentration facilities. The tank contained a limestone bed through which the condensate percolated, reacted, and then overflowed to the 216-B-12 Crib. UPR-200-E-64 documents that a small-diameter pipe (approximately 2 in. diameter) was visible near the 216-E-1 Neutralization Tank. The pipe was identified as a "swab riser" with an underground pipeline. The pipe was reported with a dose rate of 30 mrad/hr in 1985. The contamination was reported to be associated with mainly cesium-137 and strontium-90.
200-CS-1 Operable Unit RI/FS Work Plan and RCRA TSD Unit Sampling Plan, DOE/RL-99-44, Rev. 0	This document describes the waste sent to 200-CS-1 OU (chemical sewer) waste sites. The representative waste site, 216-B-63 Ditch, was the only identified waste site overlying the 200-BP-5 OU. This ditch is located in the north-central portion of the 200 East Area.

Table A-3. Vadose Zone Bibliography

Document	Summary
200-CS-1 Operable Unit RI/FS Work Plan and RCRA TSD Unit Sampling Plan, DOE/RL-99-44, Rev. 0 (cont'd.)	The document provides a final list of COCs for chemical sewer waste streams as follows: americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, tritium, neptunium-237, nickel-63, plutonium-238, plutonium-239/240, radium-228, strontium-90, technetium-99, thorium-232, uranium-234, uranium-235, uranium-238, arsenic, barium, beryllium, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, selenium, vanadium, zinc, ammonia/ammonium, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, sulfide, acetone, 1-butanol (butyl alcohol), 2-butanone (MEK), carbon tetrachloride, chloroform (trichloromethane), decane, dichloromethane (methylene chloride), ethanol, halogenated hydrocarbons, methyl isobutyl ketone (MIBK), propanol (isobutyl alcohol), toluene, 1,1,1-trichlorethane, 1,1,2-trichloroethene, xylene, normal paraffins, TBP, kerosene, PCBs, and naphthalene. Note that some of the following waste site descriptions were also provided by the WIDS database. The 216-B-63 Ditch waste site was the source of BY Tank Farm in-tank solidification unit #2 cooling water from March to May 1970. It also received 2902-B high tank (potable sanitary water), cooling water from the B Plant and Waste Encapsulation Storage Facility air compressor after-coolers, some of the 221-B (B Plant) steam condensate, and demineralizer effluent. Minor contributions came from the chemical makeup overflow system (e.g., sodium hydroxide and sodium nitrate), air conditioning units, and space heaters. These minor contributions were determined to be controlled to levels below dangerous waste designation limits. In August 1970, the bottom of the ditch was dredged. The dredged material was contaminated with beta/gamma levels up to 300 counts/min. The only documented hazardous effluent discharges in the past consisted of regeneration solutions from the B Plant demineralizers (271-B Building). These effluents were routine corrosive discharges (D002) of aqueous sulfuric acid and sodium hydroxide solutions. The corrosive discharges occurred from 1970 until October 1985. A conceptual contaminant distribution model was provided for the 216-B-63 Ditch representative waste site in this document. This document also describes the planned investigations at two test pits and one borehole along this ditch.
Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units, DOE/RL-2001-66, Rev. 0	This document describes the waste sent to 200-LW-1 and 200-LW-2 OU (chemical laboratory) waste sites. The following waste sites were identified as overlying the 200-BP-5 OU: 216-B-6 Reverse Well and 216-B-10A&B Cribs. All three of these sites were identified as analogous sites for the 200-LW-1 OU. Note that both of the representative sites for this OU were located in the 200 West Area. The representative sites are the 216-T-28 Crib and the 216-B-58 Trench.

Table A-3. Vadose Zone Bibliography

Document	Summary
Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units, DOE/RL-2001-66, Rev. 0 (cont'd.)	The document provides a final list of COCs for laboratory waste streams as follows: americium-241, carbon-14, cesium-137, cobalt-60, europium-152, europium-154, europium-155, neptunium-237, nickel-63, tritium, plutonium-238, plutonium-239/240, strontium-90, technetium-99, thorium-232, uranium-234, uranium-235, uranium-238, antimony, arsenic, barium, beryllium, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, selenium, ammonia/ammonium, bismuth, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, sulfide, acetone, 1-butanol (butyl alcohol), benzene, 2-butanone (MEK), carbon tetrachloride, chlorobenzene, chloroform, cis-1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, dichloromethane (methylene chloride), ethylbenzene, ethylene glycol, methyl isobutyl ketone (MIBK), n-butyl benzene, tetrachloroethylene (PCE), toluene, trichloroethylene (TCE), trans-1,2-dichloroethylene, 1,1,1-trichloroethane, xylene, kerosene, normal paraffins, phenol, TBP, and PCBs. (Note: A representative site for the analogous sites was not identified in this document.) Note that some of the following waste site descriptions were also provided by the WIDS database. The 216-B-6 waste site is located west of the 222-B Building and was the source of decontamination sinks and sample slurper waste from the 222-B Building from 1945 to 1949. The waste inventory indicates that this waste site received 6,000,000 L (1.6 million gal) of effluent with 100 kg of $Na_2Cr_2O_7$. However, recent median SIM estimates indicate that nearly 2,500 kg of chromium were disposed to this waste site. The reverse well construction was uncertain, with two possible screen intervals; the depths of the screen interval were either 49 or 92 m (161 or 302 ft) bgs. A WIDS database report indicated that this waste site was similar to the discharges associated with the 222-T Laboratory, with 2.6 Ci of fission product and 600 mg of plutonium per month. Again, recent SIM estimates indicate that the median inventory for any mobile radionuclide did not exceed 1 Ci. The highest mobile radionuclide Curie content, according to the SIM, was associated with tritium and technetium. Nitrate, chloride, and sodium concentrations also were significant (58,373 kg, 675 kg, and 26,954 kg, respectively). The 216-B-10A Crib waste site is located south of the west end of the 222-B Building and was the source of decontamination sink and sample slurper waste from the 222-B Building and floor drainage from the 292-B Building from 1949 to 1952. The waste inventory indicates that this waste site received 9,990,000 L (2,615,000 gal) of effluent with 9.1 kg of uranium, 9.8 g of plutonium, 0.401 Ci of cesium-137, 1.89 Ci of strontium-90, and 1,000 kg of nitrate. The 216-B-10B waste site is located south of the west end of the 222-B Building and was the source of decontamination sink and sample slurper waste from the 222-B Building, floor drainage from the 292-B Building, and decontamination sink and shower waste from the 221-B Building (B Plant) from 1949 to 1973. The waste inventory indicates that this waste site received 28,000 L (7,397 gal) of effluent with 0.0001 Ci of cesium-137 and 0.0002 Ci of strontium-90.

Table A-3. Vadose Zone Bibliography

Document	Summary
200-MW-1 Miscellaneous Waste Group Operable Unit RI/FS Work Plan, DOE/RL-2001-65, Rev. 0	This document describes the waste sent to the 200-MW-1 representative waste site (200-E-4 French Drain) and analogous sites (216-B-4 and 216-C-2 Reverse Wells; and the 216-B-13, 200-E-55, 200-E-25, 209-E-WS-2, and 2704-C-WS-1 French Drains). Note that four of the sites (216-B-4 and 216-C-2 Reverse Wells, and the 216-B-13 and 200-E-55 French Drains) are associated with the process facility ventilation stack and sand filter sources. The representative site for these analogous sites is the 216-A-4 Crib. The other four sites are represented by 200-E-4 French Drain and are part of the nonradiological process steam condensate sources with radiological cross-contamination. The document provides a final list of COCs for these miscellaneous process facilities' ventilation stack and sand filter source waste streams as follows: americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, iodine-129, tritium, plutonium-238, plutonium-239/240, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, cadmium, chromium, hexavalent chromium, copper, lead, mercury, silver, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, acetone, 1-butanol (butyl alcohol), benzene, 2-butanone (MEK), cis-1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, dichloromethane (methylene chloride), ethylbenzene, methyl isobutyl ketone (MIBK), n-butyl benzene, tetrachloroethylene (PCE), toluene, trichloroethylene (TCE), trans-1,2-dichloroethylene, 1,1,1-trichlorethane, xylene, normal paraffins, TBP, and PCBs. The 200-E-4 French Drain was selected as the representative site for the 200-E-25, 209-E-WS-2, and 2704-C-WS-1 French Drains. The 200-E-4 French Drain received steam condensate from the steam trap in a valve pit located approximately 1 m (3.3 ft) from the French drain and steam condensate from the equipment room in the service building (209-E Building). Critical experiments were conducted in the Critical Mass Laboratory from 1960 to 1983 using plutonium nitrate and enriched uranium solutions. A conceptual contaminant distribution model was provided for the 200-E-4 French Drain representative waste site in this document. This document describes the planned investigations associated with this French drain. A conceptual contaminant distribution model was provided for the 216-A-4 Crib representative waste site in this document.

Table A-3. Vadose Zone Bibliography

Document	Summary
200-MW-1 Miscellaneous Waste Group Operable Unit RI/FS Work Plan, DOE/RL-2001-65, Rev. 0 (cont'd.)	Note: The 216-A-4 Crib was identified as the representative site for analogous sites 216-B-4 and 216-C-2 Reverse Wells and 216-B-13 French Drain. The 216-B-4 Reverse Well waste site is located south of the 221-B Building (B Plant) and was the source of 291-B stack drainage and 292-B floor drainage from 1945 to 1949. The reverse well extended 34 m (112 ft) bgs. The derived waste inventory indicates that this waste site did not receive significant radionuclide concentrations. The SIM for the mobile contaminants reported the following: chromium (0.557 g), nitrate (0.123 kg), ammonia (0.652 g), tritium (1.19 E-5 Ci), iodine-129 (4.89 E-9 Ci), technetium-99 (4.9 E-6 Ci), and uranium (0.498 E-4 g). The 216-B-13 French Drain waste site is located south of the 221-B Building and was the source of 291-B stack drainage from 1945 to 1976. The construction of the French drain extended 6 m (19.7 ft) bgs. The 216-C-2 Reverse Well waste site is located southeast of the former 291-C-1 stack location, in the Hot Semiworks Plant area, and was the source of 291-C stack drainage and seal water drainage from stack ventilation filters from 1953 to 1988. The reverse well extended 12 m (39.3 ft) bgs.
200-CW-1 Operable Unit RI/FS Work Plan and 216-B-3 RCRA TSD Unit Sampling Plan, DOE/RL-99-07, Rev. 0	This document describes the waste sent to the 200-CW-1 OU representative waste sites (216-A-25 Gable Mountain Pond, 216-B-2-2 Ditch, 216-B-3 Pond, and 216-B-3-3 Ditch) and analogous sites (216-B-2-1 and -3 Ditches, 216-B-3-1 and -2 Ditches, 216-B-59 Trench and Retention Basin, 216-C-9 Pond, 216-N-8 West Lake, and 200-E-PD). The representative sites were selected mainly for the UPRs associated with these sites (UPR-200-E-32, 200-E-34, 200-E-51, and 200-E-138) as described in the following text. The document provides a final list of COCs for these innocuous liquid waste streams as follows: americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, tritium, neptunium-237, nickel-63, plutonium-238, plutonium-239/240, strontium-90, technetium-99, thorium-232, uranium-234, uranium-235, uranium-238, arsenic, barium, beryllium, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, silver, selenium, vanadium, zinc, ammonia, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, sulfide, acetone, 1-butanol (butyl alcohol), 2-butanone (MEK), butylated hydroxyl toluene, carbon tetrachloride, chloroform (trichloromethane), decane, dichloromethane (methylene chloride), ethanol, halogenated hydrocarbons, propanol (isopropyl alcohol), toluene, 1,1,1-trichlorethane, 1,1,2-trichloroethane, normal paraffins, naphthalene, TBP, kerosene, and PCBs.

Table A-3. Vadose Zone Bibliography

Document	Summary
200-CW-1 Operable Unit RI/FS Work Plan and 216-B-3 RCRA TSD Unit Sampling Plan, DOE/RL-99-07, Rev. 0 (cont'd)	Note that some of the following waste site descriptions were also provided by the WIDS database. The 216-A-25 Gable Mountain Pond is located to the north of the 200 East Area and was the source of 202 Building cooling water. The pond routinely received low-level effluent from PUREX, the 242-A Evaporator, 244-AR Vault, 200 East Powerhouse, and A Tank Farm effluent from 1958 to 1987. The low-level effluent was reported to contain low levels of americium, cesium, plutonium, ruthenium, strontium, and uranium. In addition, this site was the location of a UPR (200-E-34) in June 1964 that resulted in the discharge of approximately 10,000 Ci of mixed fission products. The fission products included niobium-95, yttrium-91, strontium-89, cesium-144, and praseodymium-144. Shoreline readings after the event were reported at 500 mrem at 5.1 cm (2 in.). Bentonite clay was spread over the pond bottom for contamination control to immobilize radionuclides in the upper sediment layers. Copper sulfate was added to the pond to eliminate the algae and invertebrate life, thus breaking the link in the food chain of migratory waterfowl. The 216-B-2-1 Ditch is located in the north-central portion of the 200 East Area and operated from 1945 to 1963. The ditch is associated with a vitrified clay pipe that initiated at the 207-B Retention Basin and terminated at the 216-B-3-1 Ditch. This ditch transported steam condensate, process cooling water, and chemical sewer water from the 221-B Building. After March 1952, 241-CR Vault cooling water also was included. The site was reported in November 1963 with UPR-200-E-32: release of rare earth storage tank liquids at the head end of the 216-B-2-1 Ditch. A dam was built 300 m (984 ft) downgradient of head end, which contained the liquid to the first third of the ditch. Release surveys were reported to range from 500 mrem to 2 rad/hr. Constituents released mainly were cesium-144 and strontium-89. A plastic root barrier was emplaced with backfill for environmental protection. The 216-B-2-2 Ditch is located in the north-central portion of the 200 East Area and operated from 1963 to 1970. The ditch replaced the 216-B-2-1 Ditch. This ditch transported and percolated 241-CR Vault cooling water, 221-B Building cooling water and steam condensate, and 284-E Powerhouse chemical sewer water. From January 1965 to November 1967, the BY Tank Farm in-tank solidification unit #1 cooling water also was transported and percolated by the ditch. From February 1968 to April 1970, the BY Tank Farm in-tank solidification unit #2 was released to the ditch. After April 1970, the site received cleanup waste from the 207-B Retention Basin. The ditch was reported with UPR-200-E-138 in March 1970 that resulted in the release of approximately 950 Ci of strontium-90 and 1 Ci of cesium-137 to the ditch. Initial readings near the outfall were 5 rad/hr. The 216-B-3-3 Ditch is located in the north-central portion of the 200 East Area and was the source of B Plant cooling water and PUREX cooling water and chemical sewer waste from 1970 to 1994. This ditch received one UPR (200-E-51) of 15 kg of cadmium nitrate in May 1977. The incident was associated with an errant flowsheet causing cadmium nitrate rinsate from 61 drums to be released to the 216-B-3-3 Ditch instead of to TK-324. Water samples reported cadmium concentrations five times above DWSs.

Table A-3. Vadose Zone Bibliography

Document	Summary
200-CW-1 Operable Unit RI/FS Work Plan and 216-B-3 RCRA TSD Unit Sampling Plan, DOE/RL-99-07, Rev. 0 (cont'd.)	The 216-B-3 Pond (B Pond) is located east of the 200 East Area and was the source of cooling water and chemical sewer effluent from PUREX. Most of the effluent contained low concentrations of radionuclides and chemicals. The pond received three UPRs. One was an approximate 2,500 Ci of mixed fission products released to the 216-B-3-1 Ditch in 1964. Another release was associated with the 1,000 Ci strontium release to the 216-B-2-2 Ditch in March 1970. The third release was associated with a 15 kg release of cadmium nitrate in 1977. Note: The analogous sites received similar effluent as discussed for the 216-A-25 Gable Mountain Pond and B Pond because they were associated with these waste sites; therefore, details are not provided for the analogous sites. A conceptual contaminant distribution model was provided for the 216-B-3, 216-A 25, 216-B-2-2, and 216-B-3-3 Ditch representative waste sites in this document. This document also described the planned investigations at the representative sites.
216-B-5 Reverse Well Characterization Study, RHO-ST-37	The purpose of this study was to determine the following: actual distribution of radionuclides adsorbed on the sediments proximal to the 216-B-5 Reverse Well, radionuclide concentrations in the groundwater, and the quantity of plutonium retained in the 241-B-361 Settling Tank. It was concluded that the radioactive COCs (cesium, strontium, americium, and plutonium) were retained in sediments associated with the well's perforation interval (74 to 92 m [242.8 to 301.8 ft] bgs). The greatest concentrations were found in the sediments located at the position of the water table when the reverse well was in use. Cesium also was detected in a silt layer above the groundwater table and near the impermeable basalt boundary at the base of the unconfined aquifer. The relative mobility of the cesium was not understood; however, soil column retention studies demonstrated that at lower concentrations, colloidal and charged ionic species may not be retained linearly from the point of contamination (e.g., greatest concentrations near the release and lowest concentrations furthest from the release). Early groundwater contamination was considered to be primarily ruthenium-106, based on the low alpha results and/or rapidly decaying beta-gamma concentrations. In addition, sediment samples collected during monitoring well placement did not report elevated radiological readings, further indicating that high groundwater concentrations were due to radionuclides that do not sorb to the aquifer sediments (e.g., ruthenium-106).

Table A-3. Vadose Zone Bibliography

Document	Summary
The Underground Disposal of Liquid Wastes at the Hanford Works, Washington, HW-17088	This document provides discussion on the early studies of the waste disposal at various bismuth-phosphate waste sites before 1950. The report provides the results of characterization activities to identify and determine contaminant distribution in the vadose and saturated zones. The discussion from this report focused mainly on the 216-B-7A&B Cribs, 216-B-8 Crib and Tile Field, and 216-B-9 Crib waste sites and the vadose zone contaminant distributions underlying the waste sites. The 216-B-7A&B Cribs began receiving second-cycle waste in 1946 from the 201-B Settling Tank. The 216-B-7A&B Cribs received 3,300,000 L (871,768 gal) of waste before May 1947 at an average rate of 379 L/min (100 gpm). Three wells were installed 5.5 m (18 ft) from the center of the crib (to 45.7 m [150 ft] bgs) in May 1947 to assess the lateral and vertical extent of contamination. No contamination was reported in these wells. Once the 201-B Settling Tank was filled with sludge, it was replaced with the 241-B-204, 241-B-203, and 241-B-202 Tanks connected in series to the 216-B-7A&B Cribs. From May 1947 to January 1950, an estimated 10 g of plutonium and 20 Ci of fission products were jetted to the 216-B-7A&B Cribs. As of 1950, no contamination had been found from the adjacent Well 224-B-4 (now 299-E33-18, approximately 30.5 m [100 ft] southwest of the 216-B-7B Crib and 22.9 m [75 ft] west of the 216-B-7A Crib). The 216-B-8 Crib began receiving second-cycle waste in March 1948. The crib received 7,500,000 L (1,981,290 gal) of waste containing approximately 7 g of plutonium and 12 Ci of fission products between March 1948 and January 1950 at an average rate of 189 L/min (50 gpm). Before crib startup, a shaft was constructed next to the cribs to study the vertical migration of contamination beneath the crib. The shaft included two horizontal pipes that extruded beneath the crib at 3.0 and 6.1 m (10 and 20 ft), respectively. Liquid samples were collected from cups placed along these horizontal pipes. In addition, ports for sediment samples were installed every 0.6 m (2 ft) to a depth of 6.1 m (20 ft) below the crib. Correlation between liquid and soil samples demonstrated that plutonium was retained in sediments beneath the crib while fission products decreased (but not as rapidly as plutonium). There was very little difference of fission product activity in the liquid samples from 3.0 to 6.1 m (10 to 20 ft), below the crib. In August 1948, sludge from the 241-B-104 Tank was accidentally jetted to the crib. To increase the capacity of the crib, citric ($C_6H_8O_7$) and hydrochloric acid (HCl) were sent to the crib, but this was not significantly successful. Therefore, the tile field was put into service shortly after the incident. This report provided results of limited field characterization for the 216-B-9 Crib and Tile Field. Nine wells were drilled to 45.7 m (150 ft) before using the crib and tile field. The crib was clogged with sludge within 3 months because of the absence of a settling tank. Thus, at the time of the report, only 4 million L (1,056,000 gal) had been released to the crib. Before taking the crib out of service, acid was added to suspend the sludge and increase capacity. Within 8 months, liquid was detected in a test hole approximately 45.7 m (150 ft) northeast of the crib, near the tile field. A liquid sample indicated that both alpha and beta contamination were present. It was considered that the acid promoted mobilization of the contamination by ionizing the contaminants until the acids were neutralized further down in the vadose zone and, thus, re-adsorbed.

Table A-3. Vadose Zone Bibliography

Document	Summary
The Underground Disposal of Liquid Wastes at the Hanford Works, Washington, HW-17088 (cont'd.)	Conclusions from the field and laboratory samples to determine fixation and retention of radioactive materials on soils of varying types also were described. Plutonium was observed to be one of the quickest removed from the solution and thoroughly retained by the soil column. Retention of soils is related to the grain size, dilution of the waste solutions, ion-exchange capacity, moisture content, pH, and solubility. Based on these findings, Hanford Site soils are considered to be good to excellent for retention capacity of contaminants. The only notable exceptions were anions, ruthenium, alkali metals, and uranyl ion.
PNNL geophysical logging records	Historical well logs from the late 1950s to the early 1970s within and proximal to the 216-B-7A&B Cribs, 216-B-8 Crib and Tile Field, 216-B-11A&B, and 216-B-9 Crib waste sites were reviewed. The information from these wells provided partial determination of the vertical and lateral flow of contamination for the waste site; however, only key wells are discussed below to support the conceptual model. Well logs for 299-E33-58, 299-E33-59, and 299-E33-60 (located near 216-B-7A&B Cribs) were reviewed. Activity in May 1963 reported elevated gamma concentrations throughout the well length (149 ft bgs). In 2002, logging results were provided in GJO-2002-343-TAR. Information is provided for cesium and uranium. Cesium was detected in all three of the wells. The deepest concentration was at 44.5 m (146 ft) bgs. Uranium was detected in one of the wells between 12.5 and 16.2 m (41 and 53 ft) bgs. The May 5, 1959, log at Well 299-E33-18, which is located near the 216-B-7A&B Cribs, recorded peak concentration of gamma activity from various depths (e.g., 15.2 m [50 ft] bgs, 59.4 m [195 ft] bgs, 66.8 m [219 ft] bgs, and 69.5 m [228 ft] bgs). In 1968 and 1970, results were near background throughout the vadose zone, with gamma activity peaks only within the saturated zone. In 2002, logging results were provided in GJO-2002-343-TAR. Information is provided for cesium, cobalt, and uranium. Cesium was found between 5 and 10 ft bgs. Cobalt and uranium were reported from approximately 71.3 m (234 ft) bgs to approximately 254 ft (77.4) bgs. Conclusions were drawn from GJO-2002-343-TAR that the contamination may have been associated with high groundwater elevations. However, the groundwater record has not reported elevations that would correlate with a groundwater elevation at 71.3 m (234 ft) bgs in this well.

Table A-3. Vadose Zone Bibliography

Document	Summary
PNNL geophysical logging records (cont'd.)	The May 5, 1959, log at Well 299-E33-16, which is located near the 216-B-8 Crib, recorded peak concentration of gamma activity from various depths (e.g., 5.5 to 8.5 m [18 to 28 ft] bgs, 14.6 [48 ft] bgs, 19.8 to 21.0 m [65 to 69 ft] bgs, 29.9 to 32.0 m [98 to 105 ft] bgs, 56.1 m [184 ft] bgs, 64.6 m [212 ft] bgs, and 66.8 to 73.2 m [219 to 240 ft] bgs). In 1970, results were similar, with gamma activity peaks at 4.9 to 8.8 m (16 to 29 ft), 11.6 to 13.1 m (38 to 43 ft), 21.9 to 24.1 m (72 to 79 ft), and 69.5 m (228 ft). In 2002, logging results were provided in GJO-2002-343-TAR. Information on specific gamma emitters (cesium and cobalt) was provided. Cesium was found throughout the vadose zone column, and cobalt was reported in the intervals between 66.1 to 68.0 m (217 to 223 ft) and 72.2 to 77.3 m (237 to 253.5 ft) bgs. This indicates that the acid and/or other possible complexes promoted the movement of cobalt and cesium throughout the vadose zone at the 216-B-8 Crib and Tile Field. Uranium was reported in the Stoller logs to be at or below background. Thus, it is difficult to determine how much of the 146 kg of uranium inventory remains in the vadose zone beneath the 216-B-8 Crib. Similar results were reported at the 216-B-9 Crib. In conclusion, cesium, cobalt, strontium, and uranium are believed to be in contact with groundwater from both the 216-B-8 Crib and Tile Field and 216-B-9 Crib and Tile Field areas. The May 23, 1963, log at Well 299-E33-19, which is located near the 216-B-11B Reverse Well, recorded peak concentration of gamma activity from various depths (e.g., 27.7 to 29.0 m [91 to 95 ft] bgs and 71.6 to 72. 5 m [235 to 238 ft] bgs). In 1970, results were similar with gamma activity peaks at 28.7 m (94 ft) and 69.5 m (228 ft). In 2002, logging results were provided in GJO-2002-343-TAR. Information is provided for cesium and cobalt. Cesium was detected at 1.5, 4.6, 33.2, 70.1, and 75.9 m (5, 15, 109, 230, and 249 ft) bgs. Cobalt was detected at 36.6 m (120 ft) and at the bottom of the borehole.
Geological log and geophysical survey correlation of Well 299-E33-18, from the Hanford Well Information System database, and PNNL records	The geologic profile for Well 299-E33-18 was reviewed to determine if the lithology correlates with activity from the geophysical surveys. An initial survey from May 1959 indicates that elevated activity was first recorded in a clay and gravel stratigraphic break. The activity was reported over several lithology changes (e.g., clay and gravel, to sand to gravel, to gravel and clay, to clay and sand, to silt to sand, to sand and fine gravel, to coarse sand) with no significant change in activity other than a peak at 15.2 m (50 ft) bgs in the first sand bed mentioned. Another peak was seen in a clay horizon at 69.6 m (225 ft). The 1963 log recorded near-background activity throughout the soil column, except for the sand and the gravel unit from 50 to 58 ft bgs.

Table A-3. Vadose Zone Bibliography

Document	Summary
History and Discussion of Specific Retention Disposal of Radioactive Liquid Wastes in the 200 Areas, HW-54599	The primarily focus of this document for the purpose of the 200-BP-5 OU DQO process was the discussion of the liquid disposal of first-cycle decontamination waste to the BX Trenches (216-B-35 through 216-B-41). This disposal was the first disposal of intermediate-level radioactive waste. Two methods of monitoring the waste migration (groundwater and soil sample collection, and analysis from a characterization borehole/well) were employed at this site. The groundwater was sampled from monitoring wells proximal to the BX Trenches. Beta-gamma contamination was detected in a well (well number was not provided in the document, but it is speculated to be 299-E33-8) sometime after disposal to the trenches. The second method employed involved a well drilled to groundwater within the 216-B-36 Trench in 1957 (Well 299-E33-21). The extent of detected radionuclide concentrations was approximately 24.4 m (80 ft) bgs. Although radionuclides were not detected lower than 80 ft bgs, it was concluded that radionuclides may have penetrated past the 24.4 m (80 ft) level. One alternative mechanism mentioned supporting the detection of radionuclides in the groundwater and not below 24.4 m (80 ft) in the soil samples from the characterization well was that some of the liquid effluent may have migrated vertically along the well casing where groundwater was reported (e.g., 299-E33-8). Based on the sample results, it was concluded in this document that the specific moisture retention factor be lowered from 10 percent to 6 percent for volume release calculations.
Borehole Summary Report for Boreholes C3103 and C3104, and Drive Casing C3340, C3341, C3342, C3343, and C3344, in the 216-B-38 Trench and 216-B-7A Crib, 200-TW-2 Tank Waste Group Operable Unit, BHI-01607	This document provided the borehole stratigraphy and geophysics completed for the RI at 216-B-7A Crib and 216-B-38 Trench. The borehole stratigraphy for the 216-B-7A Crib reports three lower permeability layers from the bottom of the trench to groundwater. The first lower permeability layer was described as gravelly, silty sand from 10.7 to 12.2 m (35 to 40 ft) bgs. The second lower permeability layer includes silty sand from 51.4 to 51.5 m (168.5 to 169 ft) bgs, and slightly silty sand from 51.5 to 54.9 m (169 to 180 ft) bgs, with a silty sand stringer at 52.6 m (172.5 ft) bgs. The third lower permeability layer was described as a silt layer from 66.4 to 67.8 m (218 to 222.5 ft) bgs (bottom of the borehole). The borehole was not advance beyond 67.8 m (222.5 ft) because of the presence of perched water; therefore, the silt layer may extend much deeper. The neutron log reported increased moisture at 67.1 m (220 ft) bgs.

Table A-3. Vadose Zone Bibliography

Document	Summary
Borehole Summary Report for Boreholes C3103 and C3104, and Drive Casing C3340, C3341, C3342, C3343, and C3344, in the 216-B-38 Trench and 216-B-7A Crib, 200-TW-2 Tank Waste Group Operable Unit, BHI-01607 (cont'd.)	Borehole geophysical results correlate with the soil analytical results, indicating that the contaminants with high K_d values (e.g., cesium) remained in the upper portion (not found below 21.3 m [70 ft] bgs) of the vadose zone. In addition, geophysical surveys for uranium concentrations were very low (background) for the 216-B-7A Crib, which is consistent with the deep vadose zone analytical results. The waste sent to the 216-B-7A Crib was reported as second-cycle, 224-B, and fractionation waste. Most of this waste was generated after the removal of most of the uranium (approximately 90 percent) in the metal waste stream, with a reported waste inventory of approximately 4.5 kg of uranium. However, the waste fractionation waste released to this site in 1966 and 1967 was reported to contain 191.6 kg of uranium. Technetium inventory was only reported as a total 0.094 Ci for all waste streams. The borehole stratigraphy for the 216-B-38 Trench reports three lower permeability layers from the bottom of the trench to groundwater. The first lower permeability layer includes silty sand from 33.7 to 35.7 m (110.5 to 117 ft) bgs and slightly silty sand from 35.7 to 42.7 m (117 to 140 ft) bgs. The second lower permeability layer includes slightly silty sand from 59.4 to 66.1 m (195 to 217 ft) bgs; silty sand from 66.1 to 66.6 m (217 to 218.5 ft) bgs; and a silty, sandy gravel from 66.6 to 69.8 m (218.5 to 229 ft) bgs. The third is described as silty, sandy gravel at 76.2 m (250 ft) bgs. The gross-neutron log reported increased moisture at 33.5, 67.1, and 74.7 m (110, 220, and 245 ft) bgs. Borehole geophysical results correlate with the soil analytical results, indicating that the contaminants with high K_d values (e.g., cesium, and europium) remained in the upper portion (not found below 21.3 m [70 ft] bgs) of the vadose zone. In addition, geophysical surveys for uranium concentrations were very low (background) for the 216-B-38 Trench, which is consistent with the deep vadose zone analytical results. This also is consistent with the expectations and inventory of the type of waste disposed to these trenches. The first-cycle waste was generated after removal of the metal waste containing most of the uranium and fission products (approximately 90 percent). The SIM reported a uranium waste inventory of approximately 48.9 kg and a technetium inventory of 0.289 Ci for this trench.
Phase I Remedial Investigation Report for 200-BP-1 Operable Unit, Vols. 1 and 2, DOE/RL-92-70, Rev. 0	This report provides the results of several tasks that were completed in order to characterize the release and determine the risk of migrating scavenged waste from the BY Cribs, 216-B-50 Crib, and 216-B-57 Crib. The tasks consisted of the following: (1) evaluating the seismic survey for the basalt layer, (2) drilling and sampling in the vadose zone and saturated zone, (3) analyzing past and present soil and groundwater analytical results, (4) evaluating the fate and transport of COCs, and (5) evaluating the analytical results in comparison with the regulatory compliance levels. Waste sites in this investigation were later assigned as representative waste sites for analogous waste sites in the vadose zone overlying the 200-BP-5 OU. The associated waste sites included the 216-B-11A&B Cribs, the 216-B-42 Crib, and the 216-B-43 through 216-B-50 Cribs.

Table A-3. Vadose Zone Bibliography

Document	Summary
Phase I Remedial Investigation Report for 200-BP-1 Operable Unit, Vols. 1 and 2, DOE/RL-92-70, Rev. 0 (cont'd.)	The first task listed involved the survey of seismic refraction technology to define the surface elevation of the uppermost basalt stratum and to identify possible paleochannels in the basalt that might influence the migration of contaminant plumes. The survey used 10-gauge shotgun shells instead of the proposed KINEPAK two-component explosives. This method had insufficient percussive energy to produce definitive seismic reflections from the basalt surface, thereby leading to inconclusive results. Another task involved installing vadose zone characterization borehole/wells to delineate contaminant plumes in the soils underlying the BY Cribs and the 216-B-57 Crib. One borehole was drilled at each of the following cribs to groundwater: 216-B-43, 216-B-49, and 216-B-57. Samples were collected approximately every 7.6 m (25 ft) from the bottom of the cribs to groundwater. This information was used to determine the chemical distribution within the vadose zone. Because of the uncertainty regarding the nature of the chemicals discharged to the cribs, samples were analyzed for all CERCLA target compound list and target analyte list constituents, major anions, bismuth, cyanide, and major radioisotopes. The results reported detectable concentrations or above natural background levels for the following constituents from approximately 38.1 m (125 ft) bgs to groundwater: radium-226, cobalt-60, strontium-90, technetium-99, total uranium, cadmium, chromium, nickel, silver, sodium, cyanide, nitrate, and sulfate. The geophysical data from the deep boreholes also reported elevated concentrations of cobalt-60 considered mobile for this processed waste, which is consistent with the analytical data of other mobile contaminants (e.g., technetium-99, cyanide, nitrate, sulfate, and possibly uranium) from this interval (e.g., 38.1 m [125 ft] bgs) down. This document also reported that cyanide was present in a complex state based on analytical and leach studies. Sorption studies and stability constant evaluations for cobalt and zinc provided inconclusive evidence whether cobalt was possibly complexed with cyanide. Because the results were inconclusive, another possible explanation included EDTA. However, no documentation was found that could verify EDTA was released to this site. Other contaminants that would be expected to be affected by EDTA were not realized from analytical results. Another task included modeling contaminant migration within the vadose zone to identify those contaminants, which may potentially transverse the unsaturated zone and enter the underlying unconfined aquifer. Several COCs were identified for potential transport through the vadose zone to groundwater: antimony; arsenic; barium; cadmium; total and free cyanide; complexed cyanide; chromium; copper; lead; manganese; nickel; selenium; silver; thallium; vanadium; fluoride; nitrate; nitrite; sulfate; trichloroethene; TBP; 4,4'-DDT; cesium-137, cobalt-60; potassium-40; plutonium-238; plutonium-239/240; radium-226; radium-228; strontium-90; technetium-99; total uranium; and tritium. However, only the contaminants that were identified as having a significant impact on the groundwater (i.e., TBP, cesium-137, cobalt-60, nitrate, plutonium-238, plutonium-239/240, strontium-90, technetium-99, and total uranium) were selected for modeling using a finite difference computer code (PROFLO-3).

Table A-3. Vadose Zone Bibliography

Document	Summary
Phase I Remedial Investigation Report for 200-BP-1 Operable Unit, Vols. 1 and 2, DOE/RL-92-70, Rev. 0 (cont'd.)	Modeling parameters included saturated hydraulic conductivity, unsaturated hydraulic conductivity, porosity, specific storativity, dry bulk density, K_d, molecular diffusivity, dispersivity, and decay. The conceptual model stratigraphy consisted of four flat-lying soil layers (sandy gravel layer 6.1 m [20 ft] thick, sand layer 45.7 m [150 ft] thick, silt layer 0.9 m [3 ft] thick, and a silty-sandy gravel layer 9.8 m [32 ft] thick). Specific parameters were derived from actual soil tests. Four vadose zone soil transport models were completed. One model presented a significant 22.54 cm/yr (8.874 in./yr) infiltration rate. The results predicted plutonium, uranium, nitrate, technetium, and cobalt to impact the groundwater. However, even with the significant infiltration rate, plutonium does not impact groundwater for 9,500 years. By comparison using this same infiltration rate, uranium impacted groundwater 3 years after disposal. Uranium, when modeled with a realistic natural recharge rate (1 cm/yr [0.39 in./yr]), showed insignificant impact to groundwater. Figure 5-51 shows the effect of total uranium on the groundwater over time using this recharge rate (1 cm/yr [0.39 in./yr]). By comparison, Figure 5-55 shows the effect of nitrate on the groundwater over time using a recharge rate of 1 cm/yr (0.39 in./yr). The results of the 1 cm/yr (0.39 in./yr) recharge model predicted plutonium, uranium, nitrate, cobalt, and technetium to impact the groundwater. However, as discussed, uranium and plutonium transport would be severally delayed. Because it was concluded that a point of compliance for soil cleanup levels based on protection of groundwater will not be met, compliance monitoring and possibly other requirements were recommended to ensure long-term integrity of the groundwater. Another task involved installing groundwater monitoring wells to delineate contaminant plumes in the unconfined aquifer that are associated with the 200-BP-1 OU (Figure 2-6). The wells were located based on existing hydrogeologic data; however, a groundwater gradient was difficult to establish because of pronounced differences in water table elevations. The gradient was estimated to be approximately 0.0001 to 0.0002. From the slight elevation differences, a northwestern gradient was interpreted through the waste sites surrounding the BY Cribs and northward into Gable Butte and Gable Mountain Gap. This document recommended that the lateral extent of contaminant underlying the BY Cribs be investigated and that groundwater sampling and analysis for technetium-99, cobalt-60, and uranium be continued for assessing whether groundwater impacts below the operable source are changing as predicted. Contaminant plumes that were present throughout the 200-BP-1 OU study area at concentrations significantly higher than background levels, risk-based screening concentrations, or other regulatory criteria were identified for gross beta, total cyanide, cobalt-60, nitrate, technetium-99, and tritium.

Table A-3. Vadose Zone Bibliography

Document	Summary
Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit), DOE/RL-2002-42, Rev. 0	This document provides all of the sampling results for the 200-TW-1 and 200-TW-2 OU RIs. Specific radionuclides were reviewed to determine the extent of migration in the vadose zone. The 216-B-7A Crib and 216-B-38 Trench waste sites were selected as representative sites for the other associated 200-TW-1 and 200-TW-2 OU waste sites. The associated waste sites included 216-B-8 Crib and Tile Field, 216-B-9 Crib, and 216-B-35 through 216-B-41 Trenches. The 216-B-7A Crib was analyzed for several contaminants at the following intervals (in m [ft] bgs): 0.9 to 1.5 (2.5 to 5.0), 1.7 to 2.4 (5.5 to 8), 3.0 to 3.8 (10 to 12.5), 3.8 to 4.6 (12.5 to 15), 5.6 to 6.4 (18.5 to 21), 6.9 to 7.6 (22.5 to 25), 9.1 to 9.9 (30 to 32.5), 10.7 to 11.4 (35 to 37.5), 14.63 to 15.2 (48 to 50), 22.1 to 22.9 (72.5 to 75), 29.7 to 30.5 (97.5 to 100), 45.0 to 45.7 (147.5 to 150), and 66.8 to 67.5 (219 to 221.5). A discussion of select COCs is presented below for this borehole. Contaminants not mentioned were either at or below background levels or not detected in the deep vadose zone between 22.1 m (72.5 ft) bgs to a perched water zone. • Uranium and technetium concentrations reported in samples collected from intervals below 11.4 m (37.5 ft) bgs were consistent with Hanford Site natural background concentrations or nondetect, respectively. • Nitrate and ammonia were detected at peaks in the deep vadose zone (e.g., greater than 22.1 m [72.5 ft] bgs) at the 45.0 to 45.7 m (147.5 to 150 ft) bgs interval. Results for this interval were reported to be 493 and 3.1 mg/kg, respectively. Results below this interval were reported as nondetect for ammonia. Ammonia also was detected in the intervals from 107 to 11.4 m (35 to 37.5 ft) bgs and 14.63 to 15.2 m (48 to 50 ft) bgs. • Elevated concentrations of phosphate and fluoride were reported in the sample interval from 66.8 to 67.5 m (219 to 221.5 ft) bgs. Phosphate and fluoride also were detected in all the intervals, except 29.7 to 30.0 m (97.5 to 100 ft) bgs and 45.0 to 45.7 m (147.5 to 150) ft bgs. • Tritium was detected at estimated levels, except for the interval at 66.8 to 67.5 m (219 to 221.5 ft) bgs. • Cyanide was detected at estimated values from beneath the crib to the 14.8 to 15.2 m (48.5 to 50 ft) bgs interval. • Strontium-90 was detected at elevated levels from beneath the crib to the 14.8 to 15.2 m (48.5 to 50 ft) bgs interval.

Table A-3. Vadose Zone Bibliography

Document	Summary
Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit), DOE/RL-2002-42, Rev. 0 (cont'd.)	The 216-B-38 Trench was analyzed for several contaminants at the following intervals (in m [ft] bgs): 1.1 to 1.5 (3.5 to 5.0), 2.9 to 3.7 (9.5 to 12), 4.4 to 4.7 (14.5 to 15.5), 5.5 to 6.2 (18 to 20.5), 6.9 to 7.6 (22.5 to 25), 8.8 to 9.6 (29 to 31.5), 11.4 to 12.2 (37.5 to 40), 15.8 to 16.6 (52 to 54.5), 29.7 to 30.5 (97.5 to 100), 45.0 to 45.7 (147.5 to 150), 60.2 to 61.0 (197.5 to 200), and 80.5 to 20.0 (264 to 265.5). A discussion of selected COCs is presented below for this borehole. Contaminants not mentioned were either at or below background levels or not detected in the deep vadose zone at 29.7 m (97.5 ft) bgs to groundwater. • Uranium concentrations reported in samples collected from intervals below 16.6 m (54.5 ft) bgs were consistent with Hanford Site natural background concentrations. • Nitrate and technetium concentrations were detected at peaks in the deep vadose zone (e.g., greater than 16.6 m [54.5 ft] bgs) at the 45.0 to 45.7 m (147.5 to 150 ft) bgs interval. Results for this were reported as 3,180 mg/kg and 0.888 pCi/g, respectively. Results below this interval were reported as below background and nondetect, respectively. • Cesium-137 and cobalt-60 were detected at the sample interval of 60.2 to 61.0 m (197.5 to 200 ft) bgs. This interval is in slightly silty sand. None of the mobile contaminants are elevated in this interval, and the geophysics does not report any detection of cesium or cobalt at this interval. All of the others report nondetect values, except cesium in the capillary zone.
Feasibility Study for the 200-TW-1 Scavenged Waste Group, the 200-TW-2 Tank Waste Group, and the 200-PW-5 Fission-Product Rich Waste Group Operable Units, DOE/RL-2003-64, Draft A Reissue	This document describes the results of soil characterization sampling and future impacts based on various remedial alternatives for the 216-B-5 Reverse Well, 216-B-7A&B Cribs, BX Trenches, BY Cribs, and 216-B-57 Crib and their analogous sites. The distribution of contamination and the long-term effectiveness and permanence for groundwater protection were modeled for five remedial actions. Below is a summary of the protection of groundwater based on the minimum and maximum remedial action provided. Under some of the alternatives discussed (e.g., capping), additional maintenance requirements are necessary based on deterioration of barriers: • **216-B-5 Reverse Well:** The 216-B-5 Reverse Well was evaluated based on the soil and groundwater characterization samples collected in 1979 from soils within and proximal to this well. The major vadose zone and groundwater-detected contaminants were reported as strontium-90, cesium-137, uranium, and plutonium-239/240. Under the maintain existing soil cover, institutional controls, and monitored natural attenuation alternatives, this well and analogous sites would require groundwater monitoring as an institutional control for the COCs listed previously based on DOE/RL-95-59. The treatability test report concluded that the risks from migration of the groundwater at the 216-B-5 reverse well were below levels of concern because of the relative immobility of the principal contaminants. Thus, this alternative was considered protective of groundwater.

Table A-3. Vadose Zone Bibliography

Document	Summary
Feasibility Study for the 200-TW-1 Scavenged Waste Group, the 200-TW-2 Tank Waste Group, and the 200-PW-5 Fission-Product Rich Waste Group Operable Units, DOE/RL-2003-64, Draft A Reissue (cont'd.)	• **216-B-7A&B Cribs:** This document describes the results of 12 soil characterization samples collected from soils within and directly beneath the 216-B-7A Crib to a perched groundwater zone. The contaminants detected below 15.4 m (50.5 ft) were reported as ammonia, nitrate, phosphate, and tritium. The distribution of contamination and the long-term effectiveness and permanence for groundwater protection for the next 150 years is described for several alternatives. Under the maintain existing soil cover, institutional controls, and monitored natural attenuation alternatives, this crib and analogous sites would require groundwater monitoring as an institutional control for the following COCs: cyanide, fluoride, nitrate, technetium-99, uranium-233/234/238, and strontium-90. This alternative is not considered protective of groundwater. However, if the partial removal, treatment, and disposal with capping alternative is selected, the groundwater would be considered protected. • **216-B-35 through 216-B-41 Trenches:** The FS determined possible future impacts to the groundwater from the BX Trenches. Remedial action alternative maintain that existing soil cover, institutional controls, and monitored natural attenuation was determined to cause future impact to the groundwater beneath the BX Trenches. Under this alternative, monitoring for the following contaminants would be necessary: nitrate, nitrite, uranium, technetium-99, and isotopic uranium (e.g., uranium-233/234/238). However, if the partial removal, treatment, and disposal with capping alternative is selected, the groundwater would be considered protected. • **216-B-42 through 216-B-49 Cribs:** The FS determined possible future impacts to the groundwater from the BY Cribs. Remedial action alternative maintain existing soil cover, institutional controls, and monitored natural attenuation was determined to continue to cause future impact to the groundwater beneath the BY Cribs. Under this alternative, monitoring for the following contaminants would be necessary: antimony, cadmium, cyanide, nitrate, uranium, technetium-99, cobalt-60, radium-226, and isotopic uranium (e.g., uranium-233/234/238). • **216-B-50 and 216-B-57 Cribs:** The FS determined possible future impacts to the groundwater from the 216-B-57 Crib. The remedial action alternative to maintain existing soil cover, institutional controls, and monitored natural attenuation was determined to cause future impact to the groundwater beneath the 216-B-57 Crib. Under this alternative, monitoring for technetium-99 would be necessary.
Feasibility Study for the 200-CW-1 and 200-CW-3 Operable Units and the 200 North Area Waste Sites, DOE/RL-2002-69, Draft A	This document describes the results of soil characterization sampling and future impacts based on various remedial alternatives for the 216-A-25 Gable Mountain Pond, 216-B-3 B Pond, 216-B-2-2 Ditch, and 216-B-3-3 Ditch and their analogous sites. The distribution of contamination and the long-term effectiveness and permanence for groundwater protection was modeled for five remedial actions. Below is a summary of the protection of groundwater based on the minimum and maximum remedial action provided. Under some of the alternatives discussed (e.g., capping), additional maintenance requirements are necessary based on deterioration of barriers.

Table A-3. Vadose Zone Bibliography

Document	Summary
Feasibility Study for the 200-CW-1 and 200-CW-3 Operable Units and the 200 North Area Waste Sites, DOE/RL-2002-69, Draft A (cont'd.)	• **216-A-25 Gable Mountain:** The 216-A-25 Gable Mountain Pond was evaluated based on the soil and groundwater characterization samples collected during the RI from soils within and beneath the pond. The risk assessment for groundwater protection of chemical COCs with no action concluded that groundwater protection standards were not exceeded. Under the alternative to maintain existing soil cover, institutional controls, and monitored natural attenuation, this site was determined to be protective of groundwater for radionuclides because no driving force existed and the contaminants are sorbed onto the soils. Thus, this alternative was considered protective of groundwater. • **216-B-3 Pond:** The 216-B-3 Pond (B Pond) was evaluated based on the soil and groundwater characterization samples collected during the RI from soils within and beneath the pond. The risk assessment for groundwater protection of chemical and radionuclide COCs with no action concluded that groundwater protection standards were not exceeded. Under the alternative to maintain existing soil cover, institutional controls, and monitored natural attenuation, this site was determined to be protective of groundwater for radionuclides because no driving force existed, and the contaminants are sorbed onto the soils. Thus, this alternative was considered protective of groundwater. • **216-B-3-3 Ditch:** The 216-B-3-3 Ditch was evaluated based on the soil and groundwater characterization samples collected during the RI from soils within and beneath the ditch. The risk assessment for groundwater protection of chemical COCs with no action concluded that groundwater protection standards were not exceeded. Under the alternative to maintain existing soil cover, institutional controls, and monitored natural attenuation, this site was determined to be protective of groundwater for radionuclides because no driving force existed, and the contaminants are sorbed onto the soils. Thus, this alternative was considered protective of groundwater. • **216-B-2-2 Ditch:** The 216-B-2-2 Ditch was evaluated based on the soil and groundwater characterization samples collected during the RI from soils within and beneath the ditch. The risk assessment for groundwater protection of chemical COCs with no action concluded that groundwater protection standards were exceeded for PCBs. This constituent was modeled to calculate estimated impact to groundwater. The calculation exceeded the 1,000-year time frame of the model. The risk assessment determined radionuclide COCs were less than groundwater protection requirements and, therefore, the groundwater was determined to be protective of radionuclides. Because of the PCBs, the more aggressive remove and dispose alternative was proposed to be protective of groundwater. Thus, this alternative was considered protective of groundwater.
A History of the 200 Area Tank Farms, WHC-MR-0132	This document summarizes the history of liquid waste generation and subsequent handling and storage in the tank farms.

Table A-3. Vadose Zone Bibliography

Document	Summary
Hanford Tank Farms Vadose Zone, B Tank Farm Report, GJO-99-113-TAR, GJO-HAN-28	This report presents the results of an initial baseline characterization effort based on spectral-gamma logging in existing cased boreholes within the B Tank Farm. The report provides a review of historical documents and data, including gross-gamma logs, drilling logs, groundwater monitoring information, geology, hydrology, tank leak documentation, and tank operations information. Three-dimensional visualizations of gamma-emitting contaminant plumes were developed, and figures derived from these visualizations are used to illustrate the probable extent of contamination in the shallow vadose zone. Based on this effort, the following conclusions and recommendations were provided. Evidence was provided through geophysical surveying of 50 tank leak detection monitoring boreholes that radionuclides cesium-137 and cobalt-60 generally were present in vadose zone soils near the assumed leaking Tanks 241-B-101, 241-B-103, 241-B-105, 241-B-107, 241-B-110, 241-B-111, and 241- B-112. Assumptions were made from the level of contamination and the depth of elevated contamination regarding possible leak sources. Recommendations mainly were to continue spectral-gamma monitoring for all of the tanks on certain time frames. The time frames ranged from annually, to once every 5 years, to during tank closure operations. The time frame was based on the degree of deep contamination in the soil column, amount of liquid present in a tank, and the status of the tank. In addition, four new boreholes were recommended adjacent to the 241-B-105, 241-B-106, 241-B-110, and 241-B-112 Tanks. This was considered to have the highest risk associated with vertical migration based on the concentrations reported in the spectral-gamma monitoring and the depth at which it was reported. Finally, five older boreholes were considered to be potential pathways for accelerated migration because of well configuration. It was recommended that these wells be replaced with new wells for continued monitoring.
Vadose Zone Characterization Project at the Hanford Tank Farms BX Tank Farm Report, GJPO-HAN-19	This report presents the results of an initial baseline characterization effort based on spectral-gamma logging in existing cased boreholes within the BX Tank Farm. The report provides a review of historical documents and data including gross-gamma logs, drilling logs, groundwater monitoring information, geology, hydrology, tank leak documentation, and tank operations information. Three-dimensional visualizations of gamma-emitting contaminant plumes were developed, and figures derived from these visualizations are used to illustrate the probable extent of contamination in the shallow vadose zone. Based on this effort, the following conclusions and recommendations were provided. Evidence was provided through geophysical surveying of 74 tank leak detection monitoring boreholes that radionuclides cesium-137 and cobalt-60, and sometimes uranium, were present in vadose zone soils near the assumed leaking Tanks 241-BX-101, 241-BX-102, 241-BX-108, 241-BX-110, and 241-BX-111. Assumptions were made from the level of contamination and the depth of elevated contamination regarding possible leak sources. This report also speculates that isolated contamination found under the south side of BX-106 is evidence that the 241-BX-106 Tank most likely leaked, although this tank is not recognized as an assumed leaker. This report also speculates that contamination from a near-surface pipeline may have contributed to contamination reported on the south side of the 241-BX-107 Tank.

Table A-3. Vadose Zone Bibliography

Document	Summary
Vadose Zone Characterization Project at the Hanford Tank Farms BX Tank Farm Report, GJPO-HAN-19 (cont'd.)	Three primary recommendations were made for the BX Tank Farm. The recommendations consisted of continued spectral-gamma monitoring for all the tanks, well deepening for deep vadose zone (30.5 m [100 ft] to groundwater) characterization, and installation of a borehole near the 241-BX-102 Tank for characterization of additional contaminants not identified by spectral-gamma logging.
Vadose Zone Characterization Project at the Hanford Tank Farms BY Tank Farm Report, GJPO-HAN-6	This report presents the results of an initial baseline characterization effort based on spectral-gamma logging in existing cased boreholes within the BY Tank Farm. The report provides a review of historical documents and data including gross-gamma logs, drilling logs, groundwater monitoring information, geology, hydrology, tank leak documentation, and tank operations information. Three-dimensional visualizations of gamma-emitting contaminant plumes were developed, and figures derived from these visualizations are used to illustrate the probable extent of contamination in the shallow vadose zone. Based on this effort, the following conclusions and recommendations were provided. Evidence was provided through geophysical surveying of 71 tank leak detection monitoring boreholes that radionuclides cesium-137 and cobalt-60 generally were present in vadose zone soils near the assumed leaking Tanks 241-BY-103, 241-BY-105, 241-BY-106, 241-BY-107, and 241-BY-108. Assumptions were made from the level of contamination and the depth of elevated contamination regarding possible leak sources. Three primary recommendations were made for the BY Tank Farm from this report. The recommendations consisted of (1) continued spectral-gamma monitoring for all the tanks, (2) well deepening for deep vadose zone (45.7 m [150 ft] to groundwater) characterization, and (3) installing a borehole for characterization of additional contaminants not identified by spectral-gamma logging. It was mentioned in this document that evidence exists for continuing contaminant movement in the BY Tank Farm. HNF-3532 evaluated gross-gamma logs and identified 26 boreholes in the BY Tank Farm where gamma-emitting contaminants were determined to be "unstable" at some time between 1975 and 1994, and stated that nine of these boreholes continued to be unstable in 1994 when the gross-gamma logging program was discontinued. Repeat logging reported in the addendum to the BY Tank Farm report suggests that movement may be continuing in at least two of these boreholes as late as 2001. In both cases, cobalt-60 concentrations appear to be increasing at the lower margin of the plume.
Field Investigation Report for Waste Management Area B-BX-BY, RPP-10098	This report presents the most recent comprehensive assessment of existing and new information to clarify the current understanding of the nature and extent of past releases in the B-BX-BY Tank Farms that comprise WMA B-BX-BY. Included are the field investigation analytical results, computer simulation results, and risk assessment results. From these actions, interim actions were completed and conclusions and recommendations were offered.

Table A-3. Vadose Zone Bibliography

Document	Summary
Field Investigation Report for Waste Management Area B-BX-BY, RPP-10098 (cont'd.)	The field activities included borehole drilling, as well as soil and groundwater sampling at six locations. These locations were identified as the following boreholes or waste sites: Borehole 299-E33-45 (241-BX-102 Tank/241-BX-101 Tank release investigation), Borehole 299-E33-46 (241-B-110 Tank release investigation), 216-B-38 Trench (BX Trench investigation, west of BX Tank Farm), 216-B-7A Crib waste effluent crib investigation (north of the B Tank Farm), Borehole 299-E33-338 (southeast corner of the B Tank Farm), and experimental test Well 299-E24-111. The soils from three boreholes near the tank farms (216-B-7A Crib, 216-B-38 Trench, and Borehole 299-E33-338) were investigated using laboratory analyses and geophysical logging. The results from these studies at the 216-B-7A Crib and 216-B-38 Trench showed relatively minimal contamination levels in the deep vadose zone. Further information is provided in the summaries for DOE/RL-2002-42 and DOE/RL-2003-64 above. Borehole 299-E33-338 was determined to be representative of background soils. Most of the summary information provided in this document is the investigation of soils impacted by releases in the B and BX Tank Farms, specifically the 241-B-110, 241-BX-101, and 241-BX-102 Tanks. The 241-B-110 Tank release is associated with UPR-200-E-128. UPR-200-E-128 was identified a transfer line leak attached to the 241-B-110 Tank in the late 1960s to early 1970s. Neither the volume nor the waste type is well understood. Historical records suggest a plausible waste stream derived from strontium recovery waste from dissolved PUREX fuel. The 241-BX-101 and 241-BX-102 Tanks were identified with three UPRs: 200-E-5, 200-E-131, and 200-E132. UPR-200-E-5 was identified as a 1951 release of 346,744 L (91,600 gal) of metal waste that contained 22.5 tons of uranium. The UPRs 200-E-131 and 200-E-132 are believed to be associated with the BX-101 pump pit loss identified in this document. According to investigations completed in this document, the release occurred over a 4-year period (1968 to 1972) and was associated with three major waste types that were processed in B Plant: aged PUREX supernatants, PUREX-sludge supernatant, and diluted aged REDOX Plant supernatant. A volume estimate was not provided for the 241-BX-101 Tank release. The investigation described in this document included drilling and soil sample collection associated with two boreholes, 299-E33-45 and 299-E33-46. Analyses reported in this document included the following: nitrate, nitrite, chloride, fluoride, sulfate, phosphate, bicarbonate, aluminum, arsenic, calcium, chromium, iron, magnesium, manganese, potassium, selenium, silicon, sodium, strontium, isotopic uranium, radioactive strontium, tritium, and technetium-99. The primary analyses included an extensive pore water chemistry process. The means of measuring pore water composition was to add deionized water to soil samples to generate enough water for performing analyses. By back-calculating for the dilution introduced by the added water, true concentrations were derived. For 14 sediment samples, pore water was directly separated from the sediment and analyzed. By comparing the dilution-corrected water extract data with the pore water data in these samples, an indication of the closeness of the water extract chemistry to original water chemistry was determined. In general, comparisons were not exact, but concentration values generally were within a factor or two or more, and agreement improved with increasing constituent concentration.

Table A-3. Vadose Zone Bibliography

Document	Summary
Field Investigation Report for Waste Management Area B-BX-BY, RPP-10098 (cont'd.)	Extensive water chemistry analyses were completed for Borehole 299-E33-45 samples collected between 3.1 and 77.4 m (10 and 254 ft) bgs. The primary indicator of tank fluid occurrence is elevated nitrate concentrations that are measured in the borehole from 20.7 to 77.7 m (68 to 255 ft) bgs, which is the bottom of the borehole. The maximum nitrate values occur between 42.7 and 51.8 m (140 and 170 ft) bgs, just above the primary silt-rich layer between the H_2 and H_3 subunits of the Hanford formation. A secondary enriched nitrate zone occurs between 67.1 and 70.1 m (220 to 230 ft) bgs near the bottom of the borehole. The technetium-99 concentration distributions are nearly identical to nitrate, with the most elevated concentrations occurring between 23.8 and 51.9 m (78 and 170 ft) bgs. Maximum concentrations occur between 42.7 and 50.3 m (140 to 165 ft) bgs. A secondary elevated technetium-99 concentration interval occurs between 21.8 and 70.7 m (71.5 and 232 ft) bgs. Elevated uranium concentrations primarily are found between 21.3 and 51.8 m (70 and 170 ft) bgs. Within this zone, smaller peak values are present; these tend to occur around the silt-rich layers at 22.9, 38.6, and 51.8 m (75, 120, and 170 ft) bgs. The thickest and highest uranium concentration zone occurs between 34.1 and 43.3 m (112 and 142 ft) bgs. It was concluded from the various analysis completed that the majority of the release near the 241-BX-102 Tank was confined to about 51.9 m (170 ft) bgs in this borehole. However, nitrate and technetium-99 were reported to migrate deeper. Well 299-E33-41, located directly east of the BX Tank Farm and northeast of the 241-BX-102 Tank, measured peak concentrations that were considered because of the release from the BX Tank Farm. The basis for this conclusion included (1) nitrate to technetium-99 ratios for the groundwater at this location are the same order of magnitude as in the soil profile, (2) the coincident peaks of uranium and technetium-99 in 1997, (3) significant changes in concentration levels were considered to be associated with repeated ponding of runoff from natural precipitation located in the tank farm area, and (4) a poorly sealed borehole to groundwater was present after early 1970 in the general location of the 241-BX-101 and 241-BX-102 Tanks. Various analyses also were completed near the 241-B-110 Tank release. Results confirmed that the bulk of contamination is confined to about 52 m (170 ft) bgs, similar to Borehole 299-E33-45. The deepest contamination was associated with nitrate, while the strontium-90 radionuclide extent was not reported below 25.9 m (85 ft) bgs. The strontium-90 plume was determined to be associated with a plume of sodium-HCO_3-F at a concentration of sodium-bicarbonate of 100 to 150 mmol/L. Technetium-99 was reported suspect in the shallow vadose zone, and the peaks in the H_3 unit and Plio-Pleistocene unit were considered to require unrealistic recharge rate to drive technetium-99 to these depths. Thus, this constituent was considered likely from some horizontal migration of fluids containing technetium-99. Based on this observation, it also was uncertain if the nitrate from the H_3 and Plio-Pleistocene units reflected the leading edge of the release or some other release that may be migrating laterally into this area.

Table A-3. Vadose Zone Bibliography

Document	Summary
Field Investigation Report for Waste Management Area B-BX-BY, RPP-10098 (cont'd.)	Discussion on lateral migration was provided in this document for the conceptual model associated with the release from the 241-BX-101 and 241-BX-102 Tanks. The set of spectral-gamma drywell data north and east of the 241-BX-101 and 241-BX-102 Tanks defines a northeast-trending footprint based on the presence of uranium, antimony-125, and europium-154, and to some extent cobalt-60. The Borehole 299-E33-45 data reported the bulk of the contamination was located between two silt-rich layers. These layers may be extensive and probably have hydraulic properties that contrast with adjacent sandier soils so preferential lateral flow occurred. A perched water zone was encountered above the lower silt zone at 69.2 to 70.7 m (227 to 232) ft bgs. Coincident groundwater peaks of uranium and technetium-99 occurred in Well 299-E33-41 around 1997 strongly indicating a metal waste source. This well is more than 30.5 m (100 ft) east of the tanks and indicated significant lateral migration in the vadose zone before vertical migration to the aquifer. This model is strengthened further by the apparent lack of tank waste migration to groundwater in Borehole 299-E33-45. To estimate the future impacts of past operational releases, a suite of numerical simulations were performed to predict the next 1,000 years. Note that the vadose zone boundary of the numerical models was between the 241-BX-108 Tank and the eastern fence line of the BX Tank Farm including the 241-BX-102 Tank. Simulation results indicated that two key drivers affecting future contaminant migration are vadose zone contaminant inventory and recharge. This conclusion was derived from the extensive migration results with the 3.8 L/min (1 gpm) discharge over 20 years as compared to a 10 mm/yr recharge rate. In addition, numerical simulations results suggest that high groundwater concentrations of technetium-99 cannot be explained with natural recharge alone. The fact that peak technetium-99 concentrations for the simulated water-line leak model were the same order of magnitude as those measured in Well 299-E33-41 suggests that artificial recharge played a key role in contaminant migration in the BX Tank Farm. Risk analysis completed from modeling results indicated that technetium-99, uranium, and nitrate are key COCs from the BX Tank Farm. Proposed interim measures were identified and completed to minimize the infiltration from tank farm sources. These interim measures included the following: • Emplaced upgradient surface water run-on control measures. • Completed leak tests of sanitary and raw water lines to B-BX-BY Tank Farms resulting in no detected leaks. • Capped existing dry wells to prevent water intrusion. • Verified that the sanitary water line to the B Tank Farm had been cut and capped. In conclusion, based on the interim measures, the following statements were made: • Future impacts from waste currently in the vadose zone that results from past releases from the B-BX-BY Tank Farms are not expected to exceed DWSs at or beyond the WMA boundary as long as high-volume liquid discharges to the vadose zone are eliminated.

Table A-3. Vadose Zone Bibliography

Document	Summary
Field Investigation Report for Waste Management Area B-BX-BY, RPP-10098 (cont'd.)	• The amount of technetium-99 distributed to the vadose zone and that which has reached groundwater is uncertain but could amount to tens of curies from the BX-101 pump pit leak. • Neither uranium nor strontium-90 is expected to significantly impact groundwater in the current moisture and geochemical environment. However, the precipitated uranium phases may function as a long-term source to percolating water if artificial recharge is not controlled.
Characterization of Vadose Zone Sediment: Borehole 299-E33-45 Near BX-102 in the B-BX-BY Waste Management Area PNNL-14083	This is one of four reports that presented the results of geologic, geochemical, and select physical characterization data on sediments recovered from boreholes associated with the field investigation for WMA B and WMA BX. This report focuses on Borehole 299-E33-45, installed northeast of the 241-BX-102 Tank. This report also presents interpretation of the data in context with the sediment lithologies, the vertical extent of contamination, the migration potential of the contaminants, and the likely source of the contamination in the vadose zone, perched water, and groundwater east of the BX Tank Farm. Several fine-grained lenses within the H_2 unit at 22.7, 36.6, and 50.9 m (74.5, 120, and 167 ft) bgs were observed through sediment samples at borehole 299-E33-45. Based on the contaminant suite also found at these depths, it is likely the lenses caused horizontal spreading of percolating 241-BX-102 Tank fluids. This is further realized from the saturated conditions from 69.2 and 70.7 m (227 and 232 ft) bgs and the associated 6.4 m (21 ft) thick Plio-Pleistocene (e.g., approximately 66.4 to 72.8 m [218 to 239 ft] bgs), fine-grained silt/clay unit. Key observations were made during detailed characterization of Borehole 299-E33-45 vadose zone sediments. The pore water electrical conductivity showed two lobes of elevated contaminants. The shallower lobe, between 24.1 and 36.6 m (79 and 120 ft) bgs, resides with the middle sand sequence in the H_2 unit. The shallower lobe appears to pond on top of fine-grained paleosol at 36.6 m (120 ft) bgs. The more concentrated lobe resides between 150 and 173 ft bgs, with the most concentrated fluid between 45.7 and 48.8 m (150 and 160 ft) bgs, perhaps ponding on the fine-grained wet zone 50.9 to 51.8 m (167 to 169.8 ft) bgs, at the bottom of the H_2 unit. Water-extractable cations suggest that an ion-exchange process dominates the major constituent pore water/sediment interactions in the borehole where tank fluid passed by or currently exists. This was supported by the depletion and subsequent enrichment in alkaline earth cations deeper in the soil column. In addition, the interaction of uranium, present in the 1951 tank overfill fluids, with the vadose zone sediments appears to include a combination of surface adsorption and precipitation-dissolution with the precipitated uranium dominating.

Table A-3. Vadose Zone Bibliography

Document	Summary
Characterization of Vadose Zone Sediment: Borehole 299-E33-45 Near BX-102 in the B-BX-BY Waste Management Area, PNNL-14083 (cont'd.)	Nitrate, uranium, and technetium were prominent contaminants reported within the sediments analyzed within Borehole 299-E33-45. The elevated uranium concentrations reported in Borehole 299-E33-45 sediments were identified in the upper vadose zone sediments (22.4 to 22.7 m [73.4 to 74.5 ft], 33.8 to 36.6 m [111 to 120 ft], 36.6 to 44.2 m [120 to 145 ft], 44.2 to 51.0 m [145 to 167.2 ft], and 51.0 to 51.8 m [167.2 to 169.8 ft] bgs). Nitrate was found more extensively throughout the soil column and was considered as reaching groundwater. The technetium also was extensive in the soil column. However, technetium was not reported in sediments from 73.2 m (240 ft) bgs to groundwater. As a result, there was question as to whether technetium in the groundwater below was associated with the 241-BX-102 Tank release. Two conclusions were postulated. Either the technetium reached the aquifer at another location other than Borehole 299-E33-45, or the technetium in the aquifer may be from another source. It was concluded that near horizontally bedded anisotropic sediments with a slight northeasterly dip likely caused a preferential horizontal transport of mobile contaminants. The moisture content, pH, electrical conductivity, and the sodium, tritium, and uranium profiles do not suggest that the leading edge of the 241-BX-102 Tank vadose zone plume has penetrated below 51.8 m (170 ft) bgs. In addition, the analyses do not firmly suggest that the source of the contamination in the groundwater east of the BX Tank Farm is the 1951 overfill event at the 241-BX-102 Tank. It was noted that the lack of technetium-99 from 73.2 m (240 ft) bgs to groundwater and the differences in technetium-99-to-nitrate ratios suggests that there may be another source of contaminated water. However, near horizontal fine-grained sediment layers may have provided horizontal water flow within the vadose zone and allowed for subsequent vertical flow allowing communication with the unconfined aquifer below. The presence of two constituents, considered to be mobile (technetium-99 and nitrate), in the groundwater below suggest that the leading edge of contamination may have penetrated all the way to the groundwater. Thus, the deep vadose zone, perched water, and groundwater data at Borehole 299-E33-45 do not present a clear picture on the full transport pathway to groundwater.
"Identifying the Sources of Subsurface Contamination at the Hanford Site in Washington Using High-Precision/Uranium Isotopic Measurements," in *Environ. Sci. Tech.* (Christensen et al., 2004)	This paper used isotopic analyses to investigate the link between vadose zone and groundwater contamination, to identify contamination sources, and to provide estimates of the relative proportions of contaminant uranium in the analyzed samples. In addition, the uranium isotopic compositions measured in the vadose zone and groundwater samples are compared to estimates of the uranium isotopic compositions of different waste fluids to constrain the history of contamination events in the B-BX-BY Tank Farms.

Table A-3. Vadose Zone Bibliography

Document	Summary
"Identifying the Sources of Subsurface Contamination at the Hanford Site in Washington Using High-Precision/Uranium Isotopic Measurements," in *Environ. Sci. Tech.* (Christensen et al., 2004) (cont'd.)	Isotopic uranium ratios from vadose zone soil-water extracts from Borehole 299-E33-45 provide significant evidence that the uranium contamination in the vadose zone is from one source and must have come from a single, well-mixed source. In contrast, a pore water sample from within the perched water body encountered at 70.5 m (231 ft) depth showed a different isotopic composition. The isotopic ratio data for uranium-236 to uranium-238 versus uranium-238 to uranium-235 was plotted on a graph, and a best-fit line through Borehole 299-E33-45 plume data and background (uncontaminated) groundwater data provided a linear relationship. It was determined that the vadose zone plume samples represent a mix of reprocessed unenriched uranium fuel and natural uranium end member (e.g., 10.7 percent uranium), while the perched water body is typical of natural vadose zone pore fluid with a slight amount of uranium. The uranium may be associated with 241-BX-102 or a mix of three sources (natural background, the 241-BX-102 Tank overfill, and a third as yet unidentified source). The uranium isotopic data provide several lines of evidence for the source of the B-BX-BY Tank Farm groundwater uranium plume. The highest concentration groundwater samples closely approach the isotopic composition of Borehole 299-E33-45 vadose zone plume, with other samples falling along the end member line in decreasing order of concentration with distance from the source. This systematic relationship is most likely a result of mixing between natural background uranium and a contaminant composition represented by Borehole 299-E33-45 vadose zone plume rather than each groundwater sample representing contamination from different sources. This conclusion is further supported by the relationships between uranium-234 and uranium-238, which provides additional signatures for natural uranium and contaminant uranium because of an alpha-recoil effect that imparts a higher uranium-234 to uranium-238 ration to groundwater than the secular equilibrium ratio. Based on this information, the highest ratios reported in the groundwater were reported in decreasing ratio concentration as follows: 299-E33-9, 299-E33-44, 299-E33-18, 299-E33-38, 299-E33-26, 299-E33-5, 299-E33-13, and 299-E33-31. These select well locations were reported with ratio concentrations at greater than 90 percent contamination based on the end members discussed for Borehole 299-E33-45. Isotopic uranium ratios from soil samples collected from Borehole 299-E33-46 provide evidence that the uranium contamination in the vadose zone has a different isotopic composition not matching that of Borehole 299-E33-45. These observations point to different, separate contaminant sources for the uranium in Borehole 299-E33-45 and Borehole 299-E33-46 vadose zone plumes. It was concluded from this information that the 241-B-110 Tank release has not been a significant source of uranium contamination in the groundwater.

Table A-3. Vadose Zone Bibliography

Document	Summary
"Identifying the Sources of Subsurface Contamination at the Hanford Site in Washington Using High-Precision/Uranium Isotopic Measurements," in *Environ. Sci. Tech.* (Christensen et al., 2004) (cont'd.)	This paper suggests the initial locus of groundwater contamination was displaced from the 241-BX-102 Tank source by as much as 150 m (492 ft) to the northeast. Comparing this distance to the vertical distance to the groundwater table implies more than an 8:1 ratio of horizontal to vertical migration within the vadose zone before reaching the groundwater. It is speculated that this may have resulted from the strong anisotropy in the vertical permeability because of the presence of fine sedimentary layers in the stratigraphy, enhancing lateral migration. This paper stated that the first sign of uranium contamination in Well 299-E33-18 appeared in early 1993 and uses that time and location as a basis for travel-time calculations for the groundwater plume. Research of the HEIS database shows that uranium concentrations were similar in Wells 299-E33-1A and 299-E33-13 during this time. This paper also concludes that Well 299-E33-34, located about 775 m (2,543 ft) from Well 299-E33-18, first reported elevated uranium concentrations associated with the uranium located at Well 299-E33-18 in mid-1995 to early 1996, giving a travel time of approximately 2.5 to 3 years. However, this paper does indicate that several LWDFs (cribs) were in operation close to the B-BX-BY Tank Farms during the late 1940s and 1950s that could not be completely ruled out as sources of groundwater contamination without measurements of vadose zone samples from those locations. Thus, these past releases may have contributed to the concentrations reported at Well 299-E33-34 rather than the 241-BX-102 Tank site, although the consistency of the groundwater uranium isotopic composition with a single mixing curve argues for a uniform source. Still significant uranium contamination seen in the vadose zone near the 241-BX-102 Tank and groundwater contamination indicates a continuing potential for future contamination from the 241-BX-102 Tank vadose zone plume.
S.M. Stoller geophysical logging at Well 299-E33-41	A May 2002 log completed at Well 299-E33-41 provided comparison of uranium-235 and protactinium-234 for determining manmade uranium migration within the vadose zone. Data suggest that manmade concentrations were reported from approximately 23.8 to 73.8 m (78 to 242 ft) bgs. The relative groundwater level in this well was reported at approximately 77.07 m (252.87 ft) bgs. Ratios of uranium-235 to protactinium-234 at various depths demonstrated a linear slope. However, comparison of the slopes at different depths indicates a shift of the slope for contamination from 57.1 to 74.1 m (194 to 243 ft) bgs. The data suggest two different waste streams: one waste stream from 23.8 to 58.5 m (78 to 192 ft) bgs and a different characteristic waste stream from 57.1 to 74.1 m (194 to 243 ft) bgs.

Table A-3. Vadose Zone Bibliography

Document	Summary
Interpreted Extent of Subsurface Contamination Resulting from the 241-BX-102 Tank Leak (Sobczyk, 2004)	The manufacture of plutonium at the Hanford Site produced large volumes of radioactive waste. This waste has been stored in large underground tanks, stored in the tanks prior to discharge to the vadose zone, or discharged directly to the soil on the Hanford Site. Large plumes of contaminated groundwater are present at the Hanford Site, and their origin has been attributed primarily to the intentional release of radioactive waste to the soil. This report integrates and interprets spectral-gamma logging results obtained from 287 boreholes located in the waste sites surrounding WMA B-BX-BY and within the B-BX-BY Tank Farms. This report replicates information contained in a report (GJO-2003-545-TAC) that was never issued by DOE. The vadose zone data set consists of more than 70,000 individual measurements. The purpose of this report is to document the origin of uranium contamination in groundwater in WMA B-BX-BY. Spectral-gamma log data collected between 1991 and 2004 are used to evaluate the relationships of tank leaks, intentional releases to disposal sites, contamination, and stratigraphy. The recently completed investigation of the waste sites (DOE/RL-2002-42) and WMA B-BX-BY (RPP-10098) arrived at conflicting interpretations with respect to the development of the current uranium groundwater plume. The RI report (DOE/RL-2002-42) for the waste sites adjacent to the WMA suggested that these waste sites are not the source of the uranium observed in the groundwater; however, the field investigation report for WMA B-BX-BY implied that the nearby waste sites are the source of the current uranium groundwater contamination. Prior investigations have established the following: • A spill of 346.7 L (91,600 gal) of supernatant containing 20.4 metric tons (22.5 tons) of uranium occurred at Tank BX-102 (HW-20438). • ARH-2035 concluded that Tank BX-102 leaked from near its base in the southeast quadrant of the tank. • The processed uranium vadose zone plume near Tank BX-102 extends to Well 299-E33-41 located east of the BX Tank Farm fence line and more than 50 m (164 ft) from Tank BX-102. • Based on soil samples and spectral-gamma logging, uranium is not present in the deep vadose zone (below an elevation of 182.9 m [600 ft] or approximately 18.3 m [60 ft] bgs) above background levels (0.01 to 0.06 Bq/g or 0.3 to 1.5 pCi/g) at the nearby waste sites (BY Cribs [DOE/RL-92-19, DOE/RL-2002-69, and DOE/RL-2002-42], BX Trenches [DOE/RL-2001-65 and DOE/RL-2002-42], 216-B-11A&B French Drains [DOE/RL-2001-66 and DOE/RL-2002-42], and 216-B-57 Crib [DOE/RL-92-19, DOE/RL-2002-42, and DOE/RL-2002-69]). • Spectral-gamma log data acquired in two groundwater wells (299-E33-18 and -41) located northeast of Tank BX-102 and outside the BX Tank Farm showed an influx of uranium contamination between 1991 and 1997 (WMNW-9759114; PNNL-12086; DOE/RL-2001-66). In Well 299-E33-41, 238U increased from 7.4 to 37 Bq/g (200 to 1,000 pCi/g) between 1991 and 1997 in a zone between elevations of 132.6 and 126.5 m (435 and 415 ft) or 67.1 and 73.2 m log depth (220 and 240 ft log depth). Processed uranium was detected just above groundwater in the interval between elevations of 128.3 and 122.2 m (421 and 401 ft) or 71.3 and 77.4 m log depth (234 and 254 ft log depth) with a maximum concentration of 22.2 Bq/g (600 pCi/g) in groundwater Well 299-E33-18.

Table A-3. Vadose Zone Bibliography

Document	Summary
Interpreted Extent of Subsurface Contamination Resulting from the 241-BX-102 Tank Leak (Sobczyk, 2004) (cont'd.)	• The source of processed uranium detected by spectral-gamma logging at Boreholes 299-E33-18 and 299-E33-59 are different (DOE/RL-2001-66). Beginning in 1994, a 760 m (2,500 ft) long southeast-northwest trending uranium groundwater plume developed in the vicinity of WMA B-BX-BY (PNNL-13404). In 1994, uranium concentrations above the maximum contaminant level (MCL of 30 µg/L) were reported in only two wells (299-E33-13 and 299-E33-18) according to PNL-10817. Groundwater elevation is at approximately 122.2 m (401 ft) in this area (77.7 m [254.9 ft] log depth). Spectral-gamma measurements detected processed uranium (uranium-235 and uranium-238) in 17 of 287 boreholes. Uranium-235 concentrations are generally an order of magnitude less than uranium-238 concentrations. The only extensive area of uranium-235/238 contamination found to date is located northeast of Tank BX-102. This area contains 13 of the 17 boreholes where processed uranium was detected, and uranium-238 concentrations reached 37 Bq/g (1,000 pCi/g). In the upper vadose zone, processed uranium was detected near Tanks BX-106 and BY-111. Borehole 299-E33-18, located approximately 24.4 m (80.1 ft) west of the 216-B-7A&B Cribs, exhibited uranium-238 contamination at elevations between 128.3 and 122.2 m (421 and 401 ft) or 71.3 and 77.4 m log depth (234 and 254 ft log depth) at concentrations exceeding 18.5 Bq/g (500 pCi/g). Near the 216-B-7B Crib at Borehole 299-E33-59, uranium-235/238 was detected between elevations of 186.5 and 182.9 m (612 and 600 ft, or 42 and 54 ft log depth) at concentrations net exceeding 1.2 Bq/g (32 pCi/g) for uranium-238. Based on geophysical log data and groundwater monitoring data, the significant conclusions of this report are as follows: • Processed uranium from Tank BX-102 can be tracked in the vadose zone as far as borehole 299-E33-41 and to within 3.7 m (12 ft) above groundwater. Uranium migration in the vadose zone is following the northeast stratigraphic dip in this area and has crossed the BX Tank Farm boundary. • The increases in uranium concentrations observed in the vadose zone at Wells 299-E33-41 and 299-E33-18 are related. It is hypothesized that once uranium reaches the perched water within the Cold Creek interval; it can be transported laterally at an increased rate over relatively large distances. Processed uranium from the BX-102 Tank spill has reached groundwater Well 299-E33-18 at an elevation of 122.2 m (401 ft, or approximately 254 ft log depth and just above groundwater) and a lateral distance of 121.9 m (400 ft) to the northeast from the tank. The increases in uranium concentrations observed in the vadose zone at Wells 299-E33-41 and 299-E33-18 are also related to the development of the uranium groundwater plume. Evaluation of log data indicates the contamination reached Well 299-E33-18 between 1991 and 1997 (WMNW-9759114; PNNL-12086; DOE/RL-2001-66). • Groundwater monitoring data acquired by (PNNL-13788) indicate that uranium (above the MCL) was first detected in groundwater in April 1994 northeast of Tank BX-102 at Well 299-E33-18 and has since increased in concentration.

Table A-3. Vadose Zone Bibliography

Document	Summary
Interpreted Extent of Subsurface Contamination Resulting from the 241-BX-102 Tank Leak (Sobczyk, 2004) (cont'd.)	• The uranium groundwater plume appears to originate northeast of Well 299-E33-41 and near Wells 299-E33-18 and 299-E33-44. Between 1994 and 2002, uranium concentrations in groundwater have increased, and the uranium groundwater plume has expanded to the northwest. Uranium in groundwater has moved northwest, reached groundwater underneath the 216-B-61 Crib, and extended beyond the 200 East Area boundary. • The spill of uranium at Tank BX-102 is apparent source of the uranium contamination in the groundwater. This conclusion is supported by the results of uranium isotopic data (Appendix D in RPP-10098). Spectral-gamma logging in the study area to date has not identified other tanks and waste sites as potential sources of uranium contamination in groundwater. • The difference in the extent and impact of the BX-102 uranium vadose zone plume as evaluated in RPP-10098 and this report occur because this report attempted to include all available spectral-gamma log data in the B-BX-BY Tank Farms area, and RPP-10098 did not include spectral-gamma data from Borehole 299-E33-41. Further, RPP-10098 did not include spectral-gamma data from Borehole 299-E33-45, which was drilled for the B-BX-BY field investigation report (RPP-10098), was not included in their kriging of spectral-gamma data to estimate the extent of uranium vadose zone contamination. By excluding the log results from 299-E33-45 and 299-E33-41, both the vertical and lateral extents of the uranium contamination as evaluated in RPP-10098 are underestimated. • The initial conditions used in the vadose zone transport model for the risk assessment in RPP-10098 did not address the uranium contamination from the BX-102 Tank leak that occurs 3.7 m (12 ft) above groundwater in Borehole 299-E33-41. Instead, the initial conditions are based upon soil sample results from Borehole 299-E33-45 that places the bulk of the uranium contamination more than 30.5 m (100 ft) above groundwater. • Spectral-gamma log results are not consistent with BHI-01496 estimates for uranium and cobalt-60 releases to the vadose zone. Substantial inventories of uranium are predicted by the model (BHI-01496) for the BX Trenches, 216-B-7A&B Cribs, the BY Cribs, and the 216-B-8 Crib and Tile Field. The spectral-gamma field logging detected a minor amount of processed uranium only near the 216-B-7B Crib. The spectral-gamma results for uranium are more consistent with the prior inventory estimate (HW-20438; HW-54599; ARH-ST-156). Spectral-gamma logging indicated that the majority of the cobalt-60 contamination in the vadose zone is associated with the BY Cribs, and, to a lesser extent, the BY Tank Farm. BHI-01496 indicated that the greatest releases of cobalt-60 occurred at B Tank Farm, where a cumulative 1010 Bq (2.7 Ci) of cobalt-60 were lost to the vadose zone, and that only 5.2 × 107 Bq (0.0014 Ci) of cobalt-60 were discharged to the vadose zone at the BY Cribs. The source of the cobalt-60 detected in Borehole 299-E33-13 at elevation of 144.8 m (475 ft or log depth 157 ft bgs) is unknown. The closest potential sources are Tank BY-103, located 61 m (200 ft) to the southwest, or the BY Cribs, located 82.3 m (270 ft) to the northwest. The stratigraphic dip of the Hanford Site is to the northeast, which suggests that the leak from Tank BY-103 is the likely source.

Table A-3. Vadose Zone Bibliography

Document	Summary
Hanford Contaminant Distribution Coefficient Database and Users Guide, PNNL-13895, Rev. 1	The purpose of this document was to compile all useful K_d data determined for Hanford Site sediment and related materials into one database. In addition, technical justification and appropriate application for using the linear sorption K_d model are discussed. Furthermore, this document provides guidance on how to apply the information properly and effectively to select appropriate K_d values for numerical transport modeling efforts. Bounding conditions (e.g., sediment/soil mineralogy or physical properties, solution chemistry, or contaminant loading/concentration) of the system to be modeled are key to the application of this empirical model. Discussions of various COCs found at the Hanford Site are presented. Calculated K_d ranges are given with explanation of solution complexing conditions, which can alter the expected K_d result. Generally, contaminants fall into three categories of K_d values: high (very low mobility), moderate (moderate mobility), and low (high mobility). However, several variables can change the expected K_d, which is why other observations (i.e., mineralogy, waste chemistry, contaminant solubility for identified waste solutions, previous soil sample results, past and present groundwater data, and geophysical data) are required to reduce the uncertainty in selection of a K_d. High K_d contaminants were identified as the following: americium, cobalt, cesium, nickel, lead, and plutonium. Complexes that could affect the expected high K_d value include the presence of EDTA, low pH solutions, cyanide, highly basic solutions, and high salt concentrations. Americium, cobalt, and plutonium were cited as having reduced K_d when solutions containing EDTA are present. Americium also was cited as having a reduced K_d with low pH solutions. Cobalt was identified as having reduced K_d when solutions containing cyanide or high pH are present. Cesium was identified as having reduced K_d when solutions containing high salt concentrations (Na^+, NH_4^+, and K^+) are present. Moderately sorbing K_d contaminants identified only included strontium-90. The strontium-90 migration is fairly limited under most waste disposal sites at the Hanford Site. Strontium was identified as having reduced K_d when solutions containing low pH, EDTA, or high salt concentrations (Ca^{2+}, NH_4^+, and K^+) are present. Low sorbing contaminants were identified as the following: hexavalent chromium, iodine-129, nitrate, neptunium, selenium, technetium-99, uranium, and carbon tetrachloride. Of these contaminants, neptunium generally is considered to have a moderate K_d. Neptunium has a low K_d when contact time is one day or less and high calcium or EDTA concentrations exist.

Table A-3. Vadose Zone Bibliography

Document	Summary
Vadose Zone Characterization Project at the Hanford Tank Farms C Tank Farm Report, GJPO-HAN-18	This report presents the results of an initial baseline characterization effort based on spectral-gamma logging in existing cased boreholes within the C Tank Farm. The report provides a review of historical documents and data including gross-gamma logs, drilling logs, groundwater monitoring information, geology, hydrology, tank leak documentation, and tank operations information. Three-dimensional visualizations of gamma-emitting contaminant plumes were developed, and figures derived from these visualizations are used to illustrate the probable extent of contamination in the shallow vadose zone. Based on this activity, the following conclusions and recommendations were provided. Evidence was provided through geophysical surveying of 66 tank leak detection monitoring boreholes that radionuclides cesium-137 and cobalt-60 generally were present in vadose zone soils near the assumed leaking 241-C-101, 241-C-110, and 241-C-111 Tanks. Assumptions were made from the level of contamination and the depth of elevated contamination regarding possible leak sources. This report speculates that significant amounts of contamination near the 241-C-104, 241-C-105, 241-C-106, 241-C-108, and 241-C-109 Tanks indicate possible leaks from cascade lines between the 241-C-104, 241-C-105, 241-C-106, 241-C-108, and 241-C-109 Tanks. Alternatively, the report points to overfilling and significant liquid level drops in C-105 as a possible source of the contamination detected in the vadose zone beneath the 241-C-104 through 241-C-106 Tanks. Three primary recommendations were made for the C Tank Farm. The recommendations consisted of (1) continued spectral-gamma monitoring for all the tanks, (2) well deepening for deep vadose zone (45.7 m [150 ft] to groundwater) characterization, and (3) installation of boreholes near the 241-C-201 through 241-C-204 Tanks for characterization of releases previously identified. The well deepening was targeted mainly at areas near the 241-C-104, 241-C-105, 241-C-106, 241-C-108, and 241-C-109 Tanks, where vadose zone contamination is present. In addition, it was recommended that the vadose zone soils be characterized for contaminants not addressed through spectral-gamma logging (e.g., anions, beta emitters, and metals).
Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site, PNNL-11800	Appendix E of this document provides distribution coefficients for radionuclide materials in the ground that may interact with past releases. To accommodate the different waste source-term categories and K_d zones, the K_d values had to be determined for six source-type waste solutions and various stratigraphic types. Based on the waste solution for second-cycle waste (low-organic, low-salt) and the fact that acid was added, the cobalt K_d value was reduced to 0.2 from 5 mL/g, which is a good correlation for cobalt being detected deep in the vadose zone by geophysics surveys.
Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes, DOE/RL-92-24, Rev. 4	This document provides description on the various sediments at the Hanford Site. The major minerals and rock types found within the various lithologies are described. The various minerals are as follows: pyroxene, plagioclase, potassium feldspar, kaolinite, muscovite, biotite, orthoclase, and various placer minerals (e.g., apatite, rutile, garnet, epidote, tourmaline, and monazite).

Table A-3. Vadose Zone Bibliography

Document	Summary
Radionuclide Interactions with Soil and Rock Media Volume I: Processes Influencing Radionuclide Mobility and Retention Element Chemistry and Geochemistry Conclusions and Evaluation, EPA/520/66-78/007a	This document reports the state of knowledge of how 19 radionuclides behave in soil rock media. The report discusses the processes influencing radionuclide mobility (e.g., solid-phase and solution species, ion exchange, diffusion, replacement reactions, physical transport and filtration, saturated effects, specific retention, and K_d). Based on this understanding, the report describes the transport observations for the following radionuclides from references throughout various world settings: cobalt, cerium, europium, iodine, americium, antimony, cesium, ruthenium, strontium, technetium, thorium, neptunium, plutonium, promethium, radium, tritium, uranium, and zirconium.
Final Environmental Impact Statement Waste Management Operations Hanford Reservation, Richland, Washington, ERDA-1538	This document discusses the environmental impact for radioactive and nonradioactive materials released to the environment. Laboratory and field observations show that the bulk of plutonium in waste solutions at near neutral pH is removed from the solution by sediments relatively close to the disposal point. Plutonium is adsorbed most effectively by high surface area, high cation-exchange capacity sediments with little effect from the competing salts. The retention of strontium-90 solutions is removed by ion exchange and by precipitation as $SrCo_3$ close to the source of disposal. Cesium sorbs within the first 4.6 m (15 ft). Antimony sorbs only on fine silt where higher clay contents exist.

Table A-4. Groundwater Bibliography

Document	Summary
Underground Disposal of Liquid Wastes at the Hanford Works, Washington, HW-17088	This document provides a history of waste disposal to the various bismuth-phosphate waste sites and discusses characterization activities to identify and determine contaminant distribution in both the vadose and saturated zones. In 1945, the 216-B-5 Reverse Well began receiving waste from the 224 Building and the 5-6W Cell in the 221-B Building (B Plant). The specific gravity for the Tank 5-6 waste was reported to be nearly 1.00. On September 19, 1947, a water sample from a well north of the B Tank Farm (299-E33-18) indicated the presence of alpha activity in the groundwater 655 m (2,150 ft) north of the 216-B-5 Reverse Well. Later resampling determined the initial sample result was a false positive and that no groundwater contamination existed in this area. However, it was determined that the 216-B-5 Reverse Well was drilled 3.0 m (10 ft) into the groundwater. From this event, all waste was redirected to the 201-B Tank crib (216-B-7A&B). Eighty-two new wells were installed over the next 3+ years, and 11 of the new wells were completed around the 216-B-5 Reverse Well. Sediment samples from the saturated gravel were below detection for all of the wells, including the one well (299-E28-23) only 15.2 m (50 ft) from the 216-B-5 Reverse Well. However, groundwater contamination within 4 years had migrated at least 762 m (2,500 ft) to the southeast (Well 299-E23-1). The average groundwater velocity was calculated at 152.4 m/yr (500 ft/yr). Over a period of 3+ years before this report, 930 water samples were collected. The conclusions from this activity were the following: the groundwater was contaminated because of uranyl ions, plutonium had not migrated to Well 361-B-9 (299-E28-23), fission products were adsorbed to sediments by iron hydroxides (as weight calculations showed 44,000 time-activity difference between beta/gamma activity in monitoring well casing rust near 216-B-9 Crib than in the water), and the specific gravity of the waste (1.04 to 1.08) had no bearing on water concentration throughout the aquifer. The migrating COCs were identified as strontium, ruthenium, and zirconium. Another observation from this report was that the activity in individual wells was the same over the 3+ years of sampling. This was attributed to the flat water table. The water was mounded by the 216-2-1 swamp and the open drainage ditch. The groundwater mound created from these open ditches was considered a benefit in that it held 216-B-5 Reverse Well contaminants in place. The 216-B-8 Crib began receiving second-cycle waste in March 1948. The 216-B-8 Crib received 7,500,000 L (1,981,290 gal) of waste containing approximately 7 g of plutonium and 12 Ci of fission products between March 1948 and January 1950, at an average rate of 189.3 L/min (50 gpm). In August 1948, sludge from the 104-B Tank was jetted to the crib. To increase the capacity of the crib, citric ($C_6H_8O_7$) and hydrochloric acid (HCl) were sent to the crib, but this was not significantly successful; therefore, the tile field was put into service shortly after the incident. As of 1950, no contamination had been found from adjacent Well 224-B-4 (e.g., 299-E33-18, approximately 21.3 m [70 ft] southwest of the 216-B-7B Crib and 30.4 m [100 ft] northwest of the 216-B-7A Crib). Conclusions from the field and laboratory samples reported that Hanford Site soils are considered good to excellent for retention capacity of contaminants. The only notable exceptions were anions, ruthenium, the alkali metals, and uranyl ion.

Table A-4. Groundwater Bibliography

Document	Summary
Earth Sciences Waste Disposal Monitoring Activities, HW-36411	This document concluded that sodium and nitrate were valuable tracers for direction of groundwater movement. However, extremely low concentrations of nonradioactive salts discharged to the 216-B-5 Reverse Well precluded the use of these ions for groundwater movement. Therefore, beta-gamma emitters were used, which indicated a slow eastward movement from the vicinity of the reverse well.
Cobalt-60 in Groundwater and Separations Plant Waste Streams, HW-42612	This document discusses groundwater analytical results from the groundwater monitoring wells beneath and southeast of the BY Cribs (216-B-43 through 216-B-49 Cribs). Before cobalt-60 groundwater contamination in this area, the groundwater was interpreted as only being contaminated with ruthenium-106 and rhodium-106. Groundwater results from wells proximal to the 216-B-46 Crib reported cobalt-60 within 5 months from disposal to the 216-B-46 Crib or dispersion from other BY Cribs. Within approximately one year, cobalt-60 was reported in significant concentration (e.g., 0.07 µCi/L) approximately 304.8 m (1,000 ft) to the southeast (in Well 299-E33-18) of the 216-B-3 Crib. Conclusions were made that cobalt was either complexed or in an ion solution from the scavenging process that resulted in percolation rates similar to ruthenium-106.
Chemical Effluents Technology Waste Disposal Investigations, April-June 1957, HW-53225	This report provides results of groundwater monitoring data from wells sampled in April, May, and June 1957. Cribbed radioactive wastes (BY Cribs) reaching the groundwater underlying the 200 East Area were reported to be continuing to move westward down the hydraulic gradient. Immediately west of the 200 East Area fence, the contaminated groundwater intersects a more permeable zone and spreads to the north and south. This report also discussed groundwater studies near the BY Cribs waste site. Fission product analyses showed no detectable concentration of radioactive strontium-90 or cesium-137 in test wells monitoring the cribs within the 200 East Area. However, water samples taken from wells located adjacent to the BY Cribs disposal site revealed the presence of cobalt-60 in the groundwater in concentrations up to 1.3×10^{-3} µc/cc (1,300,000 pCi/L). These high cobalt-60 values result from TBP scavenged waste draining from the BY Cribs in the groundwater. The existence of significant amounts of cobalt-60 in the form of an anion complex in these wastes was discovered early in 1956.
Chemical Effluents Technology Waste Disposal Investigations, July-September 1957, HW-54655	This report provides results of groundwater monitoring data from wells sampled in July, August, and September 1957. This report is very similar to its predecessor HW-53255; however, it provided a detailed groundwater flow vector map. This map provided the general direction and average rate of groundwater movement based on hydrologic and hydraulic data from 1957, effective porosity and permeability of sediments, and results of a fluorescein tracer test. Groundwater flows to the north toward the Gable Mountain/Gable Gap and along the northern and southern flanks of Gable Mountain toward the Columbia River. The rate of flow to the north and along the northern and southern flanks of Gable Mountain ranges from 1.8 to 15.2 m/d (6 to 50 ft/d).

Table A-4. Groundwater Bibliography

Document	Summary
Fluctuations of Hanford Water Levels, HW-53599	At the Hanford Site, the regional water table is largely within the Ringold Formation and to a lesser extent in the glaciofluviatile deposits. These latter deposits, where below the water table, are highly permeable and occur as channels along both the northern and southern flanks of Gable Mountain. The glaciofluviatile deposits extend southeast from the western side of Gable Mountain toward the Columbia River as a narrow irregular zone paralleling the Columbia River. The contours represent lines of equal altitude on the water table expressed in feet above mean sea level. The general direction of movement of groundwater is at right angles to the contour lines in the direction of the downward slope. Thus, throughout much of the area, the general movement of water formerly was northeastward and eastward. At the time that this report was published, about 101 billion L (26.7 billion gal) of relatively uncontaminated cooling water from separations processes had been discharged to open disposal areas in two areas. One of the areas is identified in the 200 West Area. The other area identified is an elongated mound beneath the 200 East Area. Periodic process difficulties allowed trace quantities of radioactive material to enter effluent streams causing these areas to be considered disposal sites for radioactive wastes. At the time of this report, approximately 11.0 billion L (2.9 billion gal) of low-level radioactive contaminants were discharged to ground. This contaminant disposal occurred in the area between the two mounds. Although some of the liquid effluent is lost through evapotranspiration to the atmosphere, and some is retained in the pores of the sediments in the zone of aeration, most percolates down to the water table and enters the zone of saturation. The relative rise of the water table in certain wells is controlled by the extent and hydraulic characteristic of the aquifer, the distance from the point of recharge, and the rate and volume of effluent disposed. Hydrographs were provided in this report to show the water table increases over the time period from 1944 to 1957 based on the effluent disposal. Well 699-55-70 is located proximal to the 200 North Ponds (216-N-1, 216-N-4, and 216-N-6) and associated trenches (216-N-2, 216-N-3, 216-N-5, and 216-N-7). These ponds received 3.2 billion L (864 million gal) of cooling water between 1944 and 1952 and likely created a hydraulic barrier for northern groundwater flow for any location south of these ponds. Natural fluctuations in the water table near the Columbia River were reported in this report. Hydrographs show fluctuations where seepage to and from the river is a controlling factor. The hydrographs show that water levels rose during the early spring of each year, reached a peak about June to July, and declined thereafter. This was in accord with the annual rise and fall of the river. Other natural fluctuations discussed included barometric and earthquakes. It was shown that 0.06 m (0.2 ft) of change was observed in two wells by the earthquake shock associated with Ketchikan, Alaska.

Table A-4. Groundwater Bibliography

Document	Summary
Observational and Field Aspects of Groundwater Flow at Hanford, July, 1959, HW-SA-41	This paper presents the results from hydraulic field tests that were associated with average contaminant transport calculations. At the Hanford Site, approximately 61.0 m (200 ft) of sand and gravel of glacial origin (glaciofluviatile sediments) immediately underlies the waste disposal sites. Below this is an earlier glacial formation (Ringold Formation) as much as 243.8 m (800 ft) thick, consisting of silt, sand, and gravels with several clay beds. The water table, which is from 61 to 106.7 m (200 to 350 ft) below disposal sites, lies largely within the Ringold formation but extends in some places into the overlying glaciofluviatile sediments. Below these two major units is the relatively impermeable basalt. The hydraulic characteristics of the Hanford Site aquifers have been measured and estimated by a variety of established field methods. These methods include evaluation of data from pumping tests, specific capacity tests, tracer tests, cyclic fluctuations of water level, and hydraulic gradients. Mutually consistent results show that the permeability of the glaciofluviatile sediments range from approximately 10,000 gal/d/ft^2 to more than 60,000 gal/d/ft^2.

Table A-4. Groundwater Bibliography

Document	Summary
Observational and Field Aspects of Groundwater Flow at Hanford, July, 1959, HW-SA-41 (cont'd.)	Based on the information in this report, more than 35 billion gal of liquid effluent had been discharged to the ground. Such large volumes of water had profound effects on the regional water table. The direction of groundwater is best determined by drawing lines perpendicular to groundwater contours from high to low head. Three groundwater mounds were identified that create a groundwater divide, roughly concave to the south and enclose disposal sites on the west, north, and east. From the northern or outer flank of the divide, the artificial recharged water largely moves radially northwestward and northeastward. From the southern or inner flank of the divide, the infiltered wastes converge and move generally southeastward and then more eastward in a relatively narrow band. The directions of movement are those that would be taken currently by any radioactive waste product filtering to the water table from an overlying disposal site. It must be recognized, however, that deposits of sand and gravel such as comprise the glaciofluviatile and Ringold sediments are in varying degree, lenticular; thus, in the coarse materials, wastes would move more rapidly than in the fine materials. In addition, if the lenses are elongated in one direction, or the strata are inclined steeply, the direction of flow will incline in the direction in which water moves more easily than in another. This document also discusses initial tracer tests and relationship to average groundwater velocity associated with the groundwater gradient. Fluorescein tracers were detected in observation wells at various distances downgradient from injection wells. The rate of travel of the dye, based on the first detected arrival, was measured to be 170 ft/d through 50 ft of travel in one case. Another case also provided a 170 ft/d through 11,500 ft. A third case provided a 195 ft/d through 13,200 ft. In a final fourth case, 440 ft/d through 8,800 ft. The velocities were three to four times greater than the average groundwater flow calculated value. The travel time to the river based on the calculated average velocity was provided. Based on a southeastward and then more eastward flow in a relatively narrow band, the time to travel from the 200 East Area to the Columbia river was about 180 years. Although the average water flow rate was calculated to be fairly long, specific isotopes may travel faster or slower than the average water velocity. The rate of travel was determined to be dependent on ion-exchange reactions; those that selectively sorb to the sediments movement will be slower. On the other hand, those constituents that do not sorb to the sediments would diffuse as the constituent moves through the sediments. Four recommendations were provided by this report to better understand contaminant movement: (1) drill additional wells to identify heterogeneity and anisotropy of effects upon the rate and direction of waste movement; (2) complete field tests to understand dispersion effects; (3) study high-density wastes in the aquifer; and (4) implement a geophysical seismic program for improving forecasting of drilling needs and well positions, and for reducing the cost for wells.
The Effects of Ground-Water Mounds on the PUREX Operations, HW-49728	This document discusses the groundwater mounds and their effect on groundwater flow in the 200 East Area. As a result of increasing liquid disposal to the ground, groundwater mounds have increased locally and reversed the natural hydraulic gradient, thus accelerating the movement of groundwater. The size, shape, and orientation of groundwater mounds depend on the amount and rate of water recharged to these aquifers, and on the extent and hydraulic characteristics of the aquifer. The proper location of disposal sites could produce hydrological conditions such that the movement of pools of contamination may be temporarily retarded or restrained.

Table A-4. Groundwater Bibliography

Document	Summary
The Effects of Ground-Water Mounds on the PUREX Operations, HW-49728 (cont'd.)	The objective of this report was to (1) review the changes in the size and shape of the groundwater mounds consequent upon disposal of cooling water from the former B Plant operation and the present PUREX operation, (2) summarize the results of pertinent groundwater- and waste-monitoring studies and recommendations based thereon, and (3) forecast future hydrologic conditions attendant upon disposal of PUREX cooling water. In summary, channels of rapidly moving groundwater were identified flowing eastward along the northern and southern flanks of Gable Mountain, and flowing southeastward from the Chemical Separations Area (e.g., 200 Area) toward the 300 Area. Contaminated groundwater from beneath the 200 East Area disposal cribs routed to these channels would be rapidly transported to the Columbia River. This undesirable movement of contamination could be largely controlled hydrologically by the formation of three groundwater mounds. Proper distribution of PUREX cooling water to three swamps, located respectively north, east, and southeast of the 200 East Area, could be expected to raise underlying water levels to such an extent that hydraulic gradients would be locally reversed, preventing contaminated groundwater from reaching the highly permeable channels. During B Plant operations from 1944 to March 1952, 24.6 billion L (6.5 billion gal) of cooling water were discharged to B Pond. Groundwater elevations rose to approximately 123.4 to 124.7 m (405 to 406 ft) above mean sea level. The elongated orientation of the mound reflected a general northwest-southeast directional permeability in this region. Thus, it indicated that groundwater movement occurred in a northwestward or southeastward direction at higher velocity than that in other directions. Velocities estimated by dilution-velocity tests and the movement of gross-beta emitters and cesium-137 indicated magnitudes of 20 to 50 ft/d. After B Plant was shut down, the groundwater elevations subsided about 9 ft by October 1955 to an elevation of about 121.0 m (397 ft). Throughout 1956, approximately 8.7 billion L (2.3 billion gal) of effluent, an average of about 5,200,000 gal/d, were discharged to B Pond. In addition, another 1,100,000 gal/d were disposed to cribs in and adjacent to the 200 East Area. There were concerns that continued discharges of this magnitude, described in the paragraph above, could mobilize contamination beneath the waste sites in the northwest portion of the 200 East Area northward. Previous observations indicated that the channel along the southern side of Gable Mountain was bounded in part on the south by a buried ridge of basalt that extends along the northern boundary of the 200 East Area roughly parallel to Gable Mountain. It was recognized that continued large magnitude discharges would develop a strong northwestward gradient tending to route the contamination around or over the buried basalt ridge into the channels of rapid groundwater movement near the flanks of Gable Mountain. Contamination would thence be rapidly transported eastward to the Columbia River. Consequently, it was recommended that PUREX cooling water be discharged to a new swamp south of Gable Mountain to deny the contamination access to the channels of high groundwater velocities.

Table A-4. Groundwater Bibliography

Document	Summary
The Effects of Ground-Water Mounds on the PUREX Operations, HW-49728 (cont'd.)	There also was concern of significant groundwater movement to the southeast from the proposed disposal of cooling water in the Gable Mountain Pond. Studies indicated that a mound reaching an elevation of 125.0 m (410 ft) from B Pond and 123.4 m (405 ft) from Gable Mountain Pond would establish a considerable southward or southeastward gradient routing groundwater at least locally over the buried basalt ridge and under the 200 East Area. Under these conditions, any contamination in the groundwater beneath the 200 East Area may be expected to move southward into areas of high groundwater velocities. To restrain or retard this southeastward movement of groundwater contamination from the 200 East Area, it was recommended that part of the PUREX cooling water be disposed to a natural depression southeast of the 200 East Area. A groundwater mound formed beneath this site would locally reverse the prevailing southeastward gradient and act as a hydrologic dam tending to immobile the groundwater beneath the 200 East Area. Thus, a plan was recommended that included discharging 14,000,000 gal/d to the proposed Gable Mountain Pond, 2,000,000 gal/d to B Pond, and 4,000,000 gal/d to the proposed southeast pond. Such a plan was considered to retard groundwater contamination under the 200 East Area from reaching the highly permeable Gable Mountain channels and the highly permeable channel to the southeast. Gable Mountain Pond began receiving PUREX cooling water in 1957. In addition, discontinuing groundwater disposal immediately was not recommended because the regional water table was considerably higher than the natural water table and rapid subsidence of existing mounds would result in rapid movement of contamination toward the river under the influence of the exaggerated hydraulic gradient.
Aquifer Characteristics and Ground-Water Movement at Hanford, HW-60601	The purpose of this report was to describe the hydraulic studies and tests at the Hanford Site that permit the calculation of the hydraulic characteristics of the aquifer, to determine the general directions and average rates of groundwater flow, to point out important factors that affect the movement of groundwater and wastes, to estimate a mean lateral path of potential groundwater contamination from disposal sites to the Columbia River and the time of travel, and to indicate what is needed in the way of additional geological and hydrological information. The hydraulic studies show that waste that reaches the water table beneath disposal sites potentially will move in a general southeastward and eastward direction to the Columbia River. Average rates of groundwater flow indicate that travel time along this estimated mean lateral path of groundwater contamination conceivably could be completed in an average time of about 180 years. Factors such as heterogeneity and anisotropy of the aquifers, and dispersal of wastes in the groundwater, however, assume great importance in determining the path and ultimately the concentration of radioactive waste in the water.

Table A-4. Groundwater Bibliography

Document	Summary
Aquifer Characteristics and Ground-Water Movement at Hanford, HW-60601 (cont'd.)	This report suggested that movement from the 200 East Area to the north was impeded by the basaltic anticline called Gable Mountain and its extensions, and by a buried basalt ridge that parallels Rattlesnake Hills. In addition, a broad, flat mound north of Gable Butte was present in 1958. The mound was caused by recharge of adjacent aquifers while the river is at high levels. After lowering of the river, the groundwater escapes only gradually through the sediments. It was thus implied that much of the groundwater north of Gable Butte and Gable Mountain is recharged river water, some of which moves eastward and is discharged as springs and seeps to the Columbia River north of the eastern end of Gable Mountain. The 1958 pattern of groundwater movement underlying the Hanford Site had changed because of infiltration of waste effluents. The mound created a groundwater divide, roughly concave to the south and enclosing disposal sites on the west, north, and east. From the northern or outer flank of this divide, the artificially recharged water largely moves radially northwestward and northeastward. From the southern or inner flank of the divide, the infiltrated waste converges and moves generally southeastward and then eastward in a relatively narrow band.
Movement of Radioactive Effluent in Natural Waters at Hanford, HW-SA-1747	The Hanford Site has two major sources of low-level radioactive effluent solutions. One of these is the large-volume cooling water stream discharged from the reactors. The second major source of low-level activity solutions is the complex system of chemical plants used for the processing of uranium fuels to recover the plutonium product. The radioactive material contained in these wastes is largely a mixture of fission products. Typically, the relative hazard of a mixture of fission products is determined to a major extent by its concentration of strontium-90 (28-year half-life). Because this isotope is very toxic, the wastes must be decontaminated with respect to strontium-90 with exceptional efficiency or be disposed in a manner that ensures a suitably long decay interval before reaching a point accessible to the public. Controlled ground disposal of low-activity solutions from Hanford Site chemical processing plants uses primarily the long decay interval concept of protecting employees and neighboring populations from exposure to radioactive materials. Thus, wastes are permitted to infiltrate the earth sediments and those components that eventually reach the water table move slowly with the groundwater to the Columbia River. Separations process cooling water and utility steam condensate, which occasionally may be slightly contaminated from process vessel leaks, are in the category of low-level waste with radioactive concentrations less than about 5×10^{-5} µc/cc. About 1.4×10^{11} L of such water has been discharged to ground at the time of this report, and such large volumes have had profound effects upon the regional water table. Along the estimated hydraulic path from groundwater disposal sites to the river, groundwater movement occurs under an average hydraulic gradient of about 0.004 in the Ringold aquifer of permeability estimated to be 1.4×10^{-2} cc/s/cm^2. The effective porosity of this aquifer is estimated to be 10 percent; therefore, the average rate of movement is calculated to be about 0.5 m/d. Movement in the highly permeable glaciofluviatile sediments occurs chiefly under shallow gradient of only about 0.0001 and the average permeability is assumed to be 2.5 cc/s/cm^2. Average velocities of about 2 m/d are calculated for this portion of the path assuming an effective porosity of 10 percent.

Table A-4. Groundwater Bibliography

Document	Summary
Movement of Radioactive Effluent in Natural Waters at Hanford, HW-SA-1747 (cont'd.)	Direct movement of low-level activity solutions to the Columbia River through glaciofluvial sediments is inhibited by the relative positions of the groundwater mounds. Instead, the general movement occurs more to the south through Ringold deposits. Based on the average groundwater velocities calculated from measured gradients and estimated permeabilities and porosities of the aquifers affected, a travel time of about 180 years is calculated for groundwater flow from ground disposal sites to the river. It is recognized, however, that the maximum rate of movement of the groundwater and even of some materials dissolved in it (e.g., ruthenium-106 and nitrates) may be several times the average. On the other hand, those dissolved constituents that enter into adsorption reactions (e.g., strontium-90 and cesium-137) will move far slower than the water, the chemical nature of each ion establishing the degree of retardation. Studies indicated hydraulic phenomena produce velocity variation that brings about longitudinal mixing of selected intruding and displaced fluids. A diffuse zone or "concentration front" forms rather than a sharply defined interface. The depth of this zone increases in proportion to the distance traveled because of portions of the intruding contaminant moving at velocities exceeding the average. Ion-exchange reactions may modify the propagation of a radio-contaminant in two ways: (1) the median velocity of the contaminant front will be predictably less than that of the liquid front, and (2) the depth or diffuseness of the front may be modified over that resulting from purely hydraulic phenomena. When the radio-contaminant is not selectively sorbed by the exchange medium, the front will become increasingly diffuse as it progresses through the medium. When the radio-contaminant has a selective preference for the medium, the front may rather tend to sharpen as propagation continues. Another transport possibility exists for high-density wastes to settle in the zone of saturation by gravity. This concept presumes that the vertical movement under gravity will be significant compared to horizontal movement rates and with rates of dispersion throughout the aquifer. To the date of this document, no clear evidence of this phenomenon has been obtained in field studies of waste movement.
Chemical Effluents Technology Waste Disposal Investigation, *January*, *February*, *March*, *1958*, HW-55841	This report provides chemical groundwater monitoring data during the quarter of January to March 1958. Three zones of contaminated groundwater based on gross-beta activity greater than 1.5×10^{-7} µc/cc were identified in the 200 East Area. The principal sources of groundwater contamination were identified as the B Cribs and BY Cribs in the northern portion of the 200 East Area, and the other two sites were located in the southern portion of the 200 East Area. During the BY Cribs period of use ending in December 1955, roughly 430,000 Ci of beta particle emitters were discharged to these cribs. Part of these wastes are percolating the 240 ft of vadose zone sediments and entering the groundwater. During the period covered by this report, the maximum concentration of gross-beta activity detected was 5.1×10^{-2} µc/cc. The contaminants move westward and southwestward down the hydraulic gradient imposed by the 200 East Area groundwater mound. West of the 200 East Area, the water table occurs in permeable glaciofluvial sands and gravels, and contaminants reaching these sediments tend to move chiefly southward and southeastward.

Table A-4. Groundwater Bibliography

Document	Summary
Chemical Effluents Technology Waste Disposal Investigations, July- September, 1958, HW-58023	This report provides chemical groundwater monitoring data during the quarter of July to September 1958. Three zones of contaminated groundwater based on gross-beta activity greater than 1.5×10^{-7} µc/cc were identified. The principal sources of groundwater contamination were identified as the B Cribs and BY Cribs in the northern portion of the 200 East Area, and the other two sites were located in the southern portion of the 200 East Area. During the BY Cribs period of use ending in December 1955, roughly 430,000 Ci of beta particle emitters were discharged to these cribs. Part of these wastes continues to percolate the 73.2 m (240 ft) of vadose zone sediments and enter the groundwater. During the period covered by this report, the maximum concentration of gross-beta activity detected was 2.4×10^{-2} µc/cc. A significant increase in concentration was noted in two monitoring wells situated southwest of the BY Cribs in the BX Trench area. These wells are down the hydraulic gradient from the BY Area contamination and the increase in concentration may be the result of movement in this direction. However, the possible drainage of the BX Trench waste into the groundwater should not be discounted.
Chemical Effluents Technology Waste Disposal Investigations October-December, 1958, HW-58811	This report provides chemical groundwater monitoring data during the quarter of October to December 1958. The probable extent of groundwater contamination was based on gross-beta activity greater than 1.5×10^{-7} µc/cc. All areas where gross-beta activity exceeds 1.0×10^{-4} µc/cc were analyzed for cobalt-60, strontium-90, and cesium-137. Except for two areas, the radioactivity was considered to be ruthenium-106. Three zones of contaminated groundwater based on gross-beta activity were identified. The only area within the 200-BP-5 OU was the BY Cribs. In general, it was reported that monitoring wells situated to the east of the crib showed a gradual decrease in concentration during 1958, whereas the monitoring well to the southwest increased in concentration. These changes were attributed to the gradient imposed by the increasing northern groundwater mound (Gable Mountain Pond). In December, cobalt-60 was reported in 10 wells monitoring this area. This report identifies the average disposal rate of cooling water to both Gable Mountain Pond and the B Pond. An average of 4,000,000 gal/d went to Gable Mountain Pond and 4,600,000 gal/d to the B Pond in 1958. As a result, the water table elevation near Gable Mountain Pond in Well 699-55-50 had risen to 122.2 m (401 ft), while the water table elevation near the B Pond remained at 125.6 m (412 ft). The conclusion, based on the contaminated groundwater observations, was that contaminated groundwater beneath the 200 East Area is denied access to the permeable eastward-trending channels adjacent to Gable Mountain. The contamination, which is influenced by the southeastward and eastward hydraulic gradient of the groundwater mound, will move at very slow rates of about a few feet per day.

Table A-4. Groundwater Bibliography

Document	Summary
Chemical Effluents Technology Waste Disposal Investigations April – June 1959, HW-61197	This report provides chemical groundwater monitoring data during the quarter of April to June 1959. The probable extent of groundwater contamination based on gross-beta activity greater than 1.5×10^{-7} µc/cc. It was noted that the extent of contamination was uncertain because of the limited number of monitoring wells. All areas where gross-beta activity exceeds 1.0×10^{-4} µc/cc were analyzed for cobalt-60, strontium-90, and cesium-137. Cobalt-60 was reported in seven of the wells monitored. The highest concentration was in a well directly beneath the BY Cribs. The unusual, two-pronged shape of the contaminated groundwater pattern was speculated to be associated with fine Ringold sediments, which rise above the water table just southwest of the crib sites and the coarser glaciofluviatile sands and gravels, which occur just north and west of the Ringold beds. The more permeable glaciofluviatile materials are transmitting the contaminated groundwater at a much faster rate.
Chemical Effluents Technology Waste Disposal Investigations, January-June 1962, HW-74915	This report was published to provide a status of contamination in the groundwater from January to June 1962. This report indicated that no significant changes were noted in the contaminated groundwater zone at the BY Cribs and surrounding waste sites. Although the gross beta was not significantly different, the cobalt-60 concentration at Well 699-50-53, located three quarters of a mile north of the BY Cribs, had the highest detected cobalt-60 concentration. The report also stated that the BY Cribs were believed to be the source of the radioactivity present in the groundwater in monitoring Well 699-50-53. This monitoring well also had the highest nitrate concentrations. The nitrate plume had concentrations in excess of 45 ppm limit. The tritium plume also was mapped in this report for the first time. This report indicated that the tritium plume was due to B Pond. The tritium detection limit was 1.0×10^{-5} µc/cc (10,000 pCi/L). Efforts at the time of this report were being made to lower the detection limit to 1.0×10^{-8} µc/cc (10 pCi/L).
Chemical Effluents Technology Waste Disposal Investigations, July-December 1962, HW-76120	This report was published to provide a status of contamination in the groundwater from July to December 1962. This report indicated that no significant changes were noted in the contaminated groundwater zone at the BY Cribs and surrounding waste sites. The nitrate plume was attributed to scavenged waste discharged to the BY Cribs from 1954 to 1956. This was because one of the preferential pathways of groundwater movement from the BY Cribs was to the southeast. However, this document indicated that other waste sites located to the southeast made it difficult to distinguish between nitrate ions from scavenged waste disposal and other waste site disposals.
Hanford Environmental Information System database records, 2006	Select contaminants were reviewed to determine extent of transport and concentrations at wells in the area of the 216-B-8 and BY Cribs. In addition, the same contaminants were reviewed for wells located north of the 216-B-8 and BY Cribs. This work was completed to verify conceptual models provided in the Bierschenk documents of the 1950s and BNWL-B-360.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Environmental Information System database records, 2006 (cont'd.)	The highest gross-beta activity levels reported outside of the BY Cribs in the mid- to late 1950s are reported to the southeast in Wells 299-E33-13, 299-E33-15, 299-E33-16, and 299-E33-17. Concentrations in Well 299-E33-15 exceeded all other well concentrations from February 13 through July 9, 1956. Concentrations in Well 299-E33-17 consistently exceeded those in Well 299-E33-15 from August 27 through December 3, 1956. Concentrations in Well 299-E33-13 exceeded those of Wells 299-E33-15 and 299-E33-9 from October 22, 1956, through July 28, 1958. Concentrations in Well 299-E33-13 also exceeded or equaled the concentrations in Well 299-E33-17 from December 10, 1956, through April 29, 1957. After April 29, 1957, Well 299-E33-17 dropped by an order of magnitude below Well 299-E33-13. Concentrations in Well 299-E33-17 were generally higher than or equal to Well 299-E33-15 from December 28, 1956 through September 25, 1957. Concentrations in Wells 299-E33-18 and 299-E33-19 were significantly lower than in Wells 299-E-33-13, 299-E33-15, and 299-E33-17 throughout the 1950s. Concentrations from September 25, 1957, through August 4, 1958, were linearly decreasing from the BY Cribs through Wells 299-E33-13, 299-E33-15, and 299-E33-17. From August 25 to September 22, 1958, concentrations in Well 299-E33-17 were significantly higher than Wells 299-E33-13 or 299-E33-15; from May 1957, concentrations were equal. Once again, the concentrations returned to a linear alignment from September 29 to November 24, 1958. Concentrations in Well 299-E33-15 again peaked from December 1, 1958, until October 5, 1959, and generally exceeded both Wells 299-E33-13 and 299-E33-17. After October 5, 1959, no continuous gross-beta records were found in the database from these wells until the 1990s. The concentration trends in these wells indicate that contamination from the BY Cribs migrated southward and predominately southeastward during the 1950s. In addition, possibly other waste sites from the southeast were adding to the extremely high concentrations occasionally reported in Wells 299-E33-15 and 299-E33-17. During 1959, concentrations increased in Well 299-E33-9 above Well 299-E33-13 while concentrations in Well 299-E33-15 were elevated. Thus, it appears the BY Cribs contamination migrated predominately south during 1959. Similarly, cobalt concentrations were reported in these wells from initial database entries beginning in 1960. Results were very sparse during the mid- to late 1960s, and other contaminants (tritium) became prominent in the late 1960s, defining groundwater flow and contaminant transport. The database was searched for cobalt and gross-beta results from wells located to the north and south of the BY Cribs for the time period from 1951 to 1970. Six wells (e.g., 699-49-55A, 699-50-53A, 699-54-57, 699-55-60A, 699-60-60, and 699-61-62) were identified within the area located north of the BY Cribs and within or south of the Gable Butte/Gable Mountain Gap. Analytical results were only reported during this time frame from Wells 699-49-55A, 699-50-53A, 699-54-57, 699-55-60A, and 699-60-60. The results during this time appear to be detection levels or naturally occurring concentrations in Wells 699-49-55A and 699-55-60A. However, Well 699-50-53A reported significant concentrations beginning in late 1959.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Environmental Information System database records, 2006 (cont'd.)	Thus, it appears that cobalt and gross-beta contamination migrated north from the BY Cribs, bypassing Well 699-49-55A. The absence of cobalt in the early 1960s and gross beta in the late 1960s at Well 699-49-55A indicates basalt structural control for migration to Well 699-50-53A. During the late 1950s and early 1960s, cobalt concentrations were the highest in Wells 299-E33-17 and 699-50-53A to the south and north, respectively. The highest concentrations between these wells alternated during this time. Since contamination was reported both to the north and south, analytical data indicate radial contaminant flow from the BY Cribs during the 1950s and early 1960s. Results were very sparse during the mid- to late 1960s, and other contaminants (tritium) became prominent in the late 1960s, defining groundwater flow and contaminant transport.
Hanford Well Information System and Hanford Virtual Library	Water-level measurements from the Hanford Virtual Library were reviewed along with well coordinates and as-built records from the Hanford Well Information System to compare against conceptual models provided in the Bierschenk documents of the 1950s. This information was used to create groundwater contours in the area beneath the 216-B-8 Crib for visualization of the actual groundwater conditions during this time. The contours demonstrate radial flow during this time. The contours were completed using the elevations and coordinates provided in the databases. Surfer 8 was used to contour the water table elevations.
Hanford Site Water Table Changes 1950 through 1980 – Data Observations and Evaluations, PNL-5506	This document provides a summary of the actions taken regarding recommendations in HW-49728. The document provides the information regarding the split of liquid effluent going to Gable Mountain and the B Pond from 1960 through 1965.
Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973, BNWL-B-360	This document provides contoured groundwater elevation maps from 1944, 1951, 1955, 1960, 1965, 1970, 1971, 1972, and 1973. The following information is specific to the northwest corner of the 200 East Area. In addition, this DQO author provided interpretative information based on review of individual well monitoring data from the Hanford Site Virtual Library. The 1944 contour map provides 10 ft contours across the Hanford Site. The overall contours indicate an easterly groundwater flow across the Site. However, the area in the northwestern portion of the 200 East Area and north to the Gable Butte/Gable Mountain Gap is not well defined because it lies between the 390 and 400 ft contour. The downgradient 390 ft contour is drawn in such a way that the groundwater flow is interpreted to flow in a couple of directions. One interpretation suggests flow to the southeast from a location near the northwest portion of the 200 East Area and a northern flow direction located near Gable Butte, moving through the Gable Butte/Gable Mountain Gap.

Table A-4. Groundwater Bibliography

Document	Summary
Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973, BNWL-B-360 (cont'd.)	The 1951 contour map shows additional contour intervals between the 390 and 400 ft intervals shown on the 1944 map. It appears that the artificial recharge at the B Pond had caused the 390 ft contour to shift significantly eastward of the 200 East Area. Mounding can be seen beneath the B Pond in this map. Two 393 ft contours bound the area within the Gable Butte/Gable Mountain Gap. The BY Cribs are located south of the southern 393 ft contour. The contouring in this map would suggest a very low gradient to the south in the BY Crib area. The 393 ft contour to the north of the 200 East Area appears to intersect Wells 699-52-54, 699-52-57, and 699-47-60. However, these wells did not exist at the time. A flow divide may be appropriate considering the location of the 200 North Ponds. Thus, as in 1944, groundwater flow between the 393 ft groundwater contours could range from south to north depending on where flow divides are interpreted. The 1955 contour map is similar to the 1951 map, except that the 393 ft elevation contours have increased to 395 ft contours and the southern contour has shifted hundreds of feet to the north (e.g., north of the 200 East Area). In addition, the mound beneath the B Pond has subsided and flow appears to be more north-south than east-west. Contours to the north of the B Pond suggest a groundwater flow corridor east of the basalt subcrop near the Gable Butte/Gable Mountain Gap and then northwest through the Gable Butte/Gable Mountain Gap. Interpretations from the contouring here would suggest that effluent released from the 216-B-7A&B Cribs, 216-B-8 Crib, and the 216-B-35 through 216-B-49 Cribs and Trenches area from 1951 to 1955 created a slight mound enough to push the 395 ft contour to the north. Contours from water elevation records from the 216-B-8 Crib wells demonstrate radial flow during this time. In addition, gross-beta concentrations were slightly elevated in Well 699-60-60 during this time. The June 1960 contour map shows increased water elevations over 1955. The 395 ft elevation contour has increased to a 402 ft contour, and the contour is drawn in the area similar to the 1951 contour. The mound beneath the B Pond has increased to 410 ft and flow contours seem to be more similar to 1951 showing a radial effect. Contours near the Gable Mountain Pond suggest groundwater flow to the east. The 402 ft groundwater contour north of the B-BX-BY Tank Farms area suggests a very low gradient to the south. The 402 ft contour appears to intersect Wells 699-52-54, 699-52-57, and 699-47-60. However, these wells were not drilled until the 1990s. The suggested southern groundwater flow in the area of WMA B-BX-BY during this time is consistent with groundwater elevation comparisons from Wells 699-54-57, 699-49-57A, 299-E32-1, and 299-E33-14. The December 1960 contour map is similar to the June 1960 groundwater contour map, except that the 402 ft groundwater elevation contour has increased to 403 ft. It appears that the increase contours north of the BY Crib area may be due to the influence of the Gable Mountain Pond. The contours suggest radial flow from the pond causing a shift of the 403 ft contour lines near the pond. Again, this information is in line with specific well elevations noted in the June contour map observations.

Table A-4. Groundwater Bibliography

Document	Summary
Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973, BNWL-B-360 (cont'd.)	The January 1965 contour map shows increases in the water elevations from 403 to 405 ft near the Gable Mountain Pond. The mound at the B Pond has declined from 410 to 405 ft since 1960. The information continues to suggest groundwater flow slightly to the south in the B-BY-BX Tank Farms area, which is consistent with specific groundwater elevations discussed in the 1960 observations. The contours suggest a divide to the north of the 200 East Area incidental with Wells 699-52-54, 699-52-57, and 699-47-60, as discussed previously; however, these wells did not exist at the time. The wells north of this apparent divide indicate northern flow, as seen in the groundwater elevation comparisons for Wells 699-54-57, 699-60-60, and 699-65-59A. The March 1972 contour map shows an increase in water elevations beneath the B Pond area from 405 ft in 1965 to 415 ft. The 405 ft contour north of the BY Crib area has shifted northward, indicating a northerly flow in this area. This interpretation is consistent with well elevations reported within Wells 299-E32-1, 299-E34-1, 699-49-57A, 699-54-57, and 699-60-60. In addition, in 1969, Well 299-E34-1 was measured with higher elevations than Well 299-E33-14, indicating a B Pond radial-gradient effect on the groundwater gradient in WMA B-BX-BY. Note that during this time, local radial mounding was created by the releases to the 216-B-50 Crib and 216-B-57 Trench. Associated tritium concentrations were reported significantly higher in Well 699-49-57A than in Wells 699-50-53A, 699-49-55A, 299-E33-3, or 299-E32-1 in the early 1970s, which suggests a northwestern flow. Other contributors to the high tritium concentrations reported in Well 699-49-57A may be due to the 216-A-10 and 216-A-36B Cribs. The July 1972 contour map is not significantly different from the March 1972 contour map. The January 1973 contour map is not significantly different from the 1972 contour maps; however, it shows a groundwater divide in the area near the 216-B-50 Crib and 216-B-57 Trench. The April 1973 contour map is similar to the July 1972 contour map. The interpretations described previously are interpreted by the author of this DQO to demonstrate that groundwater flow through the Gable Butte/Gable Mountain Gap was not significantly impacted by contaminant releases because of the influence of the Gable Mountain Pond from 1957 to 1970. However, before Gable Mountain Pond, a northern flow component must have been in effect either from the B Pond or the liquid effluent releases from the 216-B-8 Crib and the BY Cribs or a combination of both because of the gross-beta and cobalt concentrations reported in Well 699-50-53A. In late 1971, well 699-50-53A once again showed increasing concentrations of nitrate, indicating the declining presence of the Gable Mountain Pond hydraulic effect. Nitrate concentrations seem to be directed toward Well 699-49-57A rather than Well 699-50-53A beginning in late 1973. Although nitrate concentrations were reported to be increasing in Wells 699-50-53A and 699-49-57A starting in late 1971 and late 1973, respectively, nitrate concentrations were not elevated in other wells, including Gable Mountain Gap Wells 699-59-58, 699-60-60, 699-61-62, and 699-61-66.

Table A-4. Groundwater Bibliography

Document	Summary
Radiological Status of the Ground Water Beneath the Hanford Project July-December 1968, BNWL-1047	This report provides an evaluation of the status of groundwater contamination resulting from disposal of plant effluents. The data cover the time frame from July to December 1968. Of the wells drilled at this time, 250 wells were used for routine surveillance of radionuclide movement through the sediments both above and below the regional water table. Approximately one-half of the surveillance wells are located at disposal sites situated on the interior plateau. These wells are used to determine when a disposal facility is to be retired. It is assumed that ruthenium-106, tritium, and NO_3^- move at essentially the same rate as groundwater. Therefore, these constituents are used to trace the groundwater flow paths away from the major chemical processing disposal sites. Note that gross beta was analyzed for in the 200 Areas, and the results are assumed to be ruthenium-106 because past analyses have shown ruthenium-106 to be a large fraction of the gross-beta analysis. Also, total alpha, cobalt-60, strontium-90, and cesium-137 are analyzed for beneath some inactive and all active crib sites. A comparison of ruthenium-106 contamination contours with the previous 6-month reporting period, from January to June 1968, indicates that the inner and outer contours have not changed significantly. However, the middle contour has shifted northward. The concentration boundaries should not be interpreted as indicating that no radioactivity is present in the groundwater beyond these outer boundaries. As with the gross-beta plume, each tritium plume zone is the downgradient edge for that zone of contamination. It was noted that in comparison with the previous 6-month reporting period, the northwest portion of the 10 to 50 percent contaminant guide contour has shifted in a south-easterly direction, the principal direction of flow.
Radiological Status of the Ground Water Beneath the Hanford Project January-June 1969, BNWL-1233	This report provides an evaluation of the status of groundwater contamination resulting from disposal of plant effluents. The data cover the period from January to June 1969. Of the wells drilled at this time, 250 wells were used for routine surveillance of radionuclide movement through the sediments both above and below the regional water table. Approximately one-half of the surveillance wells are located at disposal sites situated on the interior plateau. These wells are used to determine when a disposal facility is to be retired. It is assumed that ruthenium-106, tritium, and NO_3^- move at essentially the same rate as groundwater. Therefore, these constituents are used to trace the groundwater flow paths away from the major chemical processing disposal sites. Note that gross beta was analyzed for in the 200 Areas, and the results are assumed to be ruthenium-106 because past analyses have shown ruthenium-106 to be a large fraction of the gross-beta analysis. Also total alpha, cobalt-60, strontium-90, and cesium-137 are analyzed for beneath some inactive and all active crib sites.

Table A-4. Groundwater Bibliography

Document	Summary
Radiological Status of the Ground Water Beneath the Hanford Project January-June 1969, BNWL-1233 (cont'd.)	There are three gross-beta concentration zones. The outer boundary of each zone is the downgradient edge. The lowest level shown corresponds to a total beta concentration of 0.2 pCi/mL. A comparison of contamination contours with the previous 6-month reporting period, from July to December 1968, indicates that the outer contour around the 200 East Area has shifted southward. However, the inner contour has shifted northward to include Well 699-50-53. The concentration boundaries should not be interpreted as indicating that no radioactivity is present in the groundwater beyond these outer boundaries. As with the gross-beta plume, each zone is the downgradient edge for that zone of tritium contamination. It was noted that in comparison with the previous 6-month reporting period, the northwest portion of the 10 to 100 percent contaminant guide contour has expanded to the north. The contour maps for BNWL-1047 and BNWL-1233 are identical, and the inventory to Gable Mountain Pond was reduced in 1969.
Radiological Status of the Ground Water Beneath the Hanford Project July-December 1970, BNWL-1613	This report provides an evaluation of the status of groundwater contamination resulting from disposal of plant effluent. The data cover the period from July to December 1970. Of the wells drilled at this time, 250 wells were used for routine surveillance of radionuclide movement through the sediments both above and below the regional water table. Approximately one-third of the surveillance wells are located at disposal sites situated on the interior plateau. These wells are used to determine when a disposal facility is to be retired. It is assumed that ruthenium-106, tritium, and NO_3^- move at essentially the same rate as groundwater. Therefore, these constituents are used to trace the groundwater flow paths away from the major chemical processing disposal sites. Note that gross beta was analyzed for in the 200 Areas, and the results are assumed to be ruthenium-106 because past analyses have shown ruthenium-106 to be a large fraction of the gross-beta analysis. Also total alpha, cobalt-60, strontium-90, and cesium-137 are analyzed for beneath some inactive and all active crib sites. There are three gross-beta concentration zones. The outer boundary of each zone is the downgradient edge. The lowest level shown corresponds to a total beta concentration of 0.2 pCi/mL. A comparison of contamination contours with the previous 6-month reporting period, from January to June 1970, indicates that the inner isopleths contour within the 200 East Area has decreased in size. A general decrease also was noted in total beta concentrations in all wells in the primary plume extending from the 200 East Area.

Table A-4. Groundwater Bibliography

Document	Summary
Radiological Status of the Ground Water Beneath the Hanford Project July-December 1970, BNWL-1613 (cont'd.)	Tritium concentrations were measured in the unconfined groundwater during the last half of 1970. A comparison of contamination contours with the previous 6-month reporting period, from January to June 1970, indicates several changes. First, the outer isopleths contour extending southeastward from the 200 East Area remained in the same general location; however, concentrations in most downgradient wells increased somewhat during this report period. The isopleths immediately north of the 200 East Area have been adjusted to show a more realistic continuous distribution of the tritium around the small basalt outcrop, even though two wells in this area (699-49-55 and 699-47-46) did not indicate detectable tritium. The portion of the 0.03 to 1 percent isopleths north of Well 699-54-57 represents a significant change from that reported in the past. Note that previous reports have shown tritium concentrations only in the immediate vicinity of the 100-N Area because the only groundwater samples analyzed for tritium were from this particular area. During the present report period, special samples were collected from a number of wells in the 100 Areas and vicinity and were analyzed for tritium because it was suspected that tritium may be more widely distributed. Based on the analyses of groundwater flow paths before recent reactor shutdowns, it appears that the tritium contamination in this region originated from waste disposal in the 100 Areas. The highest tritium concentrations are confined to the immediate vicinity of the 100-N Area. It was noted that many portions of the tritium isopleths associated with the 699 wells are based on single analyses, and are subject to change as more data are collected.
Radiological Status of Groundwater Beneath Hanford Project January-June 1972, BNWL-1737	This report was a semiannual evaluation of the groundwater contamination resulting from disposal of Hanford Site effluents. The data for this report were generated from about 300 surveillance monitoring wells. Approximately one-third of the surveillance wells are located at disposal sites situated in or near the 200 Areas separations locations. Many of these wells are used to determine when a disposal facility is to be retired. Almost all other surveillance wells are sampled to determine the status of contaminants within the groundwater system. Groundwater samples collected from wells within and near the 200 Areas are analyzed for gross beta, tritium, and nitrate. Groundwater samples also were analyzed for gross alpha, cobalt-60, strontium-90, cesium-137, and ruthenium-106 beneath all active and some inactive disposal sites within the 200 Areas. The gross-beta activity is calculated as ^{106}Ru-Rh, because radiochemical analyses have shown that this nuclide accounts for a large fraction (approximately 80 percent) of the radioactivity in the 200 Area groundwater zone. Other beta emitters, which have been identified in the groundwater away for the disposal sites but within the beta isopleths, include technetium-99, uranium, cobalt-60, chromium-51, and europium-155. Elevated gross-beta values were reported in Wells 299-E33-7, 299-E33-9, and 299-E33-27 (e.g., beneath the BY Cribs, BY Tank Farm, and BX Tank Farm, respectively). A comparison of contamination contours with the previous 6-month reporting period, from July to December 1971, indicates that the gross-beta concentration levels are declining, particularly at the outer contour of the contamination plumes. Tritium concentrations were measured in the unconfined groundwater during the first half of 1972. A comparison of contamination contours with the previous 6-month reporting period, from July to December 1971, indicates no major changes have occurred.

Table A-4. Groundwater Bibliography

Document	Summary
Radiological Status of Groundwater Beneath Hanford Project January-June 1972, BNWL-1737 (cont'd.)	Nitrate concentrations were measured in the unconfined groundwater during the first half of 1972. Elevated nitrate values were reported in Wells 299-E28-9, 299-E28-13, 299-E28-16, and 299-E33-25 (170, 71, 385, and 47 mg/L, respectively). These wells are located next to the 216-B-12 Crib, 216-B-55 Crib, 216-B-12 Crib, and northwest of the 216-B-57 Trench, respectively. A comparison of contamination contours with the previous 6-month reporting period, from July to December 1971, indicates minor changes have occurred mainly to the southeast of the 200 East Area because of reinterpretation of the contamination pattern. In the area north of the 200 East Area, gross beta, tritium, and cobalt-60 were detected at Well 699-50-53. Tritium and nitrate were detected at several of the other wells north of the 200 East Area at low concentrations.
Radiological Status of the Groundwater Beneath The Hanford Reservation January-December 1973, BNWL-1860	This report was a combination of two semiannual evaluations of the groundwater contamination resulting from disposal of Hanford Site effluents. The data for this report were generated from about 310 surveillance monitoring wells. Approximately one-third of the surveillance wells are located at disposal sites situated in or near the 200 Areas separations locations. Many of these wells are used to determine when a disposal facility is to be retired. Almost all other surveillance wells are sampled to determine the status of contaminants within the groundwater system. An evaluation of gross beta and tritium concentrations measured near the surface of the unconfined groundwater during 1973 showed that zones of detectable contamination extended in an easterly to south-easterly direction from the 200 East Area. Because of the declassification of tritium concentration data, all tritium average concentrations are now presented for the 200 Areas. Major changes in the tritium plumes include joining of contaminated zones between Gable Mountain and Gable Butte based on data from new wells. Significant average tritium values of 115,000 pCi/L were reported in Well 699-49-57 for the second half of 1973. Also, high nitrate values were reported in this well (127 mg/L) in the second half of 1973. Gross beta for this well was 1,600 pCi/L. Further to the north, there were no elevated results worth mentioning. Tritium values also were significant at the 216-B-50 Crib. The wells monitoring this site are 299-E33-23 (located beneath) and 299-E33-25 (located to the west). These wells were reported with 1,370,000 and 1,750,000 pCi/L, respectively, in early 1973. It was noted in this report that gross-beta relationship to ruthenium-106 as stated in the past was not entirely correct. It was stressed that this becomes more significant with time as ruthenium-106 decay reduces its proportion in the mixture of beta emitters. Efforts were being made to further characterize the mixture of gross-beta emitters in the groundwater away from disposal sites.

Table A-4. Groundwater Bibliography

Document	Summary
Variable Thickness Transient Groundwater Flow Model Theory and Numerical Implementation, BNWL-1703	This report was a study of the potential movement of radionuclides in the hydrogeologic system of the Hanford Site. The report contains the mathematical model and its assumptions, numerical formulation of the equations, acquisition, and preparation of the boundary and initial conditions and source terms, numerical solution techniques used in obtaining solutions or simulations of the flow field, and results of the verification simulation of a 6-year period. The model used the Dupuit-Boussinesq approximation for groundwater flow. The Dupuit theory assumes that the free surface has only small inclinations and the slope of the aquifer bottom is slight; thus, streamlines are essentially horizontal. As a result, vertical velocities were neglected. In addition, all the aquifer properties were represented by their average over the saturated thickness of the aquifer. Impermeable boundaries also were approximated as vertical surfaces through which no flow occurs. Infiltration flows resulted from disposal of process water to various facilities near the 200 Area separations plant. Each disposal site facility was assigned to a node or group of nodes based on its location and extent. The aquifer bottom surface was treated as a no-flow boundary. The no-flow boundary conditions of the aquifer bottom were uncertain because very little was known about locations and quantities of possible flow through the unconfined aquifer bottom. The information from discrete well locations was contoured and then digitized to provide the aquifer bottom elevation at each computational node of the system. Another uncertainty regarding the bottom of the aquifer was that many of the wells on the Hanford Site did not reach the bottom of the unconfined aquifer. Thus, much intuitive interpolation had to be done in preparing the aquifer bottom contour surface. An initial potential surface or groundwater table elevation surface for the test simulation was contoured from 250 field water-level measurements collected in September 1973. In conclusion, the test simulation of the groundwater flow under the Hanford Site was made for the period March 1968 through September 1973. The results were excellent where good field data exist and generally poorer in less well-known areas. Boundary and infiltration conditions were changed monthly to correspond with historical conditions. The simulation was evaluated by comparison of the calculated data with the measure and contoured water table elevation for September 1973. In the 200 East Area, the predicted elevation was higher than the contoured elevation. Outside of the 200 East Area, the predicted elevation was below the contoured elevation. One of the areas with the greatest discrepancy was at the east end of Gable Mountain. The comparison was considered poor and was associated with poor estimates of the bottom elevations. It was recommended that the recharge flows, bottom elevations, and the conductivities needed to be field measured in this area. Another conclusion was the model-predicted potentials were too low on the northern part of the reservation.
The Transmissivity Iterative Calculation Routine – Theory and Numerical Implementation, BNWL-1706	This report describes the development and determination of appropriate hydraulic conductivity and storage coefficients to be used for the simulated movement of radionuclides in the unconfined aquifer of the Hanford Site. This report was a subset of the work for the previous report (BNWL-1703).

Table A-4. Groundwater Bibliography

Document	Summary
The Transmissivity Iterative Calculation Routine – Theory and Numerical Implementation, BNWL-1706 (cont'd.)	It was determined that an alternative approach was needed to deduce the hydraulic conductivity distribution for the unconfined aquifer at the Hanford Site. The classical approach of completing several pumping tests over the Hanford Site was considered cost prohibitive because only 46 data sets were available at the time. The alternative technique employed was based on numerical integration of the Boussinesq equation along instantaneous streamtubes and solving for the conductivity. Because advantage is taken of the convergence properties of the streamtubes toward infiltration sites and channels of high transmissivity, only a small number of field-measured conductivities were required to obtain the entire distribution. A computer routine, the Transmissivity Iterative Routine, was developed for calculating the hydraulic conductivity distribution in highly heterogeneous aquifers where characterization by field measurement methods alone would be cost prohibitive. The method yields the two-dimensional distribution of the hydraulic conductivity averaged over the aquifer thickness. The preliminary verification of this distribution was accomplished by simulating the groundwater potential changes (e.g., water table contours) as functions of time for the period 1968 through 1973. As implied through the name, the transmissivity iterative routine reworked the hydraulic potential contour interpretations through evaluation of pumping test conductivity data and fitting of the conductivity distribution along referenced lines to obtain the most consistent hydraulic conductivity distribution over the entire aquifer. The rework was done by a hydrologist who used knowledge of the groundwater flow system (e.g., contour maps, transmissivity values from pumping tests, contaminant plume distribution, and contaminant travel time), the geology, and related theory. The resultant product was a transmissivity contoured map. After the contour map was completed, the map was digitized to transfer the data to the required uniform grid. Then the hydraulic conductivity was calculated by the relationship of the contour lines, depth of the aquifer, and the transmissivity contour. This was done incrementally for the period from 1968 to 1973. Some of the major assumptions for this study included the following: Darcy's law governs the flow, groundwater flows as an incompressible fluid that saturates a rigid porous soil matrix, the water table has only small inclinations and the slope of the aquifer bottom is slight, vertical velocities can be neglected so that the equations of flow can be averaged in the vertical direction, aquifer parameter distributions and the hydraulic potential are continuous over the region, and the hydraulic conductivity is isotropic locally, but heterogeneous throughout the region. In addition, because of the lack of data for a storage coefficient, a constant storage coefficient was assumed. The source term for recharge, leakage, and withdrawal was neglected because the rapid rate of change in gradient introduces significant error into the calculations. In addition, it was considered that the waste disposal discharge sites have such little flow in relation to the total groundwater flow through their local areas that no significant error results from neglecting them. It was the opinion of the author of this report (BNWL-1706) that additional data and development in measurement techniques made it impractical at the time to implement a three-dimensional solution. One of the main problems in developing the three-dimensional solution was that inhomogeneous conductivity and hydraulic potential layers would require an order of magnitude increase in the number of conductivity and hydraulic potential measurements.

Table A-4. Groundwater Bibliography

Document	Summary
The Transmissivity Iterative Calculation Routine – Theory and Numerical Implementation, BNWL-1706 (cont'd.)	Through error analysis, the two most likely sources of errors are the starting hydraulic conductivities and the interpretation of the hydraulic potential contours. By examining the pumping test records, the physical characteristics of the well and aquifer, and the models used to evaluate the data, confidence limits for the accuracy of the measurements were estimated. For example, observation wells were available for only three of the pumping tests and fewer than 65 percent of the test wells penetrated the entire estimated thickness of the aquifer. Also, most of the wells were casing perforated, rather than screened, and delayed yield effects were not considered because these effects cannot be distinguished in single well tests. Erratic pump flow rates also were a problem in many of the pumping tests. In many locations, the aquifer bottom was interpreted by hydrologists based on a slight gradient assumption. However, the lack of continuity of the bottom of the unconfined aquifer indicated that the uncertainty is likely 10 ft where well density is good. In areas where sparse well locations exist, the uncertainty of the aquifer bottom increased to 50 ft. The net result of these deficiencies in the pumping test data was determined to be difficult to evaluate quantitatively. However, in consideration of all these factors, an estimate of the typical error in the majority of available pumping test conductivity values was believed to be probably a factor of 5. It also was extremely difficult to estimate to what extent errors are introduced in the direction of the gradient vectors without conducting numerical experiments. Contamination and other hydrogeologic data were used where available to aid in verifying these vector directions. In general, measured travel times were based on entry of gross-beta emitters to certain wells, entry of tritium into certain wells, and the extent of the tritium plume in 1974. Time did not permit a more rigorous examination of the contamination data to establish additional observed travel times and determine them with greater accuracy. It was noted that the results showed that the largest errors occur as streamtubes approach stagnation points and that the calculation error is most sensitive to the control parameters (e.g., groundwater contours, transmissivity, and aquifer thickness) for the stream tubes that pass through these areas. In addition, the data indicated that streamtubes should not be generated through areas of low gradients (less than 1×10^{-4}), such as beneath the 200 East Area, because measurement errors can introduce large discrepancies into the hydraulic conductivity calculation, which are then perturbated throughout the remainder of the streamtube. An interactive computer-processing system using all the hydrogeologic data was used to obtain the most consistent gradient and hydraulic conductivity distribution. Considering the reliability of the input data and knowledge of the geohydraulic characteristics of the Hanford Site unconfined aquifer, the agreement between observed and calculated travel times was considered good. Note that because it was not possible to obtain a storage coefficient distribution for test data, it was necessary to assume that it was constant or construct a distribution from available point measurements. Because there were no point measurements, the storage coefficient was assumed to be 0.15. It was assumed that this value would be accurate to within a factor of 2.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Groundwater Scenario Studies, ARH-SA-292	The purpose of this report was to evaluate the computer modeling predictive capability and control for two groundwater scenario studies. One of the studies was to examine the hydrologic impact of increased groundwater recharge resulting from possible agricultural development in the Cold Creek Valley located west of the Hanford Site. The studied model was based on three different codes. The Variable Thickness Transient Groundwater Flow Model was used to produce a predicted water table position at monthly intervals as explained in the above documents BNWL-1703 and BNWL-1706. The MMT-DPRW model was used to predict the direction of movement and concentration of certain contaminants. The HPCP model predicts the paths and travel times from a contaminant source to the groundwater discharge area, usually the Columbia River. The boundary of this study was defined irregularly to the west and south by the Umtanum, Yakima, and Rattlesnake Ridges. In addition, two alluvial valleys between these ridges merge into the site with the Yakima River bordering the most southeastern portion and the Columbia River bordering the northern and eastern portion of the study area. Within the study area are two alluvial valleys broken by the east-west-trending void areas in the northern portion of the Hanford Site. These east-west-trending void areas are basaltic outcrops and as such are assumed to be no-flow boundaries. Water entering the region from the valley alluvium is accounted for in the model as a flux across the boundary such that the proper water table elevation is maintained. The Variable Thickness Transient Groundwater Flow Model used the same assumptions, as those in BNWL-1703 and BNWL-1706, with some recent improvements. The model was defined by data associated with 2,409 active square grid nodes, with each square being 610 m (2,000 ft) on a side. One 5-year transient version run, and one steady-state run of the water table position or potential field (actual potential gradient, hydraulic conductivity, and aquifer bottom distribution) at monthly intervals, was completed. The irrigation recharge model scenario compiled the recharge from the unconfined aquifer outside the model boundary at the model boundary. The steady-state flow model allows investigation of the ultimate changes in potential that might occur given a constant set of boundary conditions. The transient model can address how long it will take to reach this steady-state condition as well as the dynamic behavior resulting from time-varying boundary conditions. The results of the steady-state flow between no irrigation and irrigation showed relatively no major difference on the groundwater levels for the unconfined aquifer from just west of the 200 East Area and to the east.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Groundwater Scenario Studies, ARH-SA-292 (cont'd.)	The MMT-DPRW model was used to predict possible changes resulting from the postulated irrigation activities in the direction of movement and concentration of one radioactive constituent (tritium). The MMT-DPRW code considers each of the primary transport mechanisms: advection, dispersion, and source sink terms such as radioactive decay and chemical reaction. The value for the dispersivity was an approximate estimate of the average values required to give a preliminary match of historical tritium movement in the Hanford Site unconfined aquifer system. Although further work was required at the time of this report for the dispersivity as a function of space, it was determined that the average values were useful for this study because the purpose was to compare the result of the irrigation and nonirrigation scenarios. The initial condition of the tritium plume was established using 1976 well data. Four transport simulations were computed. The movement of the plume originating in the 200 Areas was predicted from January 1976 through December 1980 using a steady-state approach without irrigation, steady state with irrigation, transient without irrigation, and transient with irrigation flow fields. The results of the January 1981 transient simulations of irrigated versus nonirrigated tritium distributions were very similar just like the Variable Thickness Transient Groundwater Flow Model for contour groundwater elevations. The HPCP can be considered a simple transport model wherein only advective changes are considered. It is used as a rapid, economical, and convenient means of obtaining a basic comparison of the contaminant travel direction, travel distance, and travel times under different water table (or potential) conditions. Rather than predict the movement of the entire contaminant plume as does the MMT-DPRW model, the HPCP model predicts the paths (ignoring dispersion) and travel times (ignoring sorption, chemical reaction, and radioactive decay) from a contaminant source to the groundwater discharge area, usually the Columbia River. If steady-state conditions (static water table or potential field) are assumed, a particle released at a given source point will always arrive at the same discharge point and the travel time from source to discharge will be constant. Such constant path lines are usually referred to as "streamlines." The starting locations of 12 streamlines were positioned around a circle centered about the principal groundwater mound within the 200 West Area. The streamlines for the nonirrigation and irrigation scenarios were the same. The travel times to the Columbia River ranged from 41 years for streamline 7 to 136 years for streamline 6. Both of these streamline travel times were associated with the irrigated scenario. The contaminant travel time from source to discharge predicted by the HPCP model is conservative in the sense that lateral dispersion, chemical reaction, and decay are ignored. A large longitudinal dispersion will yield nonconservative results in that it would tend to cause the contaminant to move faster than predicted by the HPCP model. However, large longitudinal dispersivities also will tend to reduce the concentration of the contaminant at discharge. The results of the HPCP model confirmed the fact that heavy Cold Creek Valley discharge would have only a minimal impact on the waste movement from the high-level waste areas. At the time of this report, it was noted that the HPCP model uses surfaces produced by the Variable Thickness Transient Flow Model but does not incorporate the boundary calculation types of the Variable Thickness Transient model. Thus in the present path-line formulation, a path line/streamline can terminate at an internal boundary.

Table A-4. Groundwater Bibliography

Document	Summary
Geology of Gable Mountain-Gable Butte Area, RHO-BWI-LD-5	This study of Gable Mountain and Gable Butte had the following objectives: • Map and describe the rock units and geologic structures exposed on Gable Mountain and Gable Butte and project these structural and stratigraphic features into the adjacent subsurface using available borehole data as control for projections. • Map and describe the fluvial sediments that surround Gable Mountain and Gable Butte. • Evaluate the west end of Gable Mountain for use as a near-surface test facility. • Make preliminary geologic interpretation based on the above studies of the geologic features of the Gable Mountain/ Gable Butte area as they relate to basalt repository siting considerations in the Pasco Basin. Since the startup of operations at the Hanford Site, the Gable Mountain/Gable Butte area has been examined as part of numerous geologic, hydrologic, and geophysical studies. Geologic studies included mapping of the basalts, interbedded sediments, and post-basalt sediments on the ridges and the logging of trenches constructed to evaluate geologic features on Gable Mountain. Hydrologic studies included test wells drilled into the confined and unconfined aquifers on the flanks of Gable Mountain and Gable Butte. Geophysical studies included regional and local gravity and magnetic studies. The Pasco Basin is the approximate central and lowest portion of the Columbia Plateau, both topographically and structurally, and contains more than 3,000 m of volcanic rock and interbedded sediments. During the late stages of flood basalt volcanism, northwest-to-west-trending folds began forming in the central part of the plateau. These folds, known as the Yakima fold belt, include the Umtanum Ridge structure. The Umtanum Ridge structure plunges into the Pasco Basin, and the Gable Mountain and Gable Butte structures are small isolated anticlinal ridges representing an eastward extension of the Umtanum Ridge structure. Late Cenozoic folding and subsidence resulted in the deposition of fluvial sediments transported from the surrounding highlands by ancestral rivers flowing into and through the Pasco Basin. These sediments form the Ringold Formation of the Pliocene age. The late Quaternary history of the central Columbia Plateau is characterized by periodic episodes of catastrophic proglacial flooding separated by prolonged periods of loess accumulation. Floodwaters deeply scoured the basalt and Ringold surface and deposited up to 213 m of glaciofluvial sediments in the Pasco Basin. These sediments are informally named the Hanford formation. The flood deposits cover most of the Ringold Formation in the central Pasco Basin and all basalt, except for that comprising Gable Mountain and Gable Butte. Gable Mountain and Gable Butte are anticlinal ridges of basalt and interbedded sediments standing as the only extensive bedrock outcrops exposed within the central portion of the Pasco Basin. These basalt ridges are surrounded by a plain of fluvial sediments, which have filled the Pasco Basin. The surface expression of these ridges is a series of doubly plunging, en echelon anticlines and synclines. These structures are interpreted as parasitic folds situated within the closure of a large major fold (the eastern extension of Umtanum Ridge). The major fold is asymmetrical with a north flank that dips steeply into the Wahluke syncline, and a south flank that dips gently into the Cold Creek syncline.

Table A-4. Groundwater Bibliography

Document	Summary
Geology of Gable Mountain-Gable Butte Area, RHO-BWI-LD-5 (cont'd.)	The parasite folds in the study are situated within the closure of the major fold and resemble one another geometrically. Fold axes of the parasitic folds trend west to northwest, with the exception of the syncline on Gable Butte, which trends southwest. Generally, the parasitic fold axes align parallel to form a westerly trending en echelon pattern across the study area. The axial trends of individual parasitic folds are generally curvilinear; and the termini of the hinge lines in both anticlinal and synclinal folds are either doubly plunging or subdued by surrounding folds with higher amplitude and greater wavelengths. The parasite folds in profile tend to be asymmetrical. Two northwest-trending lineaments have been identified from the structural contour map on the basalt surface. The first is the lineament between Gable Mountain and Gable Butte; no vertical offset across this lineament has been found. Data from Wells 699-48-49A and 699-48-49B suggest a channel was cut between Gable Mountain and Gable Butte during the Ringold time by ancestral river systems and later widened by catastrophic floods of glacial Lake Missoula. Partial tectonic origin for this lineament is possible, but additional data are needed to test this possibility.
Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL-82-3	This document describes the characterization and feasibility of storing high-level radioactive wastes within storage tunnels in basalt within the Hanford Site. Part of this process involved describing hydrologic conceptual model information of the flow system beneath the Hanford Site. Some of the key findings regarding the conceptual model are listed below: • The flow systems in the basalt aquifers are confined. This confined assumption is supported by storage coefficients, large horizontal hydraulic conductivity contrasts between interbed or flow tops and the surrounding columnar basalts, plus hydrochemical-type and isotopic-content shifts between individual aquifers. In addition, water-level responses in the basalts from barometric changes and distant seismic events support the concept of confined systems. • The distinct hydrochemical types and isotopic breaks and contrasts in hydraulic conductivities of flow tops versus columnar zones suggest that little vertical groundwater mixing is occurring between shallow (e.g., Saddle Mountains Basalt Group) and deep flow systems (e.g., Grande Ronde Basalt) in nonstructurally deformed areas. Otherwise, the waters would be more homogeneous and in areas of suspected discharge (e.g., the Columbia River), the waters would be progressively older, isotopically heavier, and have higher total dissolved content progressing toward the surface. In addition, in many locations the vertical hydraulic heads suggest mostly lateral groundwater movement. Some vertical groundwater mixing is believed to take place along major geologic structures such as the Umtanum Ridge/Gable Mountain anticline.

Table A-4. Groundwater Bibliography

Document	Summary
Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL-82-3 (cont'd.)	In conclusion, the model indicated that in undisturbed layered basalt sequence, minimal groundwater quantities are believed to move vertically across basalt flow interiors separating the more permeable interbeds and flow tops. Although this model appears consistent for most of the Hanford Site, this did not hold true at one location: the area near the Umtanum Ridge/Gable Mountain anticline. In this region, hydraulic communication was expected because the unconfined and uppermost confined aquifers are not separated by basalt bedrock. The hydraulic communication appears to be associated with paleostream channels cut into the basalt bedrock during past major flooding events. It was noted in this area (e.g., Gable Mountain/Gable Butte Gap) that several of the confined aquifer systems have similar potentiometric water elevations. It was postulated that groundwater discharges from the unconfined aquifer to the underlying uppermost confined-aquifer system may be occurring based on the following: • Decreasing head measurements in the successively deeper confining systems south of Gable Mountain. The hydraulic head measurements with depth were collected from Borehole DB-15. • The presence of nitrate in the uppermost confined aquifer, which was linked with possible intercommunication between the unconfined aquifer and the upper Saddle Mountains Basalt aquifer. • Erosion of the Elephant Mountain Basalt in a paleochannel connecting Rattlesnake Ridge interbed and Hanford formation sediments allows for possible mixing of the unconfined aquifer and the upper Saddle Mountains Basalt aquifer. • Carbon-14 data suggest that younger groundwater is encountered in the Mabton interbed. This may be attributed to increased vertical hydraulic communication along the anticline. The hypothesis of mixing is consistent with the information provided above as well as other hydrochemical and hydraulic data. Therefore, the flow models considered both horizontal and vertical migration. Vertical migration was associated with faults and fractures across extensive basalt columnar zones of the Saddle Mountains Basalt, which have several orders of magnitude lower hydraulic conductivities than their formational flow-top counterparts. Numerical model simulation studies for vertical hydraulic conductivity across basalt flows produced 10^{-10} m/s. In addition, the fault and fracture zones were believed to be associated with clay minerals that would retard radionuclide migration. Conversely, the horizontal migration from the data provided in this report concluded the hydraulic conductivities in the interbeds were orders of magnitude less than the vertical conductivities. As part of a long-term repository performance assessment, flow paths and travel time from deep aquifer (e.g., Middle Sentinel Bluffs confined aquifer to accessible environments) were considered. Mathematical models using various hydrologic processes form the basic principles of mass and energy conservation to produce a system model capable of modeling the processes from the waste package environment through groundwater transport leading to possible dose-to-man. These modeling studies included preliminary modeling, which required substantial interpolation and subjective judgment to prepare. This was because the models required quantitative definition of geometry, material properties, and boundary conditions, whether this information was well known or not. After site characterization was complete, additional modeling was completed using the newly collected data.

Table A-4. Groundwater Bibliography

Document	Summary
Site Characterization Report for the Basalt Waste Isolation Project, DOE/RL-82-3 (cont'd.)	Based on the vertical head and hydraulic measurements, the hydrologic flow path was southeasterly, beneath the Columbia River, toward the area around Lake Wallula. The travel time was determined to be hundreds of thousands of years. Assumptions included that all the flow was through a layer that represented only 1 percent of the thickness of the Grande Ronde Basalt. This assumption is equivalent to assuming a horizontal hydraulic conductivity of 10^{-7} m/s. Adjustments were made for possible higher groundwater velocities through a fraction of the layer. After the adjustments, the final travel time was reported as greater than 100,000 years. The principal limitation of this calculation was considered to be the assumption of uniform hydraulic conductivity for the composite layers throughout the entire Pasco Basin. Although many uncertainties still exist in the revised conceptual model, a pattern of near horizontal movement away from the repository emerged. This was due to little or no upward head gradient, as measured in the field, together with the concept of a layered system of more permeable flow contacts alternating with less-permeable, dense basalts.
Hydrology of the Separations Area, RHO-ST-42	This report discussed the history and evaluation of unconfined aquifer field data to derive aquifer properties for calculations at the Hanford Site. In addition, history of the changing aquifer environment was discussed and a conceptual model of groundwater transport and travel time was presented. Guidance for future aquifer property field data collection and usage was provided as stated below: • Pump test analyses such as Theis and Copper-Jacob, which usually are used in the analysis of confined aquifer systems, can be used to estimate transmissivity in the unconfined aquifer at the Hanford Site. • Although longer pump tests give a more realistic picture as to representative aquifer properties, short-duration tests (8 to 12 hours) can be used to estimate transmissivity. Tests conducted less than 6 hours have questionable merit. • Ranges of values for transmissivity, hydraulic conductivity, and storativity are of greater worth in aquifer analyses than absolute values. Multiple testing procedures and analyses should be adopted as standard procedure for future work in order to delineate a range of values of aquifer simulations. • Transmissivity can be correlated to lithology and location within the separations area. The Hanford formation has an associated range of hydraulic conductivities an order of magnitude higher than the middle Ringold. The lower Ringold transmissivity has the lowest formational hydraulic conductivity. Transmissivities tend to increase from west to east throughout the 200 Areas because of the thinning of the Ringold Formation. • Data exist suggesting that the lower and basal Ringold act as a confined aquifer. The groundwater flow and travel time for the 200 Areas also was discussed in this report. Observations, models, flow direction, and travel time exerts are provided from the report below.

Table A-4. Groundwater Bibliography

Document	Summary
Hydrology of the Separations Area, RHO-ST-42 (cont'd.)	Natural recharge to the unconfined aquifer under the 200 Areas is from the Cold Creek and Dry Creek Valleys to the west of the 200 Areas. It was estimated that before 1952, 980,000 gal/d recharge entered the area from these valleys. Of this total, approximately 59 percent is attributed to infiltration from irrigation and leakage into the unconfined aquifer from faulty water supply wells tapping the confined aquifers. These wells were repaired in 1952, and irrigation was discontinued in 1954. After this time, recharge of the unconfined aquifer occurred by infiltration of water from Cold Creek and Dry Creek. The estimated recharge is 268,000 gal/d from Cold Creek and 132,000 gal/d from Dry Creek. From 1958 to 1969, irrigation practices ceased. In the early 1970s, irrigation began and was reported as continuing at the time of this report. In addition to the irrigation, artificial recharge at the Hanford Site was responsible for 1.6×10^{11} gal of liquid recharge to the ground through 1979. The onset of waste cooling water disposal to ponds in 1944 began to artificially recharge the unconfined aquifer at a rate that exceeded the ability of sediments to transmit this water. Thus, the formation of groundwater mounds under high-volume disposal sites was created. Although discharge drainage out of the 200 Areas was believed to be mainly toward the east and southeast during the time of this report, flow to the north between Gable Mountain and Gable Butte Gap also was recognized. The flat hydraulic gradients and the complex flow system prevented quantification of discharge at the time. A contributing factor to the flow regime was the upwelling of groundwater under the area south of the 200 East Area. It was believed that the flow system may have been "holding up" the contamination from the 200 East Area to the southeast. Thus, a smaller portion of the groundwater was available for migrating to the southeast, and a flow divide was defined with flow north and southeast. Travel time for flow from the 200 East Area to the Columbia River was calculated to the southeast as 50 years. Although transport to the north was discussed, it was not clear whether the travel time to the Columbia River via the northern route was also 50 years.
Geohydrology of the Rattlesnake Ridge Interbed in the Gable Mountain Pond Area, RHO-ST-38	This report investigated possible intercommunication between the unconfined and confined aquifers in the Gable Mountain Pond area. Before this report, all the previously published information on the Gable Mountain Pond merely suggested the potential for intercommunication between aquifers. No studies were conducted to determine the extent of radionuclide contamination in the confined aquifer. With the potential for intercommunication and the lateral extent of the confined aquifer outside the Hanford Site, it was necessary to determine the impact from the Gable Mountain Pond area on the contamination of the upper confined aquifer. As a result of the need, seven wells were drilled to characterize the upper confined aquifer through sediment analysis, borehole geophysics, hydrologic testing, and groundwater chemistry.

Table A-4. Groundwater Bibliography

Document	Summary
Geohydrology of the Rattlesnake Ridge Interbed in the Gable Mountain Pond, RHO-ST-38 (cont'd.)	To evaluate the geological controls and areal extent of intercommunication in the Gable Mountain Pond area, a multigeophysical investigation was designed to extend control data obtained from the existing and new well data. A combination of magnetic and gravity methods were employed to gain information concerning the depth and location of basalt erosional areas and structures. Electrical resistivity depth sounding provided delineation of hydrostratigraphic units and determining approximate basalt elevations. High ground and low-resolution airborne geophysical surveys confirm the presence of a subsurface anticline to the south of Gable Mountain. The total magnetic field intensity indicated a high-intensity dome coincident with the anticlinal fold axis. Gravity profiling between Gable Mountain and the 200 East Area suggests that maximum curvature of the anticline is isolated to the Gable Mountain Pond area. To the northwest, gravity and geologic profiles completed perpendicular to the structure show that it flattens or that the crest has been eroded. It was proposed in ARH-ST-156 that the buried anticline trends and plunges to the southeast. Insufficient data exist to determine an absolute axial trend or plunge direction; however, geophysical interpretations confirm an asymmetrical, northwest-trending anticlinal fold. Magnetic profiling at West Lake indicates that the Elephant Mountain Basalt is eroded fully, exposing the Pomona Basalt to the unconfined aquifer. Erosion of the Elephant Mountain Basalt suggests formation in a high-energy fluvial environment. As great volumes of water were forced to move between Gable Butte and Gable Mountain, a plunge pool may have formed behind the breached anticline. To the south of Gable Mountain and across the subsurface anticline, minor areal erosion of the basalt surface is evident because the Elephant Mountain Basalt flow top has been stripped off approximately 13 ft. However, local areas of more intense erosion are evident. For example, in Well 699-53-55A, the Elephant Mountain Basalt is completely eroded away, and in Well 699-47-50, 65 ft of the flow is gone. It was assumed in ARH-ST-156 that these more intensely eroded areas defined a southeast branch of the erosional channel identified at Gable Gap. The channel was illustrated as a continuous feature connecting these points of deeper erosion. However, high-resolution gravity and magnetic surveying between localities do not detect the expression of such a buried erosional channel. Geophysical evidence suggests that these erosional surfaces are isolated and discontinuous. It was concluded that these deeply eroded areas should be referred to as "anomalies" until additional information is available to clarify interpretations. The major mechanism for groundwater flow to the Rattlesnake Ridge interbed from the unconfined aquifer is where there is hydraulic potential for downward flow through areas of erosion in the Elephant Mountain Basalt. Artificial recharge to the unconfined aquifer owing to liquid waste disposals to cribs, trenches, and surface ponds has resulted in a rise of the water table at this disposal site. In the Gable Mountain Pond area, the water table has risen approximately 20 ft since 1944. The rise in the water table results in greater hydraulic potential for downward migration of groundwater to the confined aquifer system if the confined aquifer has a lower hydraulic head. This is one of the conditions that must be met before aquifer intercommunication can occur from the unconfined to the confined aquifer system.

Table A-4. Groundwater Bibliography

Document	Summary
Geohydrology of the Rattlesnake Ridge Interbed in the Gable Mountain Pond, RHO-ST-38 (cont'd.)	Under most conditions, confined aquifers are under hydrostatic pressure, causing the water level to rise above the level of the aquifer and forming a potentiometric surface for that particular aquifer. The hydraulic head for the aquifer is influenced by the elevation of the source of recharge (anticlinal ridges), hydraulic conductivity of the aquifer, and the regional groundwater flow. Although a potentiometric surface of the upper confined aquifer was provided, there was no comparison between the unconfined and upper confined aquifer. Thus, the only determining feature was based on hydrochemistry. Hydrochemistry data and isotopic analyses were used to evaluate the origin and source of groundwater and potential aquifer intercommunication. One of the most informational isotopes for intercommunication was tritium. The primary areas of interest were the wells around Gable Mountain Pond and Well 699-47-50 located just north of the 200 East Area. The tritium concentrations near Gable Mountain Pond were very low. However, concentrations in Well 699-47-50 were very high (308.2 pCi/L). In addition, carbon-14 age dating suggested that the groundwater in Well 699-47-50 was approximately 30 years old. The results of this report indicated no direct evidence that Gable Mountain Pond contributes significantly to radionuclide contamination of the Rattlesnake Ridge interbed. Although the hydraulic potential for downward migration is present in the area closer to Gable Mountain Pond, hydrochemical data indicate a lower degree of chemical similarity between the unconfined aquifer and Rattlesnake Ridge interbed than the area near Well 699-47-50.
An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site, RHO-RE-ST-12P	This document is a report of a hydrogeologic investigation of aquifer intercommunication in the eastern half of the 200 Areas. The investigation was focused in this area because previous work indicated the erosion of the confining bed and the presence of limited contamination in the Rattlesnake Ridge aquifer. The objectives of this investigation were to: (1) determine the geologic framework of the study area, (2) determine the flow characteristics of the Rattlesnake Ridge aquifer in the study area, (3) quantify the mixing of unconfined aquifer water in the Rattlesnake Ridge aquifer as a result of aquifer intercommunication, (4) delineate the area where aquifer intercommunication has occurred, and (5) determine the levels of contamination in the Rattlesnake Ridge aquifer. The geologic framework within the study area was defined by three first-order folds: the Umtanum Ridge/Gable Mountain structure, the Wahluke syncline, and the Cold Creek syncline. The Umtanum Ridge/Gable Mountain structure is complexly deformed. The topographic expression of this structure is Gable Mountain. North and south of the Umtanum Ridge/Gable Mountain structure are the Wahluke and Cold Creek synclines, respectively. The stratigraphy beneath the study area consists of the Yakima Basalt subgroup, composed of the Grande Ronde, Wanapum, and Saddle Mountains Basalts. The upper-confined aquifer system is defined by the Pomona and Elephant Mountain Members of the Saddle Mountains Basalt. The interbed between these two basalt units is the Rattlesnake Ridge interbed.

Table A-4. Groundwater Bibliography

Document	Summary
An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site, RHO-RE-ST-12P (cont'd.)	The upper Elephant Mountain Basalt Member has the character of an aquiclude, acting to confine the Rattlesnake Ridge aquifer. The Elephant Mountain Basalt is defined by two flow systems: I and II. Most of the Elephant Mountain II and interflow unit in the area to the north of the 200 East Area was eroded by the ancestral Columbia River. It is believed that the Columbia River eroded a channel west of Gable Mountain by maintaining its base level during uplift of the Umtanum Ridge/ Gable Mountain structure. Further erosion occurred following deposition of the Ringold, as Pleistocene catastrophic floods inundated the area. Two erosional "windows" have been identified through the Elephant Mountain Basalt. The northernmost "window" occurs at Well 699-53-55 where the Elephant Mountain Basalt is absent and the Rattlesnake Ridge interbed thins. The southern "window" is postulated to exist based on thin Elephant Mountain Basalt in Well 699-47-50. Locally, the Rattlesnake Ridge interbed was divided into four facies: (1) a clayey basalt conglomerate formed by the weathering and reworking of the Pomona flow top, (2) an epiclastic fluvial-floodplain unit deposited by the ancestral Columbia River system, (3) a tuff made up of an air fall ash, and (4) a tuffite derived from fluvially reworking the tuff and epiclastic detritus. These varying lithologies produce some degree of anisotropy and heterogeneity within the aquifer. The hydraulic conductivities calculated from various tests within the Rattlesnake Ridge interbed ranged from 10^{1} to 10^{-2} m/d. As mentioned above, the dense interior of the Elephant Mountain Basalt flow acts as an aquiclude in this area. To investigate intercommunication between the unconfined and the Rattlesnake Ridge confined aquifer, four wells were installed (299-E26-8, 699-42-40C, 699-49-55B, and 699-56-53). Two additional wells (299-E16-1 and 699-54-57) were deepened. During drilling through the Elephant Mountain Basalt, if an interflow zone was encountered, drilling was stopped, and the zone was tested and sampled. Interflow zones were identified during drilling of Wells 699-42-40C and 299-E16-1. Other investigations during this study included slug tests, sediment and groundwater sample analyses, tracer tests, and geophysical logging. The sediment analyses consisted of sieve, x-ray fluorescence, and calcium carbonate analyses. The groundwater analyses consisted of the following: cation, anion, metals, pH, silica, alkalinity, dissolved solids, and isotopes. The potentiometric surface of the Rattlesnake Ridge aquifer was constructed from water-level measurements collected during the study and from other published reports. Although the area in the north central portion of the 200 East Area had a flat hydraulic gradient (approximately 4×10^{-4} m/m), the groundwater flow regime was considered to be flowing north. This flow regime was based on the groundwater velocities in Wells 299-E33-12 and 699-49-55B, which were considered to have a southern driving source. During this study, it also was determined by comparing groundwater elevation measurements that groundwater within the Rattlesnake interbed from the middle to southern portion of the 200 East Area and west of the B Pond was moving toward the glaciofluvial-filled erosional channel to the south of Gable Mountain. Once the groundwater reached the erosional channel, it also was concluded that the confined aquifer water discharged to the unconfined aquifer and moved within the unconfined aquifer eventually being discharged to the Columbia River. Thus, any contamination in the Rattlesnake Ridge aquifer eventually will discharge back to the unconfined aquifer within this erosional channel and area of interconnection.

Table A-4. Groundwater Bibliography

Document	Summary
An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site, RHO-RE-ST-12P (cont'd.)	Finally, to restate, it was determined that erosional unconformities were the principal mechanism for direct physical interconnection between aquifers. These unconformities place the Rattlesnake Ridge lithologies in direct contact with the younger sands and gravels of the Hanford formation containing the unconfined aquifer. The large areas of erosion in the Gable Gap and the most northwestern "window" at Well 699-53-55 are prime examples. Another mechanism for creating physical connections between the aquifers is human intrusion. Improperly constructed boreholes through the confining bed can provide a direct pipeline between the aquifers, as in the case of Well 299-E33-12.
Estimation of the Release and Migration of Lead through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground, PNL-8356	This report studied the leachable lead transport pathway from the 218-E-12B Burial Ground to the groundwater and through the groundwater. Chapter 2 of this report provides the 1987 conceptual groundwater flow regime. The report states the groundwater flow in the area of the 218-E-12B Burial Ground is controlled primarily by recharge from the Cold Creek and Dry Creek drainage (located to the southwest of the Hanford Site), an artificial recharge mound associated with the B Pond, and the Columbia River. The B Pond consists of a series of unlined, interconnected wastewater disposal ponds that receive effluent from the 200 East Area. Discharges to the B Pond will be discontinued as activities at the Hanford Site shift to emphasize cleanup. Thus, the present conditions reflecting the B Pond operation are not expected to persist. Based on the December 1987 water table, groundwater in the vicinity of the 218-E-12B Burial Ground is moving from the B Pond toward the west, turning north through the gap between Gable Butte and Gable Mountain. Although this general flow pattern would be expected to persist over the near future, the exact level of the water table is subject to short-term fluctuations caused by seasonal variations in precipitation and changes in Hanford Site operations. One observation considered along with the above groundwater conceptual transport model was the relatively high hydraulic heads north of the burial grounds. It was believed that recharge from the Rattlesnake Ridge interbed to the unconfined aquifer may be responsible for the elevated head in the wells north of the 218-E-12B Burial Ground. This thinking seemed consistent with previous studies associated with wells in this area. Because the B Pond recharge was not expected to persist, two cases of regional groundwater flow in the absence of the B Pond were assessed. One assessment considered arid climate conditions with a recharge rate of 0.5 cm/yr; the other a more humid climate with a recharge rate of 5 cm/yr. The conceptual model of the aquifer groundwater flow for the more humid climate considered groundwater flow to the northwest through a saddle-type basalt topography. The saddle in the basalt was previously considered to be above the groundwater elevation (mid-1980s); however, because of increased discharges from the B Pond, the saddle was considered to be saturated at the time of this report. Streamlines from the burial grounds to the river were generated. The streamlines were developed from a finite-element grid developed for the Variable Thickness Transient Model (BNWL-1703). Because the 1980s conceptual model of the aquifer predicted that Hanford formation sediments beneath the burial ground would be unsaturated, streamlines in the aquifer transport model began south of the burial ground. The streamlines originating in the 200 East Area showed the groundwater flow direction northward through the Gable Butte/Gable Mountain Gap.

Table A-4. Groundwater Bibliography

Document	Summary
Estimation of the Release and Migration of Lead through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground, PNL-8356 (cont'd.)	Groundwater flow for an arid climate was considered to have a long vadose zone pathway eventually reaching the water table along the southern portion of the 200 East Area and flowing to the east. The average groundwater flow rate was considered to be 186 m/yr (1.67 ft/d) for both models. In conclusion, prediction of future groundwater flow direction was very uncertain; however, ultimately, all pathways analyzed led to the Columbia River.
Hydrogeologic Model for the 200 East Groundwater Aggregate Area, WHC-SD-EN-TI-019	The purpose of this document was to compile all the hydrogeologic and hydrochemical data collected in the 200 East Area for DOE/RL-91-40, *Hanford Past-Practice Strategy*. This report included compiling all environmental data for the evaluation of useful data, describing groundwater flow characteristics for both the unsaturated and saturated zones, identifying the nature and extent of groundwater contamination within the 200 East Area, and developing comprehensive hydrogeologic conceptual models. This document began with a geologic discussion, which flowed into a hydraulic and hydrochemistry discussion. The final section was devoted to conceptual model discussion. One of the interesting points in the geologic discussion was on the Elephant Mountain Member of the Saddle Mountains Basalt Formation. The Elephant Mountain Member was described as containing two basalt flows (the Ward Gap and Lower Elephant Mountain Member). It was said that most of the Ward Gap flow had been removed by erosion. Underlying the Elephant Mountain Member was the Rattlesnake Ridge interbed of the Ellensburg Formation. Typical sediments in the Rattlesnake Ridge interbed are a lower clay or tuffaceous siltstone or sandstone. Structurally, the 200 East Area was described as being situated on the south-dipping limb of the Gable Mountain anticline. This anticline consists of a series of en echelon, southeast to northwest trending folds. The main axis lies about 3 to 4 km (1.9 to 2.5 mi) north-northeast of the 200 East Area. Several small en echelon folds similar to those on Gable Mountain occur on the south limb of the anticline between the main axis of the Gable Mountain anticline and the northern boundary of the 200 East Area. One of these subsidiary anticlines lies about 1 to 2 km (0.6 to 1.2 mi) northeast of the 200 East Area, and another lies on the northern boundary of the 200 East Area. Both subsidiary anticlines trend northwest-southeast and have been lifted high enough that basalt is above the current water table. South of the two subsidiary anticlines, basalt flows, sedimentary interbeds, and the Ringold Formation dip southward into the Cold Creek syncline. Structural contour and isopach maps are provided for each formation sequence. One important note is that no Ringold Formation sequences were mapped north of the 200 East Area.

Table A-4. Groundwater Bibliography

Document	Summary
Hydrogeologic Model for the 200 East Groundwater Aggregate Area, WHC-SD-EN-TI-019 (cont'd.)	Groundwater flow discussion in this report described several areas with different groundwater flow directions. Areas of interest in the 200 East Area included the B Pond, Gable Mountain gap, and the area outside the influence of the B Pond. The influence of B Pond was considered radially outward; however, it was stated that away from the B Pond, direction was difficult to determine because of the lack of a pronounced horizontal hydraulic gradient. Thus, contaminant plumes were used to derive a northern groundwater flow direction in the northern part of the 200 East Area. This flow direction was linked to the gap in between Gable Mountain and Gable Butte. Hydraulic properties were defined in the northern portion of the 200 East Area unconfined aquifer by ten pumping tests. Seven additional pumping tests were completed in the area between the 200 East Area and the Gable Mountain Gap. A map of the hydraulic conductivity was constructed using only the results of the constant discharge tests. Although constructed with a limited number of data points and contoured without consideration of the abrupt changes that may exist in the lithology of the suprabasalt sediments, the figure is supported by hydrologic and geologic knowledge of the area. The map was defined as only a general indication of relative hydraulic conductivity trend and not as an exact value for a given location. Two relatively high hydraulic conductivity zones exist in the study area. One is located north of the basalt subcrop and is defined by the test conducted at the 699-53-55 and the 699-55-50 well clusters. A second high hydraulic conductivity zone trends cross the 200 East Area from the northwest corner southeastward to the grout complex. A comparison of the hydraulic conductivity map to the geology of the water table indicated that the high hydraulic conductivity values are associated with the undifferentiated Hanford Site gravel sequence and the lower hydraulic conductivity values are associated with the Hanford Site sand sequence and Ringold gravel unit E. Flow of groundwater from the uppermost aquifer into the Rattlesnake Ridge aquifer also was studied in this report. This was deemed important because the Rattlesnake Ridge aquifer has discharge points outside of the Hanford Site boundaries. Evidence of aquifer communication between the uppermost aquifer system and the Rattlesnake Ridge aquifer had been previously documented. It was concluded that several mechanisms permit hydraulic interconnection of the uppermost aquifer system and the Rattlesnake Ridge aquifer. These mechanisms included erosional windows in the Elephant Mountain Basalt Member, significant joint and fracture systems in the Elephant Mountain Basalt Member, and manmade intrusions (i.e., groundwater well drilling and installation) through the Elephant Mountain Basalt Member. For aquifer communication to occur, these mechanisms needed to be combined with downward-directed vertical hydraulic gradients or gravity-driven density plume migration. Significant downward vertical hydraulic gradients have existed in the past throughout much of the 200 East Area plant operations. In addition, high-salt wastes with densities greater than 1.0 are known to have been disposed to various wastewater disposal facilities in the 200 East Area.

Table A-4. Groundwater Bibliography

Document	Summary
Hydrogeologic Model for the 200 East Groundwater Aggregate Area, WHC-SD-EN-TI-019 (cont'd.)	This report assessed possible communication using several direct and indirect methods to determine location and extent. These methods included (1) analysis of the geologic conditions that could permit communication (i.e., presence of erosional windows, significant joint and fracture systems in the basalt), (2) comparison of hydraulic heads in the uppermost aquifer system and Rattlesnake Ridge aquifers for determining the direction of the vertical component of groundwater flow, (3) qualitative use of barometric efficiencies for identification of Rattlesnake Ridge aquifer monitoring wells installed near erosional windows and significant joint and fracture systems, (4) analysis of stable isotopes and natural groundwater chemistry to indicate if mixing of the uppermost aquifer system and Rattlesnake Ridge aquifer groundwater is occurring, and (5) analysis of various contaminant concentrations in the Rattlesnake Ridge aquifer to determine if manmade contaminants were actually present. It was concluded that evidence was sufficient to identify several areas where hydraulic interconnection of the uppermost aquifer system and the Rattlesnake Ridge aquifer had occurred. One of the areas identified is beneath the B Pond. The basis for communication was the substantial vertical gradient with a downward flow component because of the large groundwater mound. In addition, groundwater quality shows an increase in tritium concentrations over time. Another location was defined in Well 299-E33-12. This well had very high activity levels during the 1950s. It was concluded that because of poor well construction the well served as a conduit for contamination. The report is completed with a discussion of the hydrogeologic conceptual model. The hydraulic conditions of the uppermost aquifer system are illustrated in the conceptual hydrogeologic model. This system consists of all saturated units bounded on top by the water table and the bottom by basalt. Equivalent hydraulic conductivities were contoured for the top 6.1 m (20 ft) of the uppermost aquifer system and are shown with the geology of the water table. A comparison of the high and low zones of equivalent hydraulic conductivities to the geology at the water table indicated that relatively high values are associated with the Hanford formation undifferentiated gravel sequence and lower values are associated with Ringold unit E. Hydraulic boundaries can be identified with the use of the conceptual model. It should be noted that the 200-BP-5 OU southern boundary consists of predominately lower hydraulic conductivity sediments (e.g., Ringold), except along the western edge. The change in lithology is consistent with the structural contour and isopach maps presented in Chapter 2 of this report. Identification of these boundaries may be useful in the interpretation of aquifer tests or in the determination of boundary conditions for a numerical model.
200 East Groundwater Aggregate Area Management Study Report, DOE/RL-92-19, Rev. 0	This document is part of a comprehensive review of vadose zone waste sites and groundwater contamination in the 200 Areas that cut across the boundaries of 42 location-based OUs. The documents sought to lay out a comprehensive methodology and process to rate human health and environmental hazards and undertake remedial actions based on potential harm. This process was intended to address the then active Hanford Site past-practice strategy.

Table A-4. Groundwater Bibliography

Document	Summary
200 East Groundwater Aggregate Area Management Study Report, DOE/RL-92-19, Rev. 0 (cont'd.)	Because the nature and extent of contamination was uncertain across the 200 East Area, a DQO summary report was completed to provide direction and recommendations for resolving the uncertainty. The scoping process evaluated available historical and analytical data, described the natural setting, categorized waste sites for the potential to contaminate groundwater, identified potential COCs, and described preliminary conceptual site models. Interesting items to note from the record search were the following: • Before 1985, the operational groundwater monitoring network was designed to monitor radionuclides and nitrates to observe the response of groundwater to the storage and disposal of radioactive waste in soil at the 200 Areas. • In 1985, the operational groundwater monitoring well network list of constituents was expanded to include other hazardous chemicals. • Concurrently, Pacific Northwest Laboratory performed groundwater monitoring to comply with environmental surveillance, evaluating existing and potential pathways of exposure to radioactive and hazardous chemicals from site operations. The objective of this program was to verify compliance with environmental law and regulations, verify environmental commitments, and characterize impacts of Hanford Site operations to the environment. Between both programs, 71 wells were sampled in the 200-BP-5 OU. From 1988 to 1992, these wells were sampled to define the nature and extent of contamination from various waste sites. The waste sites included the 216-B-5 Reverse Well; the 216-B-55 and 216-B-62 Cribs; wells around B Plant; Low-Level Burial Grounds Areas 1, 2, and 3; the single-shell tanks; and B Pond. Because of lack of funding, no sampling was completed around the 216-B-63 Trench. A list of COCs was derived for each of the sites. The COCs included 11 transuranics, 6 uranium isotopes, 51 fission products, 16 metals, 14 other inorganics, 18 volatile organics, and 23 semivolatile organics. All of these contaminants were included in the COPCs for this DQO process. These wells were sampled for organics, inorganics, radionuclides, anions, and cations. Several detects were reported for each group; however, several of the detected values were near detection limits or background levels. Plume maps were created for the contaminants that exceeded groundwater quality criteria. Thirteen individual plumes were identified, which were associated with the following contaminants: arsenic, cesium-137, chromium, cobalt-60, cyanide, gross alpha, gross beta, nitrate, iodine-129, plutonium-239/240, strontium-90, technetium-99, and tritium. The locations of the plumes are as follows: • **Arsenic:** Four arsenic plumes were located in the 200-PO-1 OU. • **Cesium-137:** Cesium-137 plume was centered around the 216-B-5 Reverse Well. • **Chromium:** Two of the three chromium plumes were located in the northwest portion of the 200 East Area. • **Cobalt-60:** The cobalt plume was located north of the 200 East Area. • **Cyanide:** The one cyanide plume was located around Well 699-50-53A.

Table A-4. Groundwater Bibliography

Document	Summary
200 East Groundwater Aggregate Area Management Study Report, DOE/RL-92-19, Rev. 0 (cont'd.)	• **Gross alpha:** Two of the four gross-alpha plumes were located to the north of the 200 East Area: one was located at the northern end of the BY Cribs, and the other was located at the 216-B-5 Reverse Well. The highest concentration was located at the BY Cribs. • **Gross beta:** Four of the six gross-beta plumes were located in the 200-BP-5 OU. Two of the plumes were located to the north of the 200 East Area. One of the plumes was located north of the BY Cribs and one of the plumes was located around the 216-B-5 Reverse Well. • **Nitrate:** The nitrate plume was widespread across the 200 East Area; however, the highest concentrations were associated with Well 699-50-53A and the Gable Mountain Pond wells. • **Iodine-129:** The iodine plumes were mainly in the 200-PO-1 OU. One of the plumes extended from an apparent center of the 216-A-10 and 216-A-45 Cribs to the southern portion of the B Tank Farm. • **Plutonium-239/240:** The plutonium plume was centered at the 216-B-5 Reverse Well. • **Strontium-90:** Two of the strontium plumes were located in the 200-BP-5 OU. One of the plumes was located at the 216-A-25 Gable Mountain Pond and the other was located at the 216-B-5 Reverse Well. • **Technetium-99:** The two technetium plumes were located in the 200-BP-5 OU. Both of the plumes were located to the north of the 200 East Area. • **Tritium:** Two of the tritium plumes were located in the 200 East Area. One of the plumes was located to the north of B Pond and the other plume extended over the central portion of the 200 East Area to the southeast boundary. Organic compounds detected were reported in the 200-PO-1 OU; however, no plume maps were generated. This is due to contaminant plume mapping criteria, which require the contaminant to be reported in multiple wells that are contiguous. Chapter 5.0 of the report evaluated and ranked the health hazards of radionuclides and chemicals for both carcinogenic and noncarcinogenic health impacts. Thus, the above plumes were modeled to determine future transport and impact with the Columbia River. The model determined the relative health risk index for potential health impact to an average member of the population. The plumes considered to have the highest potential for health risk were the nitrate and technetium plumes. The cesium, chromium, cobalt, plutonium, and strontium plumes were determined not to have the potential to migrate to the Columbia River because of low mobility; thus, the relative health-risk index value was zero for these contaminants. The other plumes were ranked in the following order for health risk: arsenic, iodine-129, cyanide, and tritium. The document examined relevant regulatory requirements and paths, evaluated remedial action technologies, and recommended paths forward and specific approaches for remediating waste sites and groundwater plumes. The document followed this approach and focused on the groundwater beneath the 200 East Area as impacted by waste releases from the PUREX, Hot Semiworks, and B Plant process waste sites and facilities.

Table A-4. Groundwater Bibliography

Document	Summary
200 East Groundwater Aggregate Area Management Study Report, DOE/RL-92-19, Rev. 0 (cont'd.)	Following a discussion of partial application of the DQO process to a CERCLA-based groundwater remediation program, recommendations were presented on COCs and level of urgency for remedial actions. Strontium-90 at the 216-B-5 Reverse Well was the only analyte that was present in groundwater at contaminant levels greater than 100 times the DCG (8 pCi/L) and was regarded as qualifying for an expedited response action, which stipulated prompt application of remedial actions. The next level of risk warranted interim remedial actions where concentrations were above DCGs or DWSs included cesium-137 and plutonium-239/240 at the 216-B-5 Reverse Well; technetium-99, cobalt-60, cyanide, and nitrate at Well 699-50-53A; and uranium isotopes at Well 299-E28-21 (adjacent to the 216-B-62 Crib). Combined, these two plumes formed the basis for the 200-BP-5 OU remediation activities. A limited field investigation approach was identified for a number of contaminants within the 200 East Area, where further characterization was required to confirm plume extent and validate a conceptual model for risk assessment. Antimony, arsenic, beryllium, cadmium, chromium, selenium, thallium, iodine-129, potassium-40, ruthenium-106, bis(2-ethylhexyl)phthalate, 2-4-dinitrophenol, 2,4-dinitrotoluene, hydrazine, methylene chloride, pentachlorophenol, aldrin, dieldrin, and endrin were identified for this path. Contaminants for the RI/FS were identified based on their low health-risk priority and poor plume definition. A number of organic and inorganic chemicals plus radionuclides were identified for the RI/FS path as follows: americium-241, antimony-125, beryllium-7, carbon-14, cesium-134, cesium-144, europium-154, europium-155, lead-212, niobium-93, plutonium-238, praseodymium-144, radium, uranium-235, zinc-65, zirconium-95, aluminum, barium, boron, calcium, cobalt, curium, iron, lead, lithium, manganese, magnesium, mercury, nickel, phosphorus, potassium, silicon, silver, sodium, strontium, titanium, uranium, vanadium, zinc, ammonium, bromide, chloride, acetone, carbon tetrachloride, chloroform, 2-chlorophenol, cyclohexanone, 2,4-dichlorophenol, diethyl ether, 2,4-dimethylphenol, dimethoate, DDD, DDT, endrin aldehyde, ethyl cyanide, gamma-BHC, heptachlor, methyl ethyl ketone, 4-methyl-2-pentanone, o-nitrophenol, p-chloro-m-cresol, phenol, phorate, pyrene, styrene, 2,3,4,6-tetrachlorophenol, toluene, trichloromonofluormethane, and triethylene glycol. This path also includes the residual contaminants left after expedited response action and interim remedial measure actions were completed. The contaminants from both of these recommended activities were incorporated into the COPCs for this DQO process. Recommendations from the process included the following: provide additional well locations in the confined aquifer, resolve areas where single detections of contaminants were found, further define plumes represented by only one well, refine aquifer and geochemical properties, determine potential for continuing releases from the vadose zone, investigate the hydraulic interconnection between the unconfined and confined aquifer, and model contaminant travel times to the Columbia River.

Table A-4. Groundwater Bibliography

Document	Summary
Potential for Groundwater Contamination from High Density Wastes Disposed at the BY Cribs, 200-BP-1 CERCLA Operable Unit, WHC-SD-EN-TA-003	This report provided a thorough review of available data (e.g., physical, chemical, and radioactive characteristics) of the TBP supernatant waste stream. These data were reviewed in order to propose a program to assess the current subsurface configuration of the high-density waste and its response to the geology of the 200 East Area where reported. Chapter 2 discusses the contaminant reduction process (e.g., uranium, cesium-137, and strontium-90) of metal waste using the TBP and ferrocyanide scavenging processes (see Appendix A) before disposal at the BY Cribs. Chapter 3 discusses the density of the scavenged supernatant disposed at the BY Cribs. Several reports researched revealed that supernatant waste solution disposed at the BY Cribs had a density between 1.12 and 1.32 g/mL. Chapter 4 discusses the cribbing criteria and the later detection of cobalt-60 in the groundwater and why cobalt-60 was not sorbed to the soil before entry into groundwater. This chapter also used previous calculations from another report to determine various chemical and radionuclide inventories. Chapter 5 discusses the waste disposal to the 216-B-50 Crib from 1965 to 1968. Chapter 6 provides research of historical documents reporting information on groundwater monitoring. Documents provided in this report (e.g., Appendix B), from 1955 through 1964, reported on groundwater monitoring. A summary from the reports was provided for each year from 1955 through 1964 in the subsections of Chapter 6. According to the documents reviewed, this report described the flow directions and other studies completed during this decade for explaining contaminant migration. Most of the reports indicated that the dominant flow direction generally was south (1955 through 1964). However, in the 1956 and 1957 "Chemical Effluents Technology Waste Disposal Investigations," groundwater contamination was considered to flow north and south with a divide along the northwestern side of the 200 East Area. The northern flow was considered to sweep around/over the subsurface basalt anticline located north of the 200 East Area (HW-53225). Also in the 1961 and 1962 subsections, northern flow was mentioned. The 1962 subsection stated, "…gross beta contamination maps and the newly introduced nitrate ion and tritium ion contamination maps confirm that by 1962, a distinct groundwater divide has formed." Chapter 6 also discusses the influence of fluid density of radioactive wastes in the groundwater. In 1957 and 1960, depth-discrete groundwater samples were collected from wells identified near the 216-B-5 reverse well and 216-B-9 Crib. All of the wells sampled, except for the well farthest from the disposal site, showed increasing concentrations of radioisotopes in the sample taken from the bottom of the well. Chapter 7 provided four summaries on vertical distribution of contamination from four separate reports. One report (PNL-2724) completed in the mid-1970s did not find evidence of contamination predominately at depth; however, the focused study areas were not near or along a preferred flow paths and therefore had little potential to encounter a dense contaminant plume. Another document (WMNW-9759114) reviewed in this report had no conclusive information to either indicate or deny a contaminant plume driven by elevated density.

Table A-4. Groundwater Bibliography

Document	Summary
Potential for Groundwater Contamination from High Density Wastes Disposed to the BY Cribs, 200-BP-1 CERCLA Operable Unit, WHC-SD-EN-TA-003 (cont'd.)	Another report provided in Chapter 7 from the mid-1980s claimed that contamination reported in Well 299-E33-12 was due to a dense contaminant plume migrating through the unsealed annulus of the well. The source of this waste was considered the BY Cribs. Probably the most significant report regarding possible contaminant plumes with a density driver is the report by Smith in 1980. This report provides evidence for contaminant migration driven by density that was associated with gamma scintillation logging in wells south and east of the BY Cribs. The logging reported gamma-emitting radionuclides immediately above the basalt. The evidence for active movement was inferred by a comparison of the 1968 and 1976 gamma logs from Well 299-E28-14. No evidence exists of high gamma activity near the top of basalt of this well in 1968 and definite gamma activity at depth in 1976. Chapter 8 describes the regional geology and hydrology. This report indicates that the Hanford formation sands and gravels contain a minor proportion of silt and would feature a very high vertical conductivity. In addition, underlying Elephant Mountain Basalt forms the uppermost confining unit beneath the majority of the 200 East Area. A detailed structure contour map of the top of basalt surface beneath the 200 East Area was included. This map shows a definite southward regional dip of the top of the basalt. In addition, erosion has removed the Ringold Formation beneath the BY Cribs so that the northern limit of the Ringold Formation gravel unit A is located a few hundred meters south of the BY Cribs. This unit, normally occurring beneath the lower Hanford gravel and immediately on top of the Saddle Mountains Basalt, is continuous southward to beyond the borders of the 200 East Area. As the unit was deposited in gravelly braided fluvial channels, no continuous impermeable layer onlapping the basalt could act as a local confining unit and return any dense fluids into the sedimentary interval as the basalt dips away to the south. As illustrated in the basalt contour map, the flat relief on the top of the basalt immediately beneath the BY Cribs allowed for minor eastward or westward movement before dense contaminant began to flow to the south following the regional dip of the top of the basalt. An eastward movement of approximately 152.4 m (500 ft) would have allowed scavenged TBP supernatant to come into contact with Well 299-E33-12. Scavenged TBP supernatant descending along this unsealed well could have allowed the contamination to enter the Rattlesnake Ridge interbed.

Table A-4. Groundwater Bibliography

Document	Summary
Potential for Groundwater Contamination from High Density Wastes Disposed to the BY Cribs, 200-BP-1 CERCLA Operable Unit, WHC-SD-EN-TA-003 (cont'd.)	As described in Chapter 3 of this report, the reconstructed density of the simulated scavenged TBP supernatant solution was measured with a density of 1.21 g/mL. This value falls within the range of measured densities for 1,1-dichloroethane (1.17 g/mL), and 1,2-dichloroethane (1.26 g/mL), commonly encountered dense non-aqueous phase liquid contaminants. Because the rate of disposal was rapid and only a thin saturated zone existed at the time, practically no dilution occurred as the solution mass displaced groundwater and sank through the saturated zone. During the descent through the aquifer, a minor portion of the constituent mass could have diffused into the flow of the groundwater. The descent stopped on the top of the basalt and formed into a mobile layer that moved down the regional dip of the basalt surface under the influence of gravity. The contaminant solution could continue to flow downslope until enough solution is diffused into the surrounding groundwater that there is no density differential to drive it further. After the mass movement has ceased, a source of dilute contamination would remain stratified at the bottom of the aquifer. Chapter 9 indicates that there has been no attempt to look for contamination at the bottom of the aquifer; therefore, no proof exists that a mobile or even identifiable contaminant mass exists on the bottom of the aquifer beneath the 200 East Area. Conversely, no evidence exists that the contaminant mass identified in the earlier cited research activities has dispersed or diffused to harmless concentration levels. Consequently, a deliberate and cost-conscious investigation of the potential for groundwater contamination from high-density wastes is justified because of the evidence gathered during the earlier investigations and the lack of current data. Because gross-beta activity, cobalt-60, and technetium-99 appear to be the signatures of the scavenged TBP supernatant, borehole radioactive geophysical logging in existing groundwater monitoring wells appears to be the most cost-effective and rapid means of determining the location and concentration of these radionuclides if they can be found in the saturated sediments at the bottom of the aquifer. If it is determined that radioactive contamination at depth has advanced beyond the area covered by the list of wells, additional nearby wells that reach to the top of basalt should be logged to establish the leading edge of the contaminant mass.
200-BP-5 Operable Unit Treatability Test Report, DOE/RL-95-59, Rev. 0	This report discusses various tasks that were completed to determine the nature and extent of groundwater contamination from areas (e.g., BY Cribs, 216-B-5 Reverse Well, and Gable Mountain Pond) with contaminant concentrations (e.g., cesium, strontium, plutonium, and technetium) exceeding national groundwater drinking levels. This information was then used to develop a conceptual model and provide risk assessments to determine contaminant concentrations at core zone boundaries or potential future concentrations and transport outside of the core zone boundary. The information provided below discusses mainly the nature and extent information for technetium for the BY Crib's plume because it was determined to be the only radionuclide with a long half-life that could impact the river in the near future and, thus, presents the greatest risk.

Table A-4. Groundwater Bibliography

Document	Summary
200-BP-5 Operable Unit Treatability Test Report, DOE/RL-95-59, Rev. 0 (cont'd.)	One of the purposes of this document was to determine the distribution of the respective contaminants at each plume and improve the understanding of aquifer properties. Therefore, a hydrologic assessment was completed that included the following: (1) historical review of site operations and groundwater elevation changes and contaminant trends and distribution from the beginning of operations to the current time (mid-1990s), (2) geophysical surveys using high-resolution seismic reflection, (3) exploratory drilling and sampling, (4) water well monitoring, and (5) in situ flow and velocity tests. This information is discussed in the following paragraphs. Groundwater plume maps, hydrographs, and historical groundwater elevations were used to develop a conceptual model of the fate and transport in the 200 East Area from the beginning of the separation activities. The B Pond was identified as the source for disrupting the natural west-to-east groundwater flow direction beneath the 200 East Area. The groundwater mounding associated with B Pond established a hydrologic dam on the eastern boundary of the 200 East Area, forcing flow to divert either to the north/northwest through Gable Gap or to the southeast. The increased effluent discharges in this area resulted in a groundwater divide that controls flow diversion. The divide axis is oriented approximately east-west, and its location has migrated along a northwest-to-southeast axis beneath the 200 East Area in response to varying amounts and locations of effluent discharge. Effluent and contaminants that migrated to, or flowed with, groundwater to the south of the divide were driven to the southeast. Those that entered groundwater to the north of the divide were transported to the north-northwest and eventually through Gable Gap. The best evidence of when the hydrologic divide developed beneath the 200 East Area was the gross-beta contamination represented in the October to December 1959 contaminant map. From that time to present, hydrologic conditions have existed that have resulted in a continued north/northwesterly movement of groundwater beneath these disposal facilities. The geophysical survey (e.g., downhole seismic) proposed to define aquifer thickness and locate possible erosion channels in the basalt was not available and the expense of other alternatives would have limited other tasks; therefore, the survey task was dropped. Sonic drilling techniques were used to complete a network of eight boreholes to define the top of basalt and the nature and extent of the contaminant plume in the vicinity of Well 699-50-53A. Three wells (699-49-53, 699-49-54, and 699-50-54) were advanced far enough to reach groundwater and possibly the top of basalt; these wells were located approximately 304.8 m (1,000 ft) south, 426.7 m (1,400 ft) southwest, and 304.8 m (1,000 ft) west from Well 699-50-53A, respectively. The estimated aquifer thickness from these pushes was determined to be 6.40, 7.19, and 6.89 ft, respectively. Only Well 699-50-54 reported the same order of magnitude of technetium as Well 699-50-53A. The other two wells reported an order of magnitude less of technetium. Thus, the assumption taken in this report was that the BY Crib's plume is centered near Well 699-50-53A. Well 699-50-53A was determined to be located approximately 3,000 ft north of the BY Cribs. Groundwater flow derived from water-level measurements was not considered reliable because of the potential error using standard measuring techniques (e.g., surveying, depth-to-water measurements, and plumbness of the borehole). Therefore, flowmeter tests were completed that showed a northern groundwater flow in the area north of the 200 East Area. However, groundwater flow in the vicinity of the BY Cribs was determined to be to the south using this method. In addition, groundwater flow velocities were completed. The results indicated that the velocity north of the 200 East Area ranged from approximately 0.012 to 0.34 m/d, while the velocity near the BY Cribs was from 0.13 to 0.49 m/d.

Table A-4. Groundwater Bibliography

Document	Summary
200-BP-5 Operable Unit Treatability Test Report, DOE/RL-95-59, Rev. 0 (cont'd.)	The distribution of groundwater concentrations defined by the national DWSs was estimated for plutonium, strontium, and cesium for the 216-B-5 Reverse Well. The estimated plume distribution for plutonium defined by a 1 pCi/L contour was approximately 180 m across (e.g., northwest to southeast). The plume distribution for strontium-90 defined by an 8 pCi/L contour was estimated to be 300 m. Finally, the plume distribution for cesium-137 defined by the 120 pCi/L contour was estimated to be 200 m (656 ft). Risk assessments were completed for these radionuclides and are discussed in the following paragraphs. The best estimate for plutonium's K_d was 4,600 mL/g, which was derived from laboratory experiments that any hexavalent plutonium would be reduced by the sediments to a quatrovalence state. Contact times to establish the K_d mentioned above were estimated to be approximately 18 days. Because of the half-life of plutonium, the concentrations at the source likely will not diminish within a 1,000- or 10,000-year time frame; however, modeling from this report indicated that concentrations would not exceed MCLs at the core zone boundary by the time it was expected to reach the boundary. Concentrations were determined to be less than 1 pCi/L and the travel time was determined to be 7,500 years. Strontium is more likely to have solubility controls than cesium because it has lower solubility than calcium carbonate and is insoluble in the presence of phosphate. For Hanford Site soils, it has a K_d of approximately 25 mL/g, approximately one-half the value for cesium. However, soil sample results indicated that the K_d is not the only factor controlling mobility of strontium. Modeling of strontium from the 216-B-5 Reverse Well determined that concentrations would decay to negligible concentrations before reaching the core zone boundary. Cesium, like other alkali metals, has high solubility in aqueous systems, and the principal controlling mechanism was determined to be sorption and not solubility. It was concluded that the most reasonable K_d for cesium was 50 mL/g. Modeling of cesium from the 216-B-5 Reverse Well determined that concentrations would decay to negligible concentrations before reaching the core zone boundary. The distribution of groundwater concentrations for technetium near Well 699-50-53A was modeled. Because technetium was not estimated to achieve concentrations below the national DWS, the center of the plume was the target of the modeling. Information used to determine technetium migration and risk assessment are provided below. Technetium typically forms negative ions in oxidizing environments and does not readily complex with other chemical species. Technetium also has a very low soil-water K_d. Consequently, limited tendency exists for technetium to adsorb to the Hanford Site sediments, which makes the radionuclide mobile. Modeling was completed for the technetium for the year 2018, which indicated that the plume with centralized concentrations of 7,843 pCi/L will have moved 2,682 m north of Well 699-50-53A. The assumption is that groundwater will move north during this time toward the river at approximately 0.328 m/d. It was concluded that these concentrations were estimated to exceed the MCLs when reaching the river. The distribution of strontium was estimated for Gable Mountain Pond. Like the 216-B-5 Reverse Well, strontium was determined to have negligible effects before decaying below national DWSs.

Table A-4. Groundwater Bibliography

Document	Summary
200-BP-5 Operable Unit Treatability Test Report, DOE/RL-95-59, Rev. 0 (cont'd.)	Conceptual models were presented to explain the observed trends in contamination north and south of the BY Cribs. Contaminant concentrations north of the BY Cribs were explained by contaminants in the lower vadose zone as sorbed material on mineral surfaces and in interstitial water. Subsequent increases in the elevation of the water table beginning in the mid-1980s resaturated this contaminated zone and led to remobilization contaminants and increased observed concentrations. Contaminant concentrations to the south were explained by high-density (e.g., 1.21 to 1.32 based on process records and laboratory simulation experiments) flows allowing for the migration along the bottom of the unconfined aquifer against this document's interpreted groundwater flow direction. It was concluded that more hydrogeologic and contaminant characterization information was needed before either model could be validated. In conclusion, the risk-based decision analysis indicated that no significant future risk to human health is associated with cesium-137, plutonium-239/240, and strontium-90 contamination at the 216-B-5 reverse well. In addition, transport calculations associated with strontium-90 at Gable Mountain Pond indicate that residential incremental lifetime cancer risk would be obtained in approximately 127 years. However, the risk-based decision analysis for the BY Cribs plume (technetium-99) was predicted to reach the Columbia River at concentrations exceeding WAC 173-340, "Model Toxics Control Act—Cleanup," standards. In addition, uncertainty in the basalt structure to the north of the 200 East Area was not resolved. This unresolved part of the transport model is key to providing a driving force for this plume.
Virtual Library groundwater elevation data	Groundwater elevations were reviewed to determine historical groundwater flows to interpret groundwater contour maps, confirm previous assumptions of groundwater flow, and verify possible inventory calculations completed north of the 200 East Area. Thus, several wells were reviewed for groundwater elevations from the beginning of separations activity to 2005. From the results of various elevation reports, it was determined that key wells be selected to illustrate the various groundwater flow changes within this area. Seven key wells were selected to provide an understanding of the groundwater changes across the 200 East Area. In the mid-1950s, questions arose from varying observations and interpretations from the various groundwater reports from the 1950s to the early 1970s. The series of groundwater contours near WMA B-BX-BY in the 1950s indicate radial flow from the 216-B-8 Crib. This coupled with the discontinuation of the 200 North Ponds, continued disposal to the B Pond with increased water levels, and lack of well coverage to the north of the 200 East Area possibly allowed for northern migration to go unnoticed. However, it was considered in HW-49728 and, thus, the advent of the Gable Mountain Pond.

Table A-4. Groundwater Bibliography

Document	Summary
Virtual Library groundwater elevation data (cont'd.)	Thus, flow direction until the late 1960s was generally considered to the south. Observations from the Virtual Library during the later 1950s through the mid- to late 1960s indicated that the groundwater movement proximal to the BY Cribs was to the south based on the gradient associated with groundwater elevations from the following wells: 299-E33-14, 299-E32-1, 699-49-57A, and 699-54-57. However, further north during this time, the gradient associated with groundwater elevations from Wells 699-54-57, 699-60-60, and 699-65-59A indicate a northern flow direction. This was most likely due to Gable Mountain Pond influence. The wells just north of the 200 East Area boundary in this area (699-49-57A, 699-54-57, and 699-60-60) are almost identical, making it difficult to determine a definite gradient. This information is similar to current conditions. Thus, small amounts of flow appear to have gone north. This flow was not discernable by water elevations as evidenced by the slightly elevated tritium levels reported in wells just north of the 200 East Area during the 1960s. From the late 1960s, significant tritium, nitrate, and gross-beta concentrations in the wells just north of the 200 East Area provide clear evidence of northern flow from the 200 East Area to the Gable Mountain/Gable Butte Gap. Based on several reports cited earlier (BNWL-1703; BNWL-1706; ARH-SA-292), the noticeable change was due to startup of irrigation upgradient of the Hanford Site and increased effluent discharges to various ponds. In addition, it appears that contributions may have been influenced from liquid effluent disposal to the 216-B-50 Crib and 216-B-57 Trench (initial effluent disposal 1965 and 1968, respectively). Elevated tritium concentrations in Well 699-50-53A would seem to confirm this conclusion. However, in late 1973, nitrate concentrations increased and became predominate in Well 699-49-57A over Well 699-50-53A. The nitrate concentrations continued to be elevated in Well 699-49-57A until 1986, when effluent disposal to Gable Mountain Pond was stopped. Nitrate concentrations are consistently an order of magnitude higher in Well 699-50-53A than in Well 699-49-57A through the mid-1990s when pump-and-treat operations began in Well 699-50-53A.
HEIS database	Tritium concentrations were reported from 1962 to present in various wells located to the north of the BY Cribs. Before 1973, results were sparse and generally below current drinking water levels, except at Wells 699-49-57A and 699-50-53A. In 1973, concentrations increased significantly in Well 699-49-57A and remained over 100,000 pCi/L through 1980. From 1980 to 1987, concentrations decreased in this well, finally stabilizing in 1987. Although there were few tritium results during the 1980s near the BY Crib area, concentrations were predominantly higher to the northwest, indicating a preferential northwestern groundwater flow direction. As concentrations stabilized in Well 699-49-57A in the mid- to late 1980s, concentrations in Well 699-50-53A increased between 1986 and 1992; however, concentrations were below the MCLs. Concentrations reported in wells further north (699-59-58, 699-60-60, and 699-61-62) of Well 699-50-53A were generally much higher than Well 699-50-53A from 1973 to 1986, indicating a preferential path from Well 699-49-57A while bypassing Well 699-50-53A.

Table A-4. Groundwater Bibliography

Document	Summary
HEIS database (cont'd.)	Tritium concentrations in the early to mid-1990s appear to be more disperse throughout the area east, west, and south of the BY Crib area. Tritium trend analyses (using plume maps), since the mid- or possibly early 1990s, indicate a southeasterly flow. In conclusion, tritium data suggest that the groundwater flow was primarily to the north and northwest at varying rates from the late 1960s until the early to mid- to late 1990s as seen in flowmeter studies provided in DOE/RL-95-59. However, since 2003 uranium concentrations have continued to increase preferentially to the northwest as well as to the west. This seems to be consistent with what might have been happening in late 1958 and 1959. HW-61197 stated that the fine Ringold sediments that rose above the water table just southwest of the BY Cribs were impacting groundwater flow and that the coarser glaciofluviatile sands and gravels that occur just north and west of the Ringold beds allowed transmission of contaminated groundwater at a much faster rate. This also appears to be consistent with the geologic units at the 1992 water table (WHC-SD-EN-TI-019). Chloride concentrations were reviewed and compared from 1991 to present for 15 wells located north, west, and east of the B-BX-BY Tank Farms. Although data were present before 1991, data were very sparse. Concentrations ranged from less than 4.7 mg/L to 53.4 mg/L from 1991 to present. The highest concentrations were reported in Well 299-E33-9 in February 2001. High concentrations (e.g., greater than 30 mg/L) were first reported in Well 299-E33-9 in December 1999. Other wells reporting concentrations exceeding 30 mg/L included 299-E33-7, 299-E33-26, and 299-E33-38. Concentrations generally decrease with distance more to the south and east than to the west. Surprisingly, concentrations at Well 699-49-55A are comparable to concentrations in Well 299-E33-18, which may be the result of greater depth of groundwater in 299-E33-18 than at Well 699-49-55A. There also were slight increases in the 1990s beneath the 216-B-8 Crib during the period reviewed. In conclusion, it appears that the recent elevated chloride concentrations are central to the BY Cribs and BY Tank Farm. Possible reasons for elevated concentrations beneath the BY Cribs and BY Tank Farm are recent infiltration of chlorinated water from the vadose zone. If infiltration is occurring, slight mounds, not as significant as associated with the 216-B-8 Crib, may be driving groundwater preferentially west and northwest as explained in the previous paragraph. Uranium concentrations were reported in the BY Crib wells starting in 1955. Results indicated that uranium was migrating into the groundwater near Well 299-E33-3. Uranium analyses were included for the 216-B-8 Crib wells starting in 1956. Results indicated that uranium also migrated into the groundwater from the 216-B-8 Crib. Uranium concentrations were reported during the 1950s in pCi/L. The highest concentrations reported for the BY Crib and 216-B-8 wells were 10 pCi/L from 299-E33-3 for the BY Crib wells and 21 pCi/L from 299-E33-16 for the 216-B-8 Crib. In addition, Well 299-E33-19 was reported with the highest concentration in the 1950s at 31 pCi/L in April 1957. After December 1957, uranium results were not recorded again until August 1986 in this area. One final observation is uranium concentrations were reported higher in the wells located to the south than to the north during the 1950s. However, elevated uranium concentrations also were reported in the northern wells (e.g., 299-E33-11) demonstrating radial flow.

Table A-4. Groundwater Bibliography

Document	Summary
HEIS database (cont'd.)	Uranium concentrations reported in northern wells from 1986 to present have remained below 10 µg/L; however, some of the higher concentrations were reported in the wells further to the north, such as Well 699-55-60A. This observation indicates that elevated uranium concentrations may have migrated north during the absence of uranium monitoring. This is consistent with the nitrate concentrations reported during the 1970s through mid-1980s. Increasing uranium concentrations near the BY Tank Farm and other proximal waste sites are noticeable starting in 1993 for Well 299-E33-13. Well 299-E33-18 also reported elevated concentrations in 1994. The concentrations in Well 299-E33-18 (63.9 µg/L) were three times higher than in Well 299-E33-13 (21 µg/L) in 1994. During this time, a slight plume existed from Wells 299-E33-34 to 299-E33-36. In addition, a slight plume also existed to the west beneath the southwestern portion of LLWMA-1. Concentrations reported in Well 299-E33-13 continued to rise until 1997. The concentration reported in 1997 was 203 µg/L. Uranium concentration analyses were sparse during this period of time, and it is unclear what waste site or waste sites were responsible for the increasing uranium concentrations. In the late 1990s, additional wells were sampled and analyzed for uranium. During this time, Well 299-E33-44 had consistently reported the highest concentrations; however, Wells 299-E33-13, 299-E33-18, 299-E33-26, and 299-E33-38 also reported elevated concentrations. A noticeable plume existed from Well 299-E33-18 to Well 299-E33-34. Based on available data, the center of the plume was located near Well 299-E33-44. During the past 5 years, even more wells were sampled for uranium. During this time, the highest concentrations were consistently reported from Well 299-E33-9. The maximum concentration reported at Well 299-E33-9 was 678 µg/L in May 2001. Other wells reporting high uranium concentrations (greater than 100 µg/L) during this time included 299-E33-18, 299-E33-26, 299-E33-38, and 299-E33-44. The plume noted previously from Well 299-E33-18 to Well 299-E33-34 had increased in concentration. The plume under the southwestern portion of LLWMA-1 has not shown any significant changes. Based on the high concentrations in Wells 299-E33-9 and 299-E33-44, uranium concentrations appear to be centered near these wells. In addition, it appears that possible radial spreading preferentially to the southeast toward Well 299-E33-18 and to the northwest toward Well 299-E33-26 may be occurring. This type of migration appears to be consistent with previous cobalt, gross beta, and tritium contaminants in the past. However, additional sources may be associated with the reported concentrations being reported. Correlations between these wells are difficult to establish from the uranium data alone. Nitrate concentrations beneath and surrounding the BY Cribs were sparse in the early 1970s. Several wells (299-E28-18, 299-E33-3, 299-E33-10, 299-E33-25, and 699-49-57A) reported elevated nitrate concentrations in the mid-1970s. The highest concentrations were from Well 299-E33-3 beneath the BY Cribs with concentrations ranging from 490 to 750 mg/L in the mid-1970s. In the late 1970s, results were reported for Well 299-E33-9. Concentrations were significantly higher in Well 299-E33-9 than the other proximal wells in the area. However, during this time frame, no nitrate results were reported for the wells beneath the BY Cribs. The data indicate that spills or releases near either the BY Tank Farm or BY Cribs may have been responsible for the elevated nitrate concentrations reported during this time. From 1995 to present, nitrate concentrations have been consistently higher in Well 299-E33-16 than any other well in the northern portion of the 200 East Area. Higher concentrations also have been reported under the BY Cribs.

Table A-4. Groundwater Bibliography

Document	Summary
HEIS database (cont'd.)	Nitrate concentrations also were reviewed from 1950 to present for wells located to the north and the south of the BY Crib area. Nine wells (699-49-55A, 699-49-57A, 699-50-53A, 699-53-55C, 699-56-53, 699-59-58, 699-60-60, 699-61-62, and 699-61-66) located to the north of the BY Cribs were reviewed from 1950 to present. Nitrate results, as others, were very sparse until the late 1960s. Concentrations generally were reported below 10 mg/L for all wells, except 699-50-53A, until October 31, 1973. Concentrations reported in Well 699-50-53A ranged from 0.5 to 1,300 mg/L during this time. In late 1973, concentrations increased in Well 699-49-57A from less than 10 mg/L to 250 mg/L. Concentrations continued to fluctuate between 130 and 390 mg/L from late 1973 until early 1986. During this time, concentrations in Well 699-50-53A continued to decline and remained generally lower than 30 mg/L from 1978 to 1985. In 1985, concentrations in Well 699-50-53A rose to nearly 400 mg/L and generally fluctuated between 200 and 400 mg/L from 1985 to 1987. Concentrations from 1987 to 1991 reported continuous increases in Well 699-50-53A. From 1991 to the last report in 1995, concentrations in Well 699-50-53A decreased. From 1986 to 1995, concentrations in Well 699-49-57A remained generally lower than 100 mg/L, which was almost an order of magnitude lower than Well 699-50-53A. In conclusion, nitrate concentrations have demonstrated a northern flow from the early 1970s through the mid-1990s; however, over the past decade, plumes appear to be moving very slowly to the southeast. Monitoring wells beneath the BY Cribs and 216-B-8 Crib have definitely identified migration of nitrate into the groundwater from these sites. It is unknown if elevated concentrations previously reported in Well 299-E33-9 were due to the BY Tank Farm or if they were from the BY Cribs or some other source. It also was unknown if contamination from some southern waste site (e.g., possibly the 216-B-12 Crib) may have also added to the elevated concentrations reported in Wells 299-E28-18, 299-E33-10, 299-E33-25, and 699-49-57A. Based on all of the data presented, an interpretation including superimposed radial flow from waste sites and intermittent to predominant northerly flow from the late 1960s to the early to mid-1990s seems evident. During this time, because of the lack of analytical results and sparse monitoring well locations, it is impossible to determine the inventory of contamination in the groundwater for technetium and uranium that may have previously migrated north and is currently present north of the 200 East Area boundary. In addition, at least two routes of predominant northerly transport appear to have been demonstrated during this time. Thus, it is recommended that monitoring wells be placed in locations north of the 200 East Area fence line to determine the following: past release inventories currently in groundwater from identified routes of transfer, basalt surface, and extent of thin layer low-permeability zone. Geophysics may provide more efficient well placement to answer the questions above.

Table A-4. Groundwater Bibliography

Document	Summary
Investigation of Isotopic Signatures for Sources of Groundwater Contamination at the Hanford Site, PNNL-13763	Cleanup of contamination at the Hanford Site is complicated by the presence of multiple sources in proximity. In many cases, it is difficult to associate groundwater effects with specific sources. The resulting uncertainty in assessment of contaminant fate and transport leads to a corresponding difficulty in determining appropriate groundwater and source remediation measures needed to protect human health and the environment. Waste streams from processes have varying levels of contaminants. Many of the contaminants are found in multiple waste streams and were discharged or leaked from multiple facilities. Waste composition changed through the production history because of improvements in reactor operations and in separation processes. Knowledge of these changes provides a theoretical basis for the belief that more detailed investigations of groundwater geochemistry can help unravel the contaminant sources. In particular, this report considers the application of improved analysis of chemical isotopes to evaluate the sources of groundwater contamination. This summary discusses two of the isotopic ratio methods considered for determining contaminant sources. Sixteen samples were collected during this study in the vicinity of B Plant in the 200 East Area. Eleven of these samples were from the vicinity of the B-BX-BY Tank Farms and BY Cribs. The groundwater sampling results for uranium-236 were reported as follows: 299-E33-9 (0.039816), 299-E33-44 (0.030546), 299-E33-38 (0.008811 and 0.0088574), 299-E33-18 (0.009306 and 0.008434), 299-E33-26 (0.006667), 299-E33-5 (0.00498), 299-E33-13 (0.004477), 299-E33-41 (0.001342), and 299-E33-16 (0.000598). The results for uranium-234 were in agreement with this concentration-based sequence. The results indicate that vadose zone sources are closer to Wells 299-E33-9 and 299-E33-44. Concentrations in Wells 299-E33-38 and 299-E33-18 indicate that these wells are further from the vadose zone source. Several of the samples were reported with lower uranium-236 abundance, between approximately 2E-5 and 5E-5. The pre-1950 production shows distinctly lower uranium-236 than most of the later fuel loads. The low abundance of uranium-236 concentrations was consistent with the disposal history for the nearby facilities; however, mixing with natural uranium cannot be ruled out. Mixing with natural uranium will reduce the uranium-236 abundance. At high contaminant concentrations, any effect from natural uranium will be insignificant, but it may become a factor at lower concentrations. If natural uranium provides a significant percentage of the total, then uranium-234 should be elevated because of the alpha-recoil effect. This is where the alpha decay of uranium-238 in minerals and subsequent beta decay to uranium-234 strain the crystal lattice, leading to preferential leaching of uranium-234 relative to uranium-238, which remains in unstrained sites. The uranium-234 in several of the samples is slightly above natural abundance, but the variability in the uranium-234 abundance is similar to that in the high-concentration, high uranium-236 abundance samples. The variability, however, precludes distinguishing a low-concentration, low uranium-236 contaminant from mixing between a higher uranium-236 abundance contaminant with background water.

Table A-4. Groundwater Bibliography

Document	Summary
Investigation of Isotopic Signatures for Sources of Groundwater Contamination at the Hanford Site, PNNL-13763 (cont'd.)	High abundance of uranium-236 was reported from samples collected near a high-concentration uranium plume near the B-BX-BY Tank Farms. The uranium-236 abundance reported at greater than 7E-5 is distinct from that of Well 299-E33-16, which monitors the 216-B-8 Crib located east of the tank farms. Thus, it appears that the uranium results from these different locations are from different sources. The uranium-236 abundance estimated for the 241-BX-102 event is 5.22E-5, which is somewhat lower than the approximate 7E-5 value seen in the groundwater samples from the uranium plume. However, the uncertainties in the estimated values are not well known, so this may still be a possible source. This document explored the differences of technetium to ruthenium ratios in wells near the B-BX-BY Tank Farms. Ratios were much higher in the wells near the 241-BX-102 release as follows: 299-E33-18 (83.2), 299-E33-16 (56.4), 299-E33-44 (40.2), 299-E33-38 (14.8), 299-E33-26 (12.6), and 299-E33-9 (10). This work was concluded to be productive for distinguishing technetium sources.
A Geostatistical Analysis of Historical Field Data on Tritium, Technetium-99, Iodine-129, and Uranium, PNNL-14618	The purpose of this document was to generate maps and statistics that quantify contamination in groundwater. The maps and statistics then could be compared to predictions from the SAC model, used for verification of SAC results, and then provide an estimate of the uncertainty in the history-matching data generated. The area of interest in this report for the 200-BP-5 OU was the northern portion of the 200 East Area. Only limited information was provided for this area, which mainly focused on large plumes identified with potential to impact the Columbia River. Limitations of the statistical model include the inability to delineate plume thickness, sparse data, and uncertainty in aquifer thickness. Thus, using the available data from the HEIS database and professional judgment, inventories of tritium, technetium, iodine, and uranium were calculated. However, because of the uncertainty of the aquifer thickness in the area north of the 200 East Area, the inventory for some contaminants have a large range (e.g., technetium, 10 to 40 Ci). With such large ranges, the risk of impact to the river increases as documented in risk assessment modeling in DOE/RL-95-59. Thus, resolving the uncertainty is required. Note that if southern groundwater flow direction begins to occur in the area north of the 200 East Area, the estimated inventory added to the vadose zone inventory could exceed MCLs south of the core zone boundary. In addition, if this inventory is added to the inventory within the BC Cribs, a very large plume may be realized with increased risk for river contact to the southeast. Other contaminants (e.g., iodine) indicate the potential for a substantial inventory when considering the upper limit of uncertainty (0.04 to 1.4 Ci); however, the modeling only indicates limited lateral groundwater extent above the existing MCL (1 pCi/L). Tritium was only identified in one small area with a presence above MCLs for the time period. Uranium was not modeled in the 200-BP-5 OU.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Site Groundwater Background, DOE/RL-92-23, Rev. 0	This document provides the evaluation process and target population (e.g., specific well locations) used to determine natural background for groundwater. The target population for statistical evaluation consisted of an irregular-shaped zone about 5 km (3.1 mi) wide between Horn Rapids and Vernita Bridge. This area was considered upgradient from the influence of the Hanford Site waste management units. This document made statistical comparisons with major cations and anions. However, the document does not provide additional information to assess environmental restoration activities at the Hanford Site. An additional report (DOE/RL-96-61) was released, which provided overall constituent background levels.
Hanford Site Background: Part 3, Groundwater Background, DOE/RL-96-61, Rev. 0	This document provides the background concentrations for the major and trace elements that can be used for risk assessments or remedial actions. The information was developed from a geochemical model, which was built onto the hydrologic framework developed from DOE/RL-92-23.
An Initial Assessment of Hanford Impact Performed with the System Assessment Capability, PNNL-14027	The SAC was created because decisions needed for efficiently cleaning up and closing Hanford Site waste sites are complex, and decisions cannot be made on data and intuition alone. The SAC was developed to bring together the cumulative effects of all the waste that will remain at the Hanford Site. The SAC consists of the following modules: inventory, release, vadose, groundwater, river, riparian, and risk. When a single crib or suite of cribs is responsible for a single groundwater plume, a comparison of the combination of inventory, release, vadose zone, and groundwater can confirm or refute the ability to simulate the successive events that created the plume.
Hydrochemistry and Hydrogeologic Conditions With the Hanford Site Upper Basalt Confined Aquifer System, PNL-10817	Available hydrogeologic, hydraulic head, and hydrochemical data indicate that the principal area of aquifer intercommunication between the unconfined and upper confined aquifer occurs in the area north of the 200 East Area. The presence of manmade radionuclide constituents in the confined aquifer has been attributed to downward transference/migration of contaminated unconfined aquifer groundwater to deeper underlying basalt aquifers in the Gable Mountain/Gable Butte structural area. Direct evidence for contamination of the upper basalt confined aquifer from the overlying unconfined aquifer within this region is indicated by the presence of a variety of hydrochemical parameters, including elevated concentration levels of tritium, nitrate, and carbon-14; change in hydrochemical cation facies from an expected sodium or sodium-calcium to a calcium or calcium-magnesium water type; concentrations of technetium-99; concentrations of cobalt-60; and elevated concentrations of gross beta. Based on groundwater flow patterns, groundwater within the upper basalt confined aquifer in this region should flow northward. It was noted that several previous investigators used evidence of low barometric efficiencies as an indication of intercommunication between the upper basalt-confined and unconfined aquifer system. However, it was determined that barometric efficiencies cannot be used as indicators of intercommunication and potential mixing of groundwater between aquifer systems because of the large barometric fluctuations possible in the unconfined aquifer.

Table A-4. Groundwater Bibliography

Document	Summary
Performance Objectives for Tank Farm Closure Risk Assessments, RPP-14283, Rev. 2	In 1992, DOE, EPA, and Ecology gathered a group of stakeholders to study potential future uses for the Hanford Site land. This Hanford Future Site Uses Working Group issued a detailed report of its findings (Drummond, 1992, *The Future for Hanford: Uses and Cleanup, the Final Report of the Hanford Future Site Uses Working Group*). The report stated that the Working Group identified a single cleanup scenario for the Central Plateau. This scenario assumes that future uses of the surface, subsurface, and groundwater in and immediately surrounding the 200 West and 200 East Areas would be exclusive. Surrounding the exclusive area would be a temporary surface and subsurface exclusive buffer zone composed of at least the rest of the Central Plateau. As the risk from the waste management activities decrease, it is expected that the buffer zone would shrink commensurately. The "Record of Decision for the Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement" (64 FR 61615), which is heavily based on Drummond (1992), identified near-term land uses for the Hanford Site. The Record of Decision prescribes the use in the 200 Areas as exclusively industrial, with much of the surrounding land having the use of preservation or conservation. Most recently, DOE, EPA, and Ecology put forth a risk framework letter delineating land-use scenarios: • The core zone will have an "industrial" land-use scenario for the foreseeable future. • The core zone will be remediated and closed allowing for "other uses" consistent with an industrial land-use scenario that will maintain human presence in this area, which in turn will enhance the ability to maintain the institutional knowledge of wastes left in place for future generations. • DOE will follow the required regulatory processes for groundwater remediation to establish the points of compliance and remedial action objectives. It is anticipated that groundwater contamination under the core zone will preclude beneficial use for the foreseeable future, which is at least the period of waste management and institutional controls (150 years). It is assumed that the tritium and iodine-129 plumes beyond the core zone boundary will exceed DWSs for the period of the next 150 to 300 years. It is expected that other groundwater contaminants will remain below, or be restored to, drinking water levels outside the core zone. • No drilling for water use or otherwise will be allowed in the core zone for the foreseeable future. • Waste sites outside the core zone but within the Central Plateau will be remediated and closed based on evaluation of multiple land-use scenarios to optimize land use, institutional control cost, and long-term stewardship. • An industrial land-use scenario will set cleanup levels on the Central Plateau. • This framework does not deal with the tank retrieval decision. • Under this guidance, the groundwater between the core zone and the River Corridor is to be remediated between 2012 and 2035. The 2035 to 2150 time frame continues to restrict groundwater use. After 2150, the performance objective is multiple land uses.

Table A-4. Groundwater Bibliography

Document	Summary
Performance Objective for Tank Farm Closure Risk Assessments, RPP-14283, Rev. 2 (cont'd.)	• Relevant regulations include 40 CFR 141, "National Primary Drinking Water Regulations"; 40 CFR 143, "National Secondary Drinking Water Regulations"; and WAC 173-340. For protection of groundwater, the national primary DWSs will be used, except for those chemicals where Washington State or other federal regulations are more restrictive. However, WAC 173-340 is promulgated if hazardous substances remain at a facility after actions have been completed under other applicable laws or regulations. • Points of assessment are limited to two points the maximum point of impact at the 200 Area core zone boundary or beyond and the maximum point of impact along the Columbia or Yakima Rivers. • The time of assessment is assumed to start at 2150 and, based on the U.S. Nuclear Regulatory Commission, extend out 1,000 years.
Revised Hydrogeology for the Suprabasalt Aquifer System, 200 East Area and Vicinity, Hanford Site, Washington, PNNL-12261	The primary objective of this document was to refine the conceptual groundwater flow model for the 200 East Area. Recommendations are provided for revision and expansion of the groundwater monitoring network to provide a more accurate groundwater contaminant tracking capability.
Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit, DOE/RL-2001-49, Rev. 1	This document provided a summary of the background for arriving at the 10 COCs for the groundwater within the 200-BP-5 OU. These COCs are as follows: cesium-137, cobalt-60, cyanide, iodine-129, nitrate, plutonium-239/240, strontium-90, technetium-99, tritium, and uranium. A discussion of the extent and contour maps and of these COCs is provided. Below is a summary of the discussion of the contaminants from this document: • Tritium, iodine-129, and nitrate contamination is explained as widespread in the 200 East Area and is associated with both B Plant and PUREX operations. • The BY Cribs were important sources of technetium-99, cyanide, cobalt-60, and nitrate contamination associated with early releases and were the main contributors for plumes that move to the northwest. • WMA B-BX-BY appears to have contributed nitrate, technetium-99, and uranium that have migrated from the vadose zone into groundwater. • Monitoring in the vicinity of the 216-B-8 Crib indicates that the crib has contributed nitrate to the groundwater locally. • WMA C appears to have contributed technetium-99, nitrate, and low concentrations of cyanide to groundwater. • Groundwater monitoring at the 216-B-62 Crib indicates that this crib was a contributor of uranium locally.

Table A-4. Groundwater Bibliography

Document	Summary
Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit, DOE/RL-2001-49, Rev. 1 (cont'd.)	• Monitoring wells associated with the 216-B-5 reverse well have had detectable concentrations of strontium-90, cesium-137, plutonium-239/240, and uranium in groundwater samples. • Localized plumes of strontium-90 and nitrate in the vicinity of Gable Mountain Pond are also being monitored. This document suggested that review and monitoring of changes are required in this area because of changes in plume geometry and uncertainty in flow direction. As a result of lowering water elevations, some wells had gone dry, such as 699-50-53A, which reduced the already sparse number of wells north of the 200 East Area boundary. To better define the 900 pCi/L technetium-99 contour in this area, one well was recommended (699-50-59). In addition, it was concluded that this well also would provide information regarding groundwater flow and define the top of basalt. This document also provided rationale for reducing the number of sample locations associated with arsenic, americium-241, gross alpha, gross beta, and neptunium-237.
Data Quality Objectives Summary Report for Establishing a RCRA/ CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network, CP-15329	The purpose of this DQO process was to assess the current groundwater monitoring well networks for the 200 West and 200 East Areas. This assessment was needed to address changing contaminant plume conditions (e.g., plume migration) and to ensure that monitoring activities meet the requirements for remediation performance monitoring (i.e., CERCLA monitoring), sitewide surveillance monitoring to meet the requirements of DOE orders, and detection/assessment monitoring to meet the requirements of RCRA. This DQO summary report was prepared in support of DOE's Cleanup, Constraints, Challenges Team process. Because of the changing shape of the groundwater contaminant plume contours over time and changing programmatic needs, the 200 West Area and 200 East Area groundwater monitoring network is required to be periodically re-evaluated. The objective of the groundwater CERCLA remediation performance monitoring program is to provide a routine assessment of the effectiveness of groundwater remediation activities within the 200-ZP-1 and 200-UP-1 OUs. The objectives of the sitewide surveillance monitoring program are as follows: • Determine baseline conditions of groundwater quality and quantity. • Characterize and define hydrogeologic, physical, and chemical trends in the groundwater system. • Identify existing and potential groundwater contamination sources. • Assess existing and emerging groundwater quality problems. • Evaluate existing and potential offsite impacts of groundwater contamination. • Provide data on which decisions can be made concerning land-disposal practices and the management and protection of groundwater resources.

Table A-4. Groundwater Bibliography

Document	Summary
Data Quality Objectives Summary Report for Establishing a RCRA/ CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network, CP-15329 (cont'd.)	Finally, the objective of the RCRA detection program is to identify if TSD units are impacting groundwater quality. If impacts to groundwater are detected, the objective of the RCRA assessment program is to define the rate and extent of contaminant migration. This DQO process identified the optimum number of groundwater wells to be monitored to meet these objectives and determined that a number of new groundwater wells needed to be installed. The identity of wells in the monitoring network, sampling frequency, analyses to be performed, detection limit requirements, and other analytical performance requirements (e.g., precision and accuracy) were defined in this document. The resultant groundwater-monitoring network fulfilled the needs of the three major Hanford Site regulatory monitoring activities (i.e., CERCLA, RCRA, and AEA).
Hanford Site Groundwater Monitoring for Fiscal Year 2000, PNNL-13404	This document describes the groundwater underlying the area associated with facilities surrounding the B Plant, including the waste storage and disposal facilities north of the plant. Significant waste sources in this vicinity include the BY Cribs, the 216-B-5 Reverse Well, and several RCRA TSD facilities. The focus of this report was to determine the general groundwater flow using plume maps, contaminant trend plots, water-level trend surface analysis, water-level hydrographs for multiple wells, and in situ flow measurements at groundwater wells. The highest uranium concentrations found during the time of this report were beneath and to the east of the BY Tank Farm (Wells 299-E33-9 and 299-E33-44). Based on HEIS data reviewed for the DQO process in this time frame, concentrations were five times lower in Well 299-E33-18 (located to the southeast) and nearly 10 times lower in Well 299-E33-26 (located to the northwest). However, increasing uranium was reported west of WMA B-BX-BY (Wells 299-E33-26, 299-E33-31, and 299-E33-42), suggesting that uranium may be migrating to the west from the WMA. This report also provides another explanation that the increasing uranium seen in Wells 299-E33-31 and 299-E33-42 may be related to movement from the BY Cribs. During the time of this report, uranium was detected consistently at levels slightly above the proposed DWS in wells monitoring the 216-B-62 Crib. Uranium concentrations were over 200 µg/L in Wells 299-E28-18 and 299-E28-21 in the mid-1980s. Uranium also was found along the western side of LLWMA-1, which likely originated at the 216-B-62 Crib. The technetium-99 plume was described as extending from the area of WMA B-BX-BY, to beyond the 200 East Area fence line to the northwest. The larger part of the plume was to the north and was interpreted to represent early releases of technetium-99 from the BY Cribs. Basis is given for considerable uncertainty in the precise extent of the technetium-99 contamination to the north of the 200 East Area. In the BY Crib area, increasing technetium-99 concentrations were reported in the 1990s. Possible explanations for the increase include movement of the contaminant plume back into the 200 East Area from the north and/or an increase in transport of contamination from the vadose zone.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Site Groundwater Monitoring for Fiscal Year 2000, PNNL-13404 (cont'd.)	Another observation pointed out in this document was that technetium-99 generally decreases from north to south along the western side of WMA B-BX-BY and on the eastern side of LLWMA-1. This observation lead to the conclusion that technetium-99 is moving toward the south, which agreed with results from the in situ flowmeters, nitrate trends, and hydrographs from this region. The technetium-99 concentrations also were reported as rising in Wells 299-E33-33 and 299-E33-36, both located southeast of WMA B-BX-BY. A nitrate plume originating in the 200 East Area extends beyond the boundary fence line, extending northwest to the Columbia River. The plume within the 200 East Area has two parts: (1) a western plume that extends from the B Plant to the northwest, and (2) an eastern plume extending from the BY Cribs and surrounding cribs toward the north and northwest. The two plumes join northwest of the 200 East Area and extend through the gap between Gable Butte and Gable Mountain to the Columbia River at levels less than the allowable MCL for drinking water. Increasing nitrate and technetium-99 concentrations in the central region of WMA B-BX-BY suggest a southerly flow. However, the uranium, nitrate, and tritium concentrations are interpreted as supporting a northwest flow. This report, considering the available information on groundwater in the B Plant area, provided the following preliminary conceptual model. A groundwater divide exists, somewhere between WMA B-BX-BY and LLWMA-1, or perhaps within the southeastern half of LLWMA-1. The conceptual model is preliminary and uncertain. The elevation of the basalt across the buried anticline is not well known because wells drilled to basalt in this are sparse. It is possible that a significant gap was eroded into this anticline, and its presence remains undiscovered. If this were the case, the groundwater flow to the northwest would be more transmissive than is currently recognized. There may be other explanations for data that are inconsistent with the conceptual model, such as other sources affecting the groundwater or overlapping plumes. In particular, water-line leaks may locally affect flow direction and contaminant distribution. Therefore, efforts to verify this conceptual model and better understand groundwater flow in the B Plant area will continue.
Hanford Site Groundwater Monitoring for Fiscal Year 2002, PNNL-14187	This report discusses the groundwater flow as associated with contaminant distribution of tritium, technetium-99, iodine-129, and nitrate because they are not significantly affected by interactions with the aquifer matrix. In addition, contaminant distributions and ratios using uranium, cyanide, and cobalt-60 were compared to provide preliminary conceptual models for the transport of contamination. Contamination from the B Plant area is known to occur to the north and northwest of the 200 East Area, which means that groundwater at some time in the past moved in this direction. A recent analysis of nitrate/technetium-99 ratios and the local tritium plume at WMA B-BX-BY suggest flow in a southward direction. The movement of contaminants beneath LLWMA-1, especially tritium, generally is interpreted as supporting northwest flow.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Site Groundwater Monitoring for Fiscal Year 2002, PNNL-14187 (cont'd.)	This report evaluated nitrate to technetium-99, cyanide to cobalt-60, and uranium concentrations in Wells 299-E33-7, 299-E33-9, 299-E33-18, 299-E33-26, 299-E33-31, 299-E33-32, 299-E33-38, 299-E33-42, 299-E33-43, and 299-E33-44. Observations indicated that in all of these comparisons, no significant difference exists in the peak of technetium-99, cyanide, and cobalt-60 that was reported in January 2001. Hence, the contamination has increased and decreased across the area at about the same time. Conversely, when groundwater plumes move through an aquifer, the peak of the contamination passes by downgradient wells at a later time than observed in upgradient wells. Because there is little or no time difference when the contamination was observed at widely separated locations, the contamination may not be moving through the aquifer. At least two possible scenarios could allow peak concentrations of contamination to occur in nearly all the wells at the same time. One possibility is that contamination may be moving vertically into the groundwater from the vadose zone near the network monitoring wells. This driver must then transport residual contaminants from multiple source areas in the vadose zone to the aquifer at about the same time. Natural infiltration is the most likely driver that satisfies this condition. The mechanics of this hypothesized vadose zone migration are not clearly understood at this time; it may be that the water sources and flow paths are so complicated and of such mixed origin that we will never fully understand them. Alternatively, the contamination may be high-density waste that previously sank to the bottom of the aquifer and accumulated in the erosional pockets on the basalt surface. In this scenario, high-density tank waste from either planned or UPRs to the vadose zone sank to the bottom of the shallow sand/gravel aquifer. Flood-scoured pockets in the basalt underlying the saturated sediments may act as traps for higher density waste mixtures. Because there was no aquifer under much of this area before past-practice discharges to the ground, the initial waste may have flowed into these pockets in the hummocky basalt surface. If so, the higher density waste may still be trapped, and as the water levels continue to drop to pre-Hanford Site operation levels, the contributions of these pockets to the pumped water samples increase. Although this mechanism allows contamination to increase uniformly across the area, it is difficult to see how concentrations would subsequently decrease as reported in Wells 299-E33-7, 299-E33-18, 299-E33-26, 299-E33-31, 299-E33-32, 299-E33-42, and 299-E33-44. In addition, in this scenario, the existence of high-density waste at the bottom of the aquifer is not consistent with the observed rapid decrease in contamination across the area since early 2001. To gain a better understanding of how contamination may be entering the groundwater from the vadose zone or may be layered on the basalt, discrete-depth sampling was conducted at Well 299-E33-334. Preliminary results from Well 299-E33-334 suggested that fresh water related to natural precipitation is entering the groundwater and forming a thin, low-contamination layer at the surface of the water table. The results would support the role that steady-state natural recharge from the surface might be the primary control on the vertical movement of contamination through the vadose zone at WMA B-BX-BY.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Site Groundwater Monitoring for Fiscal Year 2002, PNNL-14187 (cont'd.)	Three plumes were identified in this report. One plume consisting of nitrate, nitrite, technetium-99, and uranium is located under and east of the BY Tank Farm. Past releases from the WMA may be the source of this contamination. Another plume with low levels of nitrate associated with relatively high tritium is found along the south border of the WMA. Movement through the vadose zone from a tritium-rich perched water table located 4.6 m above the water table under the BX Tank Farm may be the cause of this contamination. Further to the north under the BY Cribs is a plume containing high levels of nitrate, cyanide, cobalt-60, and technetium-99. These contaminants extend from the BY Cribs to the north, westward to the northeast corner of the LLWMA-1, and south to the northern part of BY Tank Farm, where only cyanide and cobalt-60 are found. Uranium also is found locally in the southern part of the BY Cribs. These contaminants are attributed to releases from the BY Cribs in the mid-1950s. Ratio data observations from Wells 299-E33-7 and 299-E33-18 provided the following conclusions. When contamination began to rise in the mid-1990s, the ratios moved off the mixing line and onto a horizontal trend that is followed until the peak values are seen in late 2000. Two observations can be made from this information. First, the horizontal plot indicates that the recent contamination (1996 to 2001) observed at Well 299-E33-38 is from a single source. Second, this single source may not be the same source as that seen in Well 299-E33-7 in the northern part of the BY Cribs because the ratios for the same time period are different; ratios for Well 299-E33-38 in the south part of the BY Cribs lie slightly below the ratios for Well 299-E33-7. Ratio data from Wells 299-E33-9 and 299-E33-44 provided the following conclusions. The early mixing curve for Well 299-E33-44, located east of the BY Tank Farm, shows the same change to a horizontal path (1999 to 2001) when contamination concentrations increase, indicating a single source for this area. The ratio for the peak concentrations for the upgradient Well 299-E33-38 is above the ratio for Well 299-E33-44. This suggests that the contamination in groundwater beneath the BY Tank Farm is from a different source than that beneath the BY Cribs. The recent ratio data for groundwater at Well 299-E33-9 appears to converge with the ratio cluster for recent data from Well 299-E33-44, suggesting that the contamination in groundwater at these two wells has a common origin. Well 299-E33-18, located north of the B Tank Farm, is one of a few wells in the area to display a well-developed mixing line when the contamination rose to the double-peak pattern. The ratio from this well moved to lower ratios/higher technetium-99 values along the same trend as the contamination found under the BY Tank Farm. This suggests that the source of the contamination around Well 299-E33-18 may be the same as that found beneath and east of the BY Tank Farm. This correlation implies that contamination is moving into the area from the northwest to the southeast. Currently, not enough data exist from the newly installed wells along the south border of the WMA to include this area in this type of study. Colloidal borescope studies were completed in 2000, which identified a southerly flow direction across WMA B-BX-BY. The direction of the groundwater flow tends to be southeast from the BY Cribs across the north of the BY Tank Farm and south to southeast through the BX and B Tank Farms.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Site Groundwater Monitoring for Fiscal Year 2002, PNNL-14187 (cont'd.)	In situ flow measurements conducted in FY 2000 indicate that the northern portion of the area under the BY Cribs and the BY Tank Farm has a low flow rate that is close to stagnant. Presently, the unconfined aquifer in the north is less than 2 m (6.6 ft) (varies from 1.5 to 3.4 m [4.9 to 11.2 ft]). This may cause the local flow path to vary markedly as the water flows around basalt highs. The combination of low transmissivity and obstacles to flow causes this north section to drain slowly. In addition, this thin aquifer is located on a hummocky basalt surface with structural relief that area returns to pre-Hanford Site conditions. Conversely, in situ flow measurements indicate that the flow in the south is quite high. Based on water elevations in wells where the borescope data indicate a strong, consistent flow, the flow rate was calculated with the Darcy equation at 0.5 m/d for FY 2002. The generally southern flow beneath WMA B-BX-BY and flow to the southwest at the 216-B-63 Trench are direct results of the declining water table, as groundwater flows in a perpendicular direction away from the southeast-northwest buried anticline. Farther from the anticline, the saturated thickness and, thus, the transmissivity, increase sharply and the flow becomes southeasterly. The flow divide between the southeast and northwest pathways, which was present to the southeast of the B Plant area during the Hanford Site operations, is migrating to the northwest in response to the declining water table because less water is being transmitted through Gable Gap. Currently, this flow divide occurs within the B Plant area somewhere between WMA B-BX-BY and LLWMA-1, or perhaps within the southeast half of LLWMA-1. As discussed in PNNL-13404, this is a preliminary conceptual model. At this time, it has been reasonably established that the contamination found in the groundwater at WMA B-BX-BY is from local sources that are superimposed on the regional plumes.
Hanford Site Groundwater Monitoring for Fiscal Year 2004, PNNL-15070	Much of the discussion in this report is based around sampling to assess the rate and extent of groundwater contamination associated with WMA B-BX-BY. Wells also were sampled to provide coverage of surrounding past-practice liquid effluent disposal facilities to distinguish nontank farm sources that may have impacted groundwater quality from tank-related sources. Studies of analytical results from well sampling have identified several distinct plumes with groups of contaminants based on chemical association, spatial and temporal relationships, historic plume movement, knowledge of process chemistry, pattern matching, and characteristic chemical ratios of constituent concentrations. Rising technetium-99, nitrate, nitrite, and uranium under and east of the BY Tank Farm was observed in wells around WMA B-BX-BY and is primarily due to vertical movement of residual waste left in the soil under the tank farms (PNNL-14187). Although the source of the water driver and vadose zone migration pathways are not clearly understood, the water driver appears to be related to long-term, steady-state recharge from natural precipitation and leaks from nearby fresh water lines.

Table A-4. Groundwater Bibliography

Document	Summary
Hanford Site Groundwater Monitoring for Fiscal Year 2004, PNNL-15070 (cont'd.)	Peak groundwater contamination reported in late 2000 to early 2001 was concluded to be driven from the vadose zone to the groundwater by comparing chloride trends across the site. Chloride levels were the highest under the BY Tank Farm in Well 299-E33-9 at six times background values. Other high chloride values (greater than five times background) were reported under the BY Cribs to the north, in Well 299-E33-7 where levels of nitrate, technetium-99, cyanide, and cobalt-60 also were reported at elevated concentrations. Elevated chloride values in late 2000 also were reported for Wells 299-E33-31 and 299-E33-26. These wells are located around the 216-B-57 Trench. It was believed that ponded precipitation or runoff water from the crib cap may have contributed to this water source. Variations in chloride levels provide insight to the sources of water drivers, both natural and manmade, which are important to understanding the complex groundwater chemistry patterns at WMA B-BX-BY. When discussing sources for the high uranium concentrations found under the BY Tank Farm, it is important to recognize that the uranium contamination does not travel alone but is associated with the mobile contaminants from the original processing source. For example, uranium levels under the BY Tank Farm, east, southeast, and north of the farm are correlated with the rising technetium-99 and nitrate contamination. However, the peak values from late 2000 to early 2001 indicate that the uranium movement is retarded with respect to the mobile technetium-99. The co-variation of the technetium-99, although offset in time, shows that the uranium has a common source with the technetium-99. The correlation between the technetium-99 and uranium trends show that the uranium is traveling with the technetium-99 and is most likely from the same contaminated soils as the elevated technetium-99, nitrate, and other corresponding contaminants. When uranium trends are compared for wells south and north of Well 299-E33-9, it can be seen that the center of the uranium plume in the groundwater is located under the BY Tank Farms, as indicated by the high concentration in Wells 299-E33-9 and 299-E33-44. This location is also where the corresponding maximum chloride levels indicate that the recent water driver was centered or close to it. The difference in trend relationships between uranium and technetium-99 may have occurred when the contaminants migrated through the vadose zone in the past, possibly when the waste was released in 1951, while the chloride trends reflect the more recent water driver impacting the groundwater in late 2000 and early 2001. This two-part scenario accounts for past multiple releases of waste both intentional and unplanned in multiple locations, mixing of waste sources in the vadose zone over time, which, when combined with one or more recent fresh water incursions produces the numerous and complex groundwater plumes observed today. Tritium and uranium also were reported in Wells 299-E33-335, 299-E33-337, and 299-E33-339. The tritium was concluded to be from the tritium-rich perched water table located in the vadose zone approximately 4.6 m above the top of the unconfined aquifer under the B and BX Tank Farms. Thus, it was concluded from this information the tritium indicates movement to the south. Contaminant contours were provided in this report for tritium, nitrate, iodine-129, technetium-99, uranium, and strontium-90.

1

Table A-5. Additional Documents Since 2004

Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2004-25	Draft A	June 2004	RL	*Remedial Investigation Report for the 200-PW-2 Uranium-Rich Process Waste Group and 200-PW-4 General Process Condensate Group Operable Units*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=D5174082	Evaluates data generated during the RI and characterization activities for the 200-PW-2 and 200-PW-4 OUs.	D, H	G	P, X, Y	M	YES	--
DOE/RL-2004-60	Rev. 1, Draft A	October 2011	RL	*200-SW-1 Nonradioactive Landfills and Dumps Group Operable Unit and 200-SW-2 Radioactive Landfills and Dumps Group Operable Unit Remedial Investigation/ Feasibility Study Work Plan*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1112150343	The work plan discusses the 200-SW-1 and 200-SW-2 OU-specific background information, defines characterization and assessment activities, defines schedules based on the framework established in the implementation plan, and identifies the steps required to complete the RI/FS and closure plan processes for the OUs.	D, H	G, H	Y	—	YES	--
DOE/RL-2005-40	Draft B	February 2006	RL	*100-B/C Pilot Project Risk Assessment Report*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=DA01944866	The purpose of the 100-B/C pilot project risk assessment was to develop a process to evaluate the protectiveness of CERCLA remedial actions performed for the 100-B/C Area OUs with the intent that lessons learned would be applied to subsequent risk assessments performed within the River Corridor. This risk assessment characterizes the potential risks to human health and the environment under the cleanup standards implemented in remedial actions performed to date. A portion of the 200-BP-5 OU extends to the river.	D, H	E, G, H	Y	—	YES	--
DOE/RL-2005-61	Draft A	March 2006	RL	*Remedial Investigation Report for 200-LW-1 300 Area Chemical Laboratory Waste Group and 200-LW-21 200 Area Chemical Laboratory Waste Group Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=DA02009333	The purpose of this RI report is to evaluate the data generated during the RI and other characterization activities at the 200-LW-1 and 200-LW-2 Chemical Laboratory Waste Group OUs. The RI field investigation was conducted from August 2004 to March 2005 at the three representative sites. The 200-LW-1 OU consists of six waste sites, and the 200-LW-2 OU consists of 14 waste sites, all which have been identified as RCRA past-practice sites.	D, H	G	P, X, Y	M	YES	YES
DOE/RL-2005-62	Draft A	April 2006	RL	*Remedial Investigation Report for the 200-MW-1 Miscellaneous Waste Group Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=DA02472205	The purpose of this RI report was to present and evaluate the data collected during the RI and other characterization activities for the 200-MW-1 Miscellaneous Waste Group OUs. The 200-MW-1 OU consisted of 44 CERCLA past-practice waste sites.	D, H	G	P, X, Y	M	YES	YES
DOE/RL-2005-63	Rev. 0	September 2008	RL	*Feasibility Study for the 200-CS-1 Chemical Sewer Group Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0087005	The FS presented the results of a remedial action evaluation addressing disposition of contaminated soil and other materials from waste sites contained in the 200-CS-1 OU. The FS was prepared in accordance with CERCLA.	H, P	C, E, G	Y	—	YES	YES

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2006-11	Rev. 0	September 2008	RL	*Hanford Facility Dangerous Waste Closure/Postclosure Plan for the 216-B-63 Trench*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0087004	The document presents a RCRA closure plan for the 216-B-63 Trench. The development of the closure plan was coordinated with the 200-CS-1 OU activities. The proposed closure strategy for the 216-B-63 Trench soils, structures, and groundwater was clean closure without the need for further field activities.	H	—	P, S	—	—	--
DOE/RL-2006-51	Rev. 0	September 2007	RL	*Remedial Investigation Report for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=DA05807591	The RI report presented data collected during RI and characterization activities for the vadose zone 200-PW-1/3/6 OUs. The data collected during the RI were used to refine the conceptual site model and evaluate impacts to groundwater.	—	G, T	S, R, Y	—	—	--
DOE/RL-2006-55	Rev. 0	January 2010	RL	*Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/ Feasibility Study*		The SAP supported the drilling of three new groundwater monitoring wells for the 200-BP-5 OU. The SAP is part of the characterization work to support the 200-BP-5 RI/FS.	—	—	—	A	—	--
DOE/RL-2006-57	Rev. 0 Reissue	February 2008	RL	*Sampling and Analysis Plan for Supplemental Remedial Investigation Activities at Model Group 5, Large Area Ponds, Waste Sites Located Within the 200-CW-1 Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1002091586	The SAP addressed supplemental data collection at the waste sites of Model Group 5, Large-Area Ponds. The Model Group 5, Large-Area Ponds at the time constituted the waste sites in the 200-CW-1 OU. The Model Group 5 comprises the thirteen 200 Areas non-tank farm waste sites originally grouped for remedial investigation in five separate process-based OUs, including 200-CS-1, 200-CW-1, 200-CW-2, 200-CW-4, and 200-CW-5.	D, H	—	Y	—	—	--
DOE/RL-2007-02	Rev. 0	November 2007	RL	*Supplemental Remedial Investigation/Feasibility Study Work Plan for the 200 Areas Central Plateau Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=00099914	The supplemental work plan consists of two volumes. Volume I contains the work plan, overarching SAP, and summary field activities to be implemented to augment existing data and information for the Central Plateau. Volume II contains the detailed sampling plans for individual waste sites or groups of waste sites to be investigated under this work plan. This supplemental work plan supports the ongoing remedial decision-making process for the Central Plateau.	—	—	—	—	—	--

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2007-18	Rev. 1	December 2008		*Remedial Investigation/ Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0901220536	The work plan defines the approach, tasks, and schedules associated with the CERCLA RI/FS activities for the 200-BP-5 OU. This document describes the 200-BP-5 OU setting and preliminary CSM, and it provides an initial evaluation of the groundwater OU in the context of the CSM. The work plan also provides rationale for the RI/FS activities summarized in this document and detailed in the associated SAP (Appendix A).	D, H	C, G, H, T	—	—	—	--
DOE/RL-2007-20		March 2007		*Hanford Integrated Groundwater and Vadose Zone Management Plan*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0098519	This document presents an integrated groundwater and vadose zone cleanup and protection strategy for the Hanford Site. The strategy includes consideration of work under the direction of both RL and ORP.	H	—	—	—	—	--
DOE/RL-2007-21	Rev. 0	March 2012		*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*	http://www.washingtonclosure.com/projects/environmental_protection/mission_completion/project_library/#rcbra	Volume I of the RCBRA presents an ecological risk assessment for the River Corridor, considering relevant sources of contamination, exposure pathways, and contaminants to evaluate current and potential future risks posed by hazardous substance releases. Volume I will be used, along with a complementary human health risk assessment (Volume II), to support cleanup decisions for the River Corridor.	H, P	C, E, G, T	Y	M	YES	--
DOE/RL-2007-27	Rev. 0	June 2011		*Feasibility Study for the Plutonium/Organic-Rich Process Condensate/Process Waste Group Operable Unit: Includes 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0093807	The FS addresses 16 CERCLA past-practice liquid waste disposal sites within three OUs (200-PW-1, 200-PW-3, and 200-PW-6), which are located in the 200 West and 200 East Areas of the Hanford Site within the industrial land-use boundary. The purpose of the FS was to develop a comprehensive, defensible, and balanced analysis of remedial alternatives (cleanup actions) that adequately address the risks to human health and the environment from the soil contamination associated with these waste sites.	H	C, G, T	Y	—	YES	YES

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2007-50	Rev. 1	June 2011		*Central Plateau Ecological Risk Assessment Data Package Report*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1108100554	The document provides an overview of the ERA activities conducted to date at the Hanford Site's Central Plateau, including a discussion of the regulatory framework, methods used in the risk assessment activities, data collected to measure risk, and published reports that document these activities and the data generated. The scope and objectives of this data package summary report provide a strengthened, detailed, and transparent presentation of data, methods, and associated uncertainties with those data and methods. The revised report presents the status of the ERA activities in the Central Plateau and describes the transition to the ERA approach that supports the Central Plateau completion strategy.	—	—	—	—	YES	—
DOE/RL-2007-56	Rev. 0	March 2008		*Deep Vadose Zone Treatability Test Plan for the Hanford Central Plateau*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0804160110	The major objective of this treatability test plan is to provide a strategy and a framework to evaluate specific vadose zone remediation technologies and includes a comprehensive set of laboratory, modeling, and field tests specifically related to technetium-99 and uranium.	B	G	—	—	—	YES
DOE/RL-2008-01	Rev. 0	February 2008		*Hanford Site Groundwater Monitoring for Fiscal Year 2007*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=00098824	The report summarizes groundwater monitoring and sampling results for FY 2007.	—	G	Y	—	—	--
DOE/RL-2008-11	Rev. 0	September 2008		*Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0810240394	The document presents a plan for initiating the CERCLA process to investigate Hanford Site releases to the Columbia River. The information gained from performing this investigation will be used to help make final regulatory decisions for cleaning up Hanford Site contamination that exists in and along the Columbia River.	D, H	—	P, S	—	YES	--
DOE/RL-2008-38	Draft A	March 2010		*Remedial Investigation/ Feasibility Study Report for the 200-MW-1 Miscellaneous Waste Sites Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1003220078	The RI/FS report focuses on the seven 200-MW-1 OU waste sites located in the eastern portion of the Hanford Site 200 Area. The scope of the RI Included downhole geophysical logging and soil sampling at the 216-A-2, 216-A-4, and 216-A-2. Cribs and the 200-E-102 Trench. A baseline risk assessment was conducted to evaluate the potential risks associated with exposure to contaminants at the 200-MW-1 OU sites. The remedial action technologies screened in DOE/RL-98-28 were re-evaluated using 200-MW-1 OU site-specific information to develop a final list of retained technologies and process options.	D, H	G, T	S, Y	—	YES	YES

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2008-41	Rev. 0	July 2008		*Sampling and Analysis Plan for the Liquid Effluent Retention Facility (LERF) Replacement RCRA Wells*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0808180154	The SAP defines the data collection requirements for the installation of two wells in support of the LERF and 200 Area ETF.	D, H	G	Y	—	—	—
DOE/RL-2008-60	Rev. 1	October 2012		*Interim Status Groundwater Monitoring Plan for the 216-B-63 Trench*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0091409	This RCRA groundwater monitoring plan presents a revised statistical indicator evaluation program for detection monitoring of the uppermost aquifer beneath the 216-B-63 Trench. The actions completed for revision of this document included geological and hydrologic interpretations, groundwater monitoring results, and a conceptual model for contaminant transport. This information was used to derive the DQOs needed for detection monitoring beneath the 216-B-63 Trench.	—	—	Y	—	—	—
DOE/RL-2008-66	Rev. 0	March 2009		*Hanford Site Groundwater Monitoring for Fiscal Year 2008*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0905131281	The report summarizes groundwater monitoring and sampling results for FY 2008.	—	G	Y	—	—	—
DOE/RL-2009-66	Rev. 1	October 2012		*Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area – T*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0090955	This plan describes the WMA T facility and operating history, waste characteristics, hydrogeology, previous monitoring at the WMA, groundwater and vadose zone contamination associated with the WMA, and the conceptual model for the WMA. This plan also addresses the following: number, locations, and depths of wells in the WMA T groundwater monitoring network; sampling requirements and schedule for monitoring WMA T; analytes, groundwater parameters, and analytical methods for hazardous wastes or hazardous waste constituents in the groundwater related to historical facility operations; procedures for evaluating groundwater quality information; and reporting requirements. This assessment plan is the principal controlling document for conducting groundwater monitoring at WMA T.	D, H	G	Y	—	—	—

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2009-70	Draft A	October 2010		*Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1012090511	The draft plan describes the WMA A-AX facility and operating history, waste characteristics, hydrogeology, previous monitoring at the WMA, groundwater and vadose zone contamination associated with the WMA, and the conceptual model for the WMA. This plan also addresses the following: number, locations, and depths of wells in the WMA A-AX groundwater monitoring network; sampling requirements and schedule for monitoring WMA A-AX; analytes, groundwater parameters, and analytical methods for hazardous wastes or hazardous waste constituents in the groundwater related to historical facility operations; procedures for evaluating groundwater quality information; and reporting requirements.	D, H	G	Y	—	—	—
DOE/RL-2009-75	Rev. 0	December 2009		*Interim Status Groundwater Monitoring Plan for the LLBG WMA-1*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084331	The scope of the plan is to obtain the necessary groundwater data for this RCRA site to for the following objectives: concentrations of specified groundwater quality parameters (annually); concentrations of groundwater contamination indicator parameters (semiannually); and elevation of the water table.	D, H	G	Y	—	—	—
DOE/RL-2009-76	Rev.0	March 2010		*Interim Status Groundwater Monitoring Plan for the LLBG WMA-2*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084331	The scope of the plan is to obtain the necessary groundwater data for this RCRA site to for the following objectives: concentrations of specified groundwater quality parameters (annually); concentrations of groundwater contamination indicator parameters (semiannually); and elevation of the water table.	D, H	G	Y	—	—	—
DOE/RL-2009-77	Rev. 0	June 2010		*Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area C*		This document presents the WMA C groundwater assessment plan to determine whether dangerous constituents (as defined in WAC 173-303-645(417)) are associated with past releases from WMA C. The plan describes the WMA C facility and operating history, waste characteristics, hydrogeology, previous monitoring at the WMA, groundwater and vadose zone contamination associated with the WMA, and the conceptual model. The plan addresses (1) the adequacy of the wells monitoring groundwater for WMA C; (2) the sampling requirements and schedule; (3) the constituents, groundwater parameters, and analytical methods necessary to determine whether past releases from WMA C area.	D, H	G	Y	—	—	—

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DOE/RL-2009-81	Rev. 0	September 2009		*Central Plateau Cleanup Completion Strategy*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1002180676	The strategy lays out the approach DOE intends to use to clean up nearly 75 mi^2 of the Central Plateau near the center of the Hanford Site. In implementing the strategy DOE will make cleanup decisions to achieve the following goals: protect groundwater, workers, the public, and the environment from radiological and chemical contamination shrink the portion of the Central Plateau that will require continued management; be compliant with all applicable and relevant regulations that guide and direct cleanup.	—	—	—	—	—	—
DOE/RL-2009-85	Rev. 1	October 2012		*Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0091415	The RI report summarized the data collected for the 200-PO-1 CERCLA RI, presented the baseline human health and ecological risk assessment, and COPCs to be considered for an FS.	D, H	C, G, T	Y	A, M	YES	—
DOE/RL-2009-121	Rev. 0	December 2010		*Sampling and Analysis Plan for the West Lake Site*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084064	This SAP directs the activities for supplemental characterization of the West Lake site (216-N-8) located approximately 3.54 km (2.2 mi) north of the 200 East Area. The West Lake site was part of the 200 Unplanned Release Waste Group OU.	H	—	S	—	—	—
DOE/RL-2010-11	Rev. 1	August 2010		*Hanford Site Groundwater Monitoring and Performance Report for 2009 Volumes 1 & 2*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084237	The report summarizes groundwater monitoring and sampling results for October 2008 to December 2009.	—	G	Y	—	—	—
DOE/RL-2010-74	Rev. 1	January 2011		*Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0093994	The test plan provided the approach for conducting a groundwater treatability test for the 200-BP-5 OU using pump-and-treat technology. The purpose of this test is to evaluate the groundwater pumping rate that can be achieved near the B Tank Farm complex. The area is located near the source of uranium and technetium-99, which are expected to be the focus of future remediation efforts.	D	—	—	—	—	YES
DOE/RL-2010-89	Rev. 0	October 2010		*Long Range Deep Vadose Zone Program Plan*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084131	The document summarizes the state-of-knowledge about the contaminant cleanup challenges facing the deep vadose zone beneath the Central Plateau and DOE's approach to solving those challenges. For the plan, the deep vadose zone is defined as that portion of the subsurface resting below the practical depth of surface excavation or surface engineered barrier influence and above the water table.	D, H	G	Y	—	—	—

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2010-117	Rev. 0	June 2012		*Columbia River Component Risk Assessment Volume I, Parts 1 & 2: Screening-Level Ecological Risk Assessment*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0092299	This document presents the methodology and results of a screening-level ecological risk assessment of the surface water, sediment, island soils, pore water, and fish of the Columbia River adjacent to and downriver of the Hanford Site. The study was conducted to obtain information about the potential for Hanford Site-related contaminants to affect the fish and wildlife species of the Columbia River. This information will be used, along with the findings from a complementary human health risk assessment, to support cleanup decisions regarding the Hanford Site that will be protective of human health and the environment.	D, H	—	—	A	YES	—
DOE/RL-2010-117	Rev. 0	September 2012		*Columbia River Component Risk Assessment Volume II, Parts 1 & 2: Baseline Human Health Risk Assessment*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0090731	The document presents the methodology and results of a comprehensive human health risk assessment of the surface water, sediment, island soils, and fish of the Columbia River adjacent to and downriver of the Hanford Site. The study was conducted to obtain information about the potential for Hanford Site-related contaminants to affect the health of individuals who use the Columbia River for fishing, recreation, or other purposes. This information will be used, along with the findings from a complementary ecological risk assessment, to support cleanup decisions regarding the Hanford Site that will be protective of human health and the environment.	—	—	—	—	—	—
DOE/RL-2011-01	Rev. 0	August 2011		*Hanford Site Groundwater Monitoring for 2010*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0093693	The report summarizes groundwater monitoring and sampling results for CY 2010.	—	G	Y	—	—	—
DOE/RL-2011-37	Rev. 0	December 2011		*Sampling and Analysis Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0093356	This SAP describes the field sampling activities and quality assurance processes for obtaining data of sufficient quality and quantity to be used in evaluating pore water extraction as a potential remedy for protecting groundwater. Pore water extraction is a vadose zone action that applies a vacuum to overcome the sediment matric potential, resulting in the removal of contaminated pore water.	—	—	—	—	—	—

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DOE/RL-2011-40	Rev. 0	December 2011		*Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0093355	This field test plan specifically defines the parameters for evaluating vacuum-assisted extraction of contaminated sediment pore water as a potential remedy. This field test plan supports DOE/RL-2007-18. The 200-BP-5 OU includes groundwater beneath the B-BX-BY Tank Farm complex, which is the source of much of the contamination associated with the perched water intercepted by the well that is the focus of this test. This field test plan specifically defines the parameters for evaluating perched water pumping/pore water extraction as a potential remedy, with a focus on uranium. The corresponding SAP is DOE/RL-2011-37.	—	—	—	—	—	—
DOE/RL-2011-50	Rev. 0	February 2012		*Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0093361	This document presents the strategy to use vadose zone models to calculate soil concentrations protective of groundwater. It addresses the following three key elements: identify the regulatory basis for use of fate and transport models for development of screening levels and preliminary remediation goals for COPCs; establish a graded approach for use of vadose flow and transport models that provides for progressively increasing rigor appropriate to the potential risk from a waste site; identify the model parameter values for use in the first steps of the graded approach when applied to waste sites on the Central Plateau.	—	—	—	A, M	YES	—
DOE/RL-2011-104	Rev. 0	January 2012		*Characterization Sampling and Analysis Plan for the 200-DV-1 Operable Unit*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=1202020261	The SAP provides the quality assurance project plan and field sampling requirements for characterization of the 200-DV-l (Deep Vadose Zone) OU waste sites. The characterization activities described in this SAP replace the characterization activities included for these waste sites in DOE/RL-2007-02-VOLII-ADD3 and DOE/RL-2007-02-VOL I1-ADD 4.	D, H	G	Y	—	—	—
DOE/RL-2011-118	Rev. 0	August 2012		*Hanford Site Groundwater Monitoring for 2011*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0091795	The report summarizes groundwater monitoring and sampling results for CY 2011.	—	G	Y	—	—	--
DOE/RL-2011-119	Rev. 0	September 2012		*Hanford Site Environmental Report for Calendar Year 2011*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0091455	The report summarizes environmental sampling at the Hanford Site for CY 2011.	—	C, G	Y	—	—	--

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DOE/RL-2012-35	Rev. 0	September 2012		*First Determination RCRA Groundwater Quality Assurance Plan for Low Level Burial Grounds Low-Level Waste Management Area-1*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0091456	The plan provides the wells to be sampled, analyses of constituents, and additional considerations for determining whether LLWMA-1 RCRA site has impacted groundwater. Additional considerations include past and present groundwater flow directions, upgradient liquid waste disposal history, and existing groundwater analytical results. Existing data will provide the framework for the sequence of actions to be completed to determine whether the LLWMA-1 has affected groundwater.	—	G	Y	—	—	--
DOE/RL-2012-53	Rev. 0	October 2012		*Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area B-BX-BY*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0091056	This plan describes the facility, its operating history, waste characteristics, hydrogeology, previous monitoring at the WMA, groundwater and vadose zone contamination associated with the WMA, and the conceptual model. It also addresses (1) the adequacy of the wells monitoring groundwater for WMA B-BX-BY; (2) sampling requirements and schedule; (3) constituents, groundwater parameters, and analytical methods; (4) procedures for evaluating groundwater quality data; and (5) reporting requirements. This plan supersedes PNNL-13022, Rev. 1, and updates the groundwater monitoring project management organization. This plan has identified the presence of cyanide at Well 299-E33-47 as a "dangerous waste or dangerous waste constituent" under 40 CFR 265, Subpart F, as well as dangerous constituent as defined in WAC 173-303-645(4) associated with the B Tank Farm. This plan also redefines the monitoring network as a result of changing flow conditions. Because the site had not been assessed for dangerous constituents listed in Ecology Publication 97-407 (which reproduces a previous version of 40 CFR 264, Appendix IX), the sampling criteria were expanded.	D, H	G	Y	—	—	--
DOE/RL-2013-18	Rev. 0	September 2013		*Hanford Site Environmental Report for Calendar Year 2012*	http://msa.hanford.gov/files.cfm/2012_DOE-RL-2013-18_REV_0_cleared.pdf	The report summarizes environmental sampling at the Hanford Site for CY 2011.	—	C, G	Y	—	—	--
DOE/RL-2013-22	Rev. 0	August 2013		*Hanford Site Groundwater Monitoring Report for 2012*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0087974	The report summarizes groundwater monitoring and sampling results for CY 2011.	—	G	Y	—	—	--

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Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
DOE/RL-2013-24	Draft A	April 2013		*216-B-3 Main Pond Closure Plan*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0088979	The document provides a RCRA closure plan for the 216-B-3 Pond. The proposed strategy for the 216-B-3 Main Pond and Ditch is clean closure.	D, H	G	—	—	—	--
PNNL-11800	Addendum 1	September 2001		*Addendum to Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* (Not previously cited)	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084085	The report summarizes the efforts to complete an addendum analysis to the first iteration of the composite analysis for low-level waste disposal in the 200 Area Plateau of the Hanford Site. The document describes the background and performance objectives of the composite analysis and this addendum analysis. The methods used, results, and conclusions for this addendum analysis are summarized, and recommendations are made for work to be undertaken in anticipation of a second analysis.	H	G	Y	A	—	--
PNNL-14049	—	September 2002		*Data Quality Objectives Summary Report – Designing a Groundwater Monitoring Network for the 200-BP-5 and 200-PO-1 Operable Units* (Not previously cited)	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084092	This document presents the results of a series of interviews held with technical, management, and regulatory staff to determine the groundwater DQOs for monitoring activities associated with the 200-BP-5 and 200-PO-1 OUs in the 200 East Area. This assessment was needed to address changing contaminant plume conditions (e.g., plume migration) and to ensure that monitoring activities meet the requirements for CERCLA, RCRA past-practice, and AEA regulatory requirements and orders.	H	—	Y	—	—	--
PNNL-15479	—	November 2005		*Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond RCRA Facility*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=DA01649608	The document provides a sampling plan for the 216-B-3 Pond. Under this plan, the following wells will be monitored for B Pond: 699-42-42B, 699-43-44, 699-43-45, and 699-44-39B. The wells will be sampled semiannually for the contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and annually for water quality parameters (chloride, iron, manganese, phenols, sodium, and sulfate). The current SAP is DOE/RL-2008-59.	D, H	G	Y	—	—	--
PNNL-15670	—	March 2006		*Hanford Site Groundwater Monitoring for Fiscal Year 2005*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084078	The report summarizes groundwater monitoring and sampling results for FY 2005.	—	G	Y	—	—	--
PNNL-15837	—	January 2007		*Data Package for Past and Current Groundwater Flow and Contamination Beneath Single-Shell Tank Waste Management Areas*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0911240061	Water-level information discussed in this document includes historic and current water table elevations; hydraulic properties including hydraulic conductivity, effective porosity, specific yield, and transmissivity; historic and current groundwater flow directions and flow rates as determined by measured hydraulic properties; and the concentrations and distributions of contaminants in the unconfined aquifer.	—	G	P, R, Y	—	—	--

Table A-5. Additional Documents Since 2004

Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-15892	—	September 2006		*Hanford Site Environmental Report for Calendar Year 2005*	http://msa.hanford.gov/files.cfm/2005_pnnl_15892.pdf	The report summarizes environmental sampling at the Hanford Site for CY 2005.	—	C, G	Y	—	—	--
PNNL-15917	—	September 2006		*Screening of Potential Remediation Methods for the 200-BP-5 Operable Unit at the Hanford Site*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15917.pdf	A screening-level evaluation of potential remediation methods for application to the COCs in the 200-BP-5 OU was conducted based on the methods outlined in EPA/540/G-89/004. The scope of this screening was to identify the most promising remediation methods for use in the more detailed analysis of remediation alternatives that will be conducted as part of the full FS. The screening evaluation was conducted for the primary COC (potential major risk drivers) identified in the groundwater SAP for the OU (DOE/RL-2001-49, Rev. 1), with additions. The COCs with similar properties were grouped for the screening evaluation.	—	—	Y	A	—	YES
PNNL-15955	—	January 2007		*Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0911240120	This data package discusses the geology of the single-shell tank farms, relating the site-specific geology to the region's geologic history. The purpose of this report is to provide the most recent geologic information available for the single-shell tank farms and the Integrated Disposal Facility.	B	G	—	—	—	--
PNNL-16346	—	March 2007		*Hanford Site Groundwater Monitoring for Fiscal Year 2006*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084077	The report summarizes groundwater monitoring and sampling results for FY 2006.	—	G	Y	—	—	--
PNNL-16559	—	April 2007		*Downhole Measurements of Shear- and Compressional-Wave Velocities in Boreholes C4933, C4996, C4997 and C4998 at the Waste Treatment Plant DOE Hanford Site*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16559.pdf	This report describes the procedures and the results of a series of downhole measurements of shear- and compression-wave velocities performed as part of the seismic boreholes project at the site of the Waste Treatment Plant. The measurements were made in several stages from October 2006 through early February 2007.	—	G	—	A	—	--
PNNL-16623	—	September 2007		*Hanford Site Environmental Report for Calendar Year 2006*	http://msa.hanford.gov/files.cfm/2006_pnnl_16623.pdf	The report summarizes environmental sampling at the Hanford Site for CY 2005.	—	C, G	Y	—	—	--
PNNL-16652	—	June 2007		*Site-Specific Velocity and Density Model for the Waste Treatment Plant, Hanford, Washington*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16652.pdf	This report updated seismic analysis for the Hanford Waste Treatment Plant area. The updated seismic response analysis used existing and newly acquired seismic velocity data, statistical analysis, expert elicitation, and ground motion simulation to develop interim design ground motion response spectra that enveloped the remaining uncertainties.	—	G	—	—	—	--

Table A-5. Additional Documents Since 2004

Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-16688	—	September 2007		*Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0911240242	The objective of this data package was to use published data to provide recharge estimates for the scenarios being considered in the RCRA facility investigation for the single-shell tank WMAs. Recharge rates were estimated for areas that remain natural and undisturbed, areas where the vegetation has been disturbed, areas where both the vegetation and the soil have been disturbed, and areas that are engineered (e.g., surface barrier).	B	C, G, T	—	—	—	--
PNNL-17348	—	February 2008		*Results of Detailed Hydrologic Characterization Tests – Fiscal and Calendar Year 2005*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17348.pdf	This report provides the results of detailed hydrologic characterization tests conducted within selected Hanford Site wells during FY and CY 2005. Detailed characterization tests performed included groundwater flow characterization, barometric response evaluation, slug tests, in-well vertical groundwater flow assessments, and a single-well tracer and constant-rate pumping test. Hydraulic property estimates obtained from the detailed hydrologic tests include hydraulic conductivity, transmissivity, specific yield, effective porosity, in-well lateral and vertical groundwater flow velocity, aquifer groundwater-flow velocity, and depth-distribution profiles of hydraulic conductivity.	—	G	—	A	—	--
PNNL-17603	—	September 2008		*Hanford Site Environmental Report for Calendar Year 2007*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0810070871	The report summarizes environmental sampling at the Hanford Site for CY 2007.	—	C, G	Y	—	—	--
PNNL-17675	—	July 2008		*BP-5 Remedial Investigation Slug-Test Characterization Results for Well 699-52-55A*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17675.pdf	Slug-test characterization was conducted at the completed 200-BP-5 OU RI Well 699-52-55A near the 200 East Area on April 22, 2008. The slug test characterization was in support of the 200-BP-5 OU RI. The portion of the unconfined aquifer tested is composed of sediments of the lower Ringold Formation and the underlying Elephant Mountain Basalt flowtop. The basalt flowtop unit was included as part of the effective test-interval length for the slug-test analysis because the flowtop unit is hydraulically communicative with the unconfined aquifer. Estimates of hydraulic conductivity for the effective test interval length represent composite values for the lower Ringold Formation and the underlying Elephant Mountain Basalt flow top.	—	—	—	A	—	--
PNNL-18427	—	September 2009		*Hanford Site Environmental Report for Calendar Year 2008*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0095787	The report summarizes environmental sampling at the Hanford Site for CY 2008.	—	C, G	Y	—	—	--

Table A-5. Additional Documents Since 2004

Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-18564	—	July 2009		*Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18564.pdf	The report describes an effort to improve the consistency, defensibility, and traceability of parameters and their ranges of variability, and to ensure a sound basis for assigning parameters for flow and transport models. The strategy was to identify the existing parameter data sets most recently used in site assessments, documenting those parameter data sets and the raw data sets on which they were based, and use the existing parameter sets to define best-estimate parameters for use in the RESRAD code. The RESRAD code is a computer model designed to estimate radiation doses and risks from residual radioactive materials. The Hanford Site-specific assessment parameters compiled for use in RESRAD are traceable back to the professional judgment of the authors of published documents. This document provides a summary of those efforts, culminating in a set of best-estimate Hanford specific parameters for use in place of the default parameters used in the RESRAD code.	B	G	—	—	—	--
PNNL-19129	—	February 2010		*Discrete Sampling Test Plan for the 200-BP-5 Operable Unit*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19129.pdf	The document describes depth discrete sampling of 14 groundwater monitoring wells in the 200-BP-5 OU, using the Spyder sampler developed by PNNL.	—	—	—	—	—	--

Table A-5. Additional Documents Since 2004

Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-19277	—	July 2010		*Conceptual Models for Migration of Key Groundwater Risk Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084238	This report offers detailed conceptual models for the distribution of two key groundwater contaminants, technetium-99 and uranium, and in less detail addresses cyanide, nitrate, and chromium within the B Complex region. The current distribution of technetium-99, uranium, and cyanide in the vadose zone are evaluated. The conceptual models identify the most likely sources (disposal facilities or single-shell tanks) and hypothesize the migration pathways that the contaminants took to reach the water table at evaluated locations. In addition, the report provides estimates for the activity of technetium-99 and mass of uranium that still remain in the vadose zone (from ground surface to the water table; with the deep vadose zone portion highlighted) and within the current groundwater plumes. The mass of cyanide in groundwater was also estimated, but the cyanide remaining in the vadose zone could not be quantitatively evaluated because the vadose zone data are too sparse. The estimated masses of contaminants remaining in the vadose zone and currently present in the groundwater plumes originating below the B Complex are compared to the estimates of the total masses disposed or released to the subsurface since the beginning of waste disposal activities.	D, H	G	Y	A	—	--
PNNL-19455	—	September 2010		*Hanford Site Environmental Report for Calendar Year 2009*	http://pdw.hanford.gov/arpir/pdf.cfm?accession=0084213	The report summarizes environmental sampling at the Hanford Site for CY 2009.	—	C, G	Y	—	—	--
PNNL-19702	—	September 2010		*Hydrogeologic Model for the Gable Gap Area*	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19702.pdf	An updated hydrogeologic conceptual model of the Gable Gap area is presented in this report. The model was based on analysis of the old and new geologic, hydrologic, and groundwater chemistry data needed to understand groundwater and contaminant movement through Gable Gap.	—	G	—	A	—	--
PNNL-20548	—	September 2011		*Hanford Site Environmental Report for Calendar Year 2010*	http://msa.hanford.gov/files.cfm/2010_PNNL-20548_Env-Report.pdf	The report summarizes environmental sampling at the Hanford Site for CY 2010.	—	C, G	Y	—	—	--

Table A-5. Additional Documents Since 2004

Document #	REV./ Draft/ Vol.	Date	Authors/ Originator	Title	Link	Summary	Background Site	Physical Setting	Contaminant Description	Analysis and Modeling	Risk Assessment	Alternatives Development
PNNL-22499	—	June 2013		*Perched-Water Evaluation for the Deep Vadose Zone Beneath the B, BX, and BY Tank Farms Area of the Hanford Site*	http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22499.pdf	The study described in this report was conducted to examine the perched-water conditions and quantitatively evaluate (1) factors that control perching behavior, (2) contaminant flux toward groundwater, and (3) associated groundwater impact. Perched water conditions have been observed in the vadose zone above a fine-grained zone that is located a few meters above the water table within the B-BX--BY Tank Farms area. The perched water contains elevated concentrations of uranium and technetium-99.	—	—	Y	—	—	--
PNNL-22520	—	May 2013		*Re-inversion of Surface Electrical Resistivity Tomography Data the Hanford Site B-Complex*	http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22520.pdf	This report documents the three-dimensional inversion results of surface electrical resistivity tomography data collected over the Hanford Site B Complex. The data were collected to image the subsurface distribution of electrically conductive vadose zone contamination resulting from both planned releases of contamination into subsurface infiltration galleries (cribs, trenches, and tile fields) and unplanned releases from the B-BX-BY Tank Farms and/or associated facilities. Electrically conductive contaminants are those that increase the ionic strength of pore fluids relative to native conditions. Most types of solutes released into the subsurface B Complex were electrically conductive.	—	—	—	A	—	--

Appendix B

Analytical Data

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Terms

bgs	below ground surface
DQA	data quality assessment
FS	feasibility study
HEIS	Hanford Environmental Information System
OU	operable unit
RI	remedial investigation
WMA	waste management area

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B1 Introduction

Appendix B provides detailed information about the sediment and groundwater samples collected during the drilling of 15 wells during the 200-BP-5 Operable Unit (OU) remedial investigation (RI), and it includes groundwater analytical data collected to support risk assessment and modeling evaluations. Table B-1 provides a summary of the well number and table number where sample information for each of those wells may be found. Tables B-2 through B-16 provide sample information from individual wells drilled for the RI. The detailed analytical data for each well is contained in the Microsoft Excel® tables on the compact disk that accompanies this appendix, one each for groundwater (Table B-17) and soil (Table B-18) samples. Table B-19 provides summary information relative to the laboratories performing the analysis of these samples as defined by the "LAB_CODE" field found in the analytical data tables.

Table B-1. Wells Installed during the 200-BP-5 OU RI

Well Number	Table Number	Groundwater Data Range
299-E24-25	B-2	12/2/2009 to 10/10/2013
299-E27-155	B-3	10/15/2007 to 9/18/2013
299-E28-30	B-4	2/9/2010 to 10/10/2013
299-E29-54	B-5	1/4/2010 to 10/22/2013
299-E33-50	B-6	3/2/2007 to 11/16/2012
299-E33-205	B-7	7/16/2008 to 6/6/2012
299-E33-340	B-8	1/12/2008 to 4/15/2013
299-E33-341	B-9	5/28/2008 to 8/16/2012
299-E33-342	B-10	4/10/2008 to 8/13/2012
299-E33-343	B-11	2/22/2008 to 1/31/2012
299-E33-344/299-E33-345	B-12	2/20/2008 to 10/22/2013
699-48-50B	B-13	12/4/2006 to 5/1/2013
699-50-56	B-14	11/28/2006 to 4/3/2013
699-52-55	B-15	12/10/2007 to 4/3/2013
699-52-55B	B-16	7/16/2008 to 12/6/2012

® Microsoft Excel is a registered trademark of Microsoft Corporation, Redmond, Washington.

B2 Summary of the Data Compiled

B2.1 Groundwater Analytical Data

Electronic groundwater data presented in Table B-17 were generated from available data from January 2008 to January 2014. The data were compiled from information available in the Hanford Environmental Information System (HEIS) database.

B2.2 Soil Analytical Data

Electronically available soils data presented in Table B-18 represents soil samples that were collected during drilling of the wells identified in Tables B-2 through B-16. The data were compiled from information available in the HEIS database. Soil analytical data for quality control samples (e.g., equipment blanks and field trip blanks) and soil physical property data are not included in this appendix. Further information regarding these samples can be found in the borehole summary reports that were generated for each well/borehole, which are identified in Tables B-2 through B-16.

B2.3 Data Verification and Validation

Data collected for the RI/feasibility study (FS) were verified and validated. Verification is the process of evaluating the completeness, correctness, and conformance/compliance of the data against the method, procedural, or contractual requirements for the laboratory.

The purpose of data validation is to determine, through the evaluation of supporting documentation, whether data meet precision and accuracy requirements of an analytical method and the data quality goals established during the planning phase have been achieved. The results of project data validation are summarized in the data quality assessment (DQA).

B2.4 Data Quality Assessment

The data quality assessment for the groundwater data collected from the wells installed during the RI is presented in SGW-44071, *Data Quality Assessment Report for the 200-BP-5 Groundwater Operable Unit*, for the period from November 2004 through May 2010. Groundwater data assessment for data in Table B-17 (data collected from January 1, 2008, through December 2013) is described in SGW-56758, *Supplement to the 200-BP-5 Groundwater Operable Unit Data Quality Assessment (2008 through 2013)*.

The DQA for a portion of the soil data collected for the wells installed during the RI is presented in SGW-46352, *Data Quality Assessment Report for Vadose Zone Samples Collected During Drilling of Wells 299-E24-25, 299-E28-30, 299-E29-54, 299-E33-205, 299-E33-342, 299-E33-343, and 299-E33-344 in the 200 East Area*. The DQA for the vadose zone soil samples collected during drilling of the remaining wells identified in Tables B-2 through B-16 is expected to be completed as part of the RI/FS process for the remaining 200 Area source OUs.

Table B-2. Sediment and Groundwater Samples for Well 299-E24-25

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E24-25 is located near the 216-C-1 Hot Semiworks Plant to investigate possible vadose zone contamination and provide additional groundwater monitoring of waste constituents (particularly chromium, uranium, plutonium, and strontium) associated with past discharges in the area. The location also allows evaluation of elevated nitrate groundwater concentrations observed in the 1960s from Wells 299-E27-5 and 299-E24-8 (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			A total of 145 grab samples were collected from ground surface to 110.6 m (363.0 ft) bgs (top of basalt), A total of 115 samples were collected in the unsaturated zone, and 30 samples were collected in the saturated zone. A total of 41 split-spoon samples were collected from pre-determined intervals beginning at 3.0 m (9.9 ft) bgs down to 109.7 m (360.0 ft) bgs (top of basalt). A total of 37 split-spoon samples (and one duplicate sample) were collected from the unsaturated zone, and four split spoons (and one duplicate sample) were collected from the saturated zone. Three groundwater samples (and one duplicate sample) were collected at intervals 95 m (312 ft), 103 m (339 ft), and 108.4 m (355.7 ft). Because the basalt was reached earlier than expected, a fourth groundwater sample was not collected. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E24-25 are presented in Appendix A of SGW-46869.
299-E24-25	Split spoon	Split-spoon samples collected every 3 m (10 ft) with continuous sampling over intervals (bgs): 73 to 79 m (240 to 260 ft) bgs, 85 to 91 m (280 to 300 ft). Additional split-spoon samples were planned to be collected based on detection of contaminants.	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over intervals (bgs): Ground surface to 93 m (305 ft). Samples collected every 3 m (10 ft) were analyzed. Additional analyses were planned to be completed based on initial results and additional intervals were analyzed as needed.	
Saturated Zone Sediment Samples			
299-E24-25	Split spoon	Four split-spoon samples were planned to be collected at the following intervals (bgs): 93 to 93.7 m (305 to 307.5 ft), 99 to 99.8 m (325 to 327.5 ft), 108 to 109.0 m (355 to 357.5 ft), and 114 to 115.1 m (375 to 377.5 ft) (assumed top of water table at 93 m (305 ft) bgs; adjusted intervals accordingly).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 93 to 116 m 305 to 380 ft).	
Groundwater Samples			
299-E24-25	Pump or KABIS	Water samples collected at split-spoon intervals (bgs): 93.7 m (307.5 ft), 99.8 m (327.5 ft), 109.0 m (357.5 ft), and 115.8 m (380 ft) (assumed depth of water table was 93 m [305 ft] bgs and the top of basalt at 116 m [380 ft] bgs; adjusted intervals accordingly).	

Table B-2. Sediment and Groundwater Samples for Well 299-E24-25

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval

Notes: Depth to groundwater is 89.6 m (294.0 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-46869, *Borehole Summary Report for the Three (3) 200-BP-5 Wells, "K," "L," and "M," Fiscal Year 2010*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-3. Sediment and Groundwater Samples for Well 299-E27-155

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E27-155 is proposed in the vicinity of the WMA C Tank Farm. This well will be used to evaluate the vertical and horizontal distribution of technetium-99 and nitrate downgradient of WMA C (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			A total of 35 grab samples were collected every 0.8 m (2.5 ft) beginning at 82 to 102.3 m (270 to 335.5 ft) bgs (top of basalt), 13 samples were collected in the unsaturated zone and 22 samples were collected in the saturated zone. A total of 14 split-spoon samples were collected from pre-determined depths beginning at 83 m (271 ft) bgs to the top Elephant Mountain Basalt at 102 m (336 ft) bgs. Three split-spoon samples were collected in the unsaturated zone, and 11 samples were collected in the saturated zone. Four groundwater samples were collected in the unconfined aquifer at four discrete depths: 89 m (292 ft) bgs, 93.7 m (307.5 ft) bgs, 99.8 m (327.5 ft) bgs, and 102 m (336 ft) bgs (top of basalt). Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E27-155 are presented in Appendix A of SGW-37834.
299-E27-155	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 76 to 85 m (250 to 280 ft). Samples from 83.1 to 85 m (272.5 to 280 ft) bgs were analyzed.	
Saturated Zone Sediment Samples			
299-E27-155	Split spoon	Four split-spoons collected over intervals (bgs): 86.7 to 87.5 m (284.5 to 287 ft), 92 to 92.8 m (302 to 304.5 ft), 98 to 98.9 m (322 to 324.5 ft), and 102 to 102.9 m (335 to 337.5 ft) (estimated water table contact at 86 m [281 ft] bgs).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 f)t over the interval (bgs): 86.1 to 103.6 m (282.5 to 340 ft).	
Groundwater Samples			
299-E27-155	Pump or KABIS	Samples collected at split-spoon intervals (bgs): 87 m (287 ft), 92.8 m (304.5 ft), 98.9 m (324.5 ft), and 102.9 m (337.5 ft) (estimated water table contact at 86 m [281 ft] bgs).	

Notes: Depth to groundwater is 86 m (281 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit.*

SGW-37834, *Borehole Summary Report for the Installation of Two Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY2007.*

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

WMA = waste management area

1

Table B-4. Sediment and Groundwater Samples for Well 299-E28-30

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E28-30 is a replacement for Well 299-E28-16 at the 216-B-12 Crib. Only one groundwater well is located near this waste site. This well could potentially be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing uranium plume (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			A total of 117 grab samples were collected from 24.2 m (79.5 ft) bgs to 112.8 m (370.0) ft bgs (top of basalt), 91 samples were collected in the unsaturated zone, and 26 samples were collected in the saturated zone. A total of 51 split-spoon samples were collected from pre-determined intervals beginning at 23.5 m (77.0 ft) bgs down to 108.8 m (357.1 ft) bgs. A total of 47 split-spoon samples were collected from the unsaturated zone, and 4 split-spoons (and one duplicate sample) were collected from the saturated zone. Four groundwater samples (and one duplicate sample) were collected at intervals 97 m (317 ft), 101 m (331 ft), 108.8 m (357.1 ft), and 114.5 m (375.6 ft). Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E28-30 are presented in Appendix B of SGW-46869.
299-E28-30	Split spoon	Split-spoon samples collected every 0.8 m (2.5 ft) over intervals (bgs): 77.5 to 125, 142 to 162, 180 to 190, 242.5 to 247.5, and 280 to 305. Additional split-spoon samples were collected based on detection of contaminants.	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 24 to 93 m (80 to 305 ft). Samples collected every 3 m (10 ft) were analyzed. Additional analysis was completed based on initial results and additional intervals were analyzed as needed.	
Saturated Zone Sediment Samples			
299-E28-30	Split spoon	Four split-spoon samples were collected over the following intervals (bgs): 94 to 95.3 m (310 to 312.5 ft), 99 to 99.8 m (325 to 327.5 ft), 107 to 107.7 m (351 to 353.5 ft), and 115.1 to 116 m (377.5 to 380 ft) (estimated water table contact at 93 m [305 ft] bgs).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (ft bgs): 93 to 116 m (305 to 380 ft). Samples from intervals 94 m (310 ft), 99 m (325 ft), 107 m (351 ft), and 118.1 m (387.5 ft) were analyzed.	
Groundwater Samples			
299-E28-30	Pump or KABIS	Water samples collected at split-spoon intervals (ft bgs): 95.3 m (312.5 ft), 99.8 m (327.5 ft), 107.7 m (353.5 ft), and 116 m (380 ft) (assumed depth of water table was 93 m (305 ft) bgs and the top of basalt at 116 m (380 ft) bgs; adjusted intervals accordingly).	

Notes: Depth to groundwater 92.6 m (303.7 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-46869, *Borehole Summary Report for the Three (3) 200-BP-5 Wells, "K," "L," and "M," Fiscal Year 2010*.

Table B-4. Sediment and Groundwater Samples for Well 299-E28-30

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-5. Sediment and Groundwater Samples for Well 299-E29-54

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E29-54 is located near the 216-B-6 reverse well, south of the B Plant, to determine the extent of contamination in the deep vadose zone and groundwater near this reverse well (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			A total of 124 grab samples were collected from 19.7 m (64.5 ft) bgs to 114.3 m (375.0 ft) bgs (top of basalt), 95 samples were collected in the unsaturated zone and 29 samples were collected in the saturated zone. A total of 36 split-spoon samples were collected from pre-determined intervals beginning at 9.1 m (30.0 ft) bgs down to 105.4 m (345.8 ft) bgs. A total of 33 split-spoon samples (and one duplicate sample) were collected from the unsaturated zone, and 3 split-spoons (and one duplicate sample) were collected from the saturated zone. Four groundwater samples (and one duplicate sample) were collected at intervals 95 m (312 ft), 99.5 m (326.4 ft), 105.5 m (346.1 ft) and 112.4 m (368.8 ft). Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E28-30 are presented in Appendix C of SGW-46869.
299-E29-54	Split spoon	Split-spoon samples were planned to be collected every 3 m (10 ft) from 49 m (160 ft) bgs to 91 m (300 ft) bgs, and continuously every 0.8 m (2.5 ft) over intervals (bgs): 59 to 69 m (195 to 225 ft) and 90 to 92.2 m (295 to 302.5). Additional split-spoon samples were collected at 9 m (30 ft) intervals between 9 and 49 m (30 and 160 ft) bgs.	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 20 to 92.2 m (65 to 302.5 ft). One sample was planned to be analyzed for every 3 m (10 ft) interval collected. Additional analysis was planned to be completed based on initial results and additional intervals were analyzed as needed.	
Saturated Zone Sediment Samples			
299-E29-54	Split spoon	Four split-spoon samples were planned to be collected at the following intervals (bgs): 93 to 93.7 m (305 to 307.5 ft), 96 to 96.8 m (315 to 317.5 ft), 104 to 104.7 m (341 to 343.5 ft), and 115.1 to 116 m (377.5 to 380.	
	Grab, quart jar	Grab samples collected over the interval (bgs): 93 to 116 m (305 to 380 ft).	
Groundwater Samples			
299-E29-54	Pump or KABIS	One sample was collected at each of the following intervals (bgs): 93.7 m (307.5 ft), 96.8 m (317.5 ft), 104.7 m (343.5 ft), and 116 m (380 ft).	

Table B-5. Sediment and Groundwater Samples for Well 299-E29-54

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval

Notes: Depth to groundwater 94.0 m (308.4 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-46869, *Borehole Summary Report for the Three (3) 200-BP-5 Wells, "K," "L," and "M," Fiscal Year 2010*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-6. Sediment and Groundwater Samples for Well 299-E33-50

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E33-50 is located south of Well 299-E33-12 to allow monitoring of the Rattlesnake Ridge confined aquifer to evaluate possible source of contaminants continuously observed in Well 299-E33-12 groundwater laboratory analyses (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			Grab samples were collected every 0.8 m (2.5 ft) beginning at 18 to 84 m (60 ft to 277 ft) bgs. A total of three split-spoon samples were collected from within the Rattlesnake Ridge interbed. Split-spoon samples were collected at three intervals; 0.5 to 1 m (1.5 to 4 ft), 7.5 to 8 m (24.5 to 27 ft), and 15 to 15.9 m (50 to 52.2 ft) below the upper Elephant Mountain Member Basalt and Rattlesnake Ridge interbed contact. One groundwater sample was collected in the unconfined aquifer and three in the confined aquifer. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-50 are presented in Appendix A of SGW-34034.
299-E33-50	Split spoon	Split-spoon samples collected from intervals (bgs) 18 to 26 m (60 to 85 ft), 32 to 37 m (105 to 120 ft), 49 to 52 m (160 to 170 ft), 56 to 59 m (185 to 195 ft), and 66.3 to 69.3 m (217.5 to 227.5 ft).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval 18 to 69.3 m (60 to 227.5 ft) bgs.	
Saturated Zone Sediment Samples			
299-E33-50	Split spoon	Split-spoon samples collected from intervals 0.8 to 2 m (2.5 to 5 ft), 8 to 8.4 m (25 to 27.5 ft), and 14.5 to 15 m (47.5 to 50 ft) bgs.	
Groundwater Samples			
299-E33-50	Pump or KABIS	Initial sample collected 0.6 m (2 ft) below basalt/interbed contact, second sample 6 m (20 ft) below first sample, third sample collected at bottom interbed/basalt contact.	

Table B-6. Sediment and Groundwater Samples for Well 299-E33-50

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval

Notes: Depth to groundwater is 69 m (225 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-34034, *Borehole Summary Report for the Installation of Three Groundwater Wells in the 200-BP-5 Operable Unit, FY 2007*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-7. Sediment and Groundwater Samples for Well 299-E33-205

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E33-205 is positioned north of the BX Tank Farm and south of the BY Tank Farm to provide vertical nature and extent of contamination from the assumed cascade line leak between Tanks 241-BX-103 and 241-BY-101, and possibly identify lateral extent of contamination from possible spills/leaks associated with Tanks 241-BX-106, 241-BX-102, and 241-BY-107. Additional data objectives at this location included identifying depth and character of low-permeability strata in vadose zone and confirming the top of the basalt in the area. (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			
299-E33-205	Split spoon	Split-spoon samples collected every 0.8 m (2.5 ft) over intervals (bgs): 20 to 26 m (65 to 85 ft), 30 to 44 m (100 to 145 ft), 47 to 43 m (155 to 175 ft), and 62 to 77.0 m (205 to 252.5 ft).	
	Split spoon	Split-spoon samples collected from intervals (bgs): 49 to 49.5 m (160 to 162.5 ft), 66.3 to 67 m (217.5 to 220 ft), and 70 to 70.9 m (230 to 232.5 ft).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 18 to 77.0 m (60 to 252.5 ft). Samples collected every 3 m (10 ft) were analyzed. Additional analysis was planned to be completed based on initial results, and additional intervals were analyzed as needed.	
Saturated Zone Sediment Samples			

Table B-7. Sediment and Groundwater Samples for Well 299-E33-205

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
299-E33-205	Split-spoon	Two split-spoon samples were collected over intervals (bgs): 78 to 78.5 m (255 to 257.5 ft) and 80.0 to 80.8 m (262.5 to 265 ft) (estimated water table contact at 254 ft bgs).	Grab samples were collected every 0.8 m (2.5 ft) from the entire length of the borehole. Split-spoon samples were collected from intervals 20 to 26 m (65 to 85 ft), 30 to 44 m (100 to 145 ft), 47 to 53 m (155 to 175 ft), and 62 to 81 m (205 to 265 ft). Two groundwater samples were collected in the unconfined aquifer at discrete depths: 80.7 m (264.9 ft) bgs and 81.4 m (267.2 ft) bgs (top of basalt). The first sample was collected with the temporary casing at a depth of 80.7 m (264.9 ft) using the KABIS sampler. The second sample was collected at the basalt contact with a submersible pump. Exact depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-205 are presented in Appendix A of SGW-39496.
	Grab quart jar	Grab samples collected every 2.5 ft over the interval (bgs): 255 to 265 (assuming water table contact at 77 m [254 ft] bgs).	
Groundwater Samples			
299-E33-205	Pump or KABIS	Two sample intervals were targeted for collection of groundwater. The intervals were planned from the split-spoon intervals 78.5 m (257.5 ft) and the top of basalt.	

Notes: Depth to groundwater is 79 m (260 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-39496, *Borehole Summary Report for the Installation of One Groundwater Monitoring Well at the 200-BP-5 Operable Unit*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

Table B-8. Sediment and Groundwater Samples for Well 299-E33-340

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
For Well 299-E33-340, if analytical data from Well C5195 demonstrate no contamination, then Well 299-E33-12 will be decommissioned, and Well C5853 would be located downgradient of Well 299-E33-12 to confirm proper decommissioning. If Well C5195 shows that the Rattlesnake Ridge interbed confined aquifer is contaminated, analysis may show there is an upgradient pathway for contaminated groundwater between the unconfined aquifer and the confined aquifer. The location of Well C5853 would likely be changed if contamination were found at Well C5195 (DOE/RL-2007-18, Table 5-2).			
Vadose-Zone Sediment Samples			Grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 64 to 67.8 m (209 to 222.5 ft) bgs and 92 to 108.7 m (302 to 356.5 ft) bgs except in intervals where no recovery was achieved. Two split-spoon samples were collected at 92 m (302 ft) and 106 m (348 ft) bgs. Three groundwater samples were collected using a submersible pump at 93 m (305 ft), 101 m (331 ft), and 109 m (356 ft) bgs. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-340 are presented in Appendix A of SGW-39626.
299-E33-340	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the intervals from 63.2 to 67.8 m (207.5 to 222.5 ft) bgs.	
Saturated Zone Sediment Samples (Confined Aquifer)			
299-E33-340	Split spoon	Split-spoon samples within Rattlesnake Ridge interbed confined aquifer were proposed at the following intervals (bgs): 95.3 to 96 m (312.5 to 315 ft), 102 to 102.9 m (335 to 337.5 ft), and 109.0 to 110 m (357.5 to 360 ft) (assumed top of interbed at 312.5 ft bgs; adjusted intervals accordingly).	
	Grab quart jar	Grab samples collected every 2.5 ft over the interval (bgs): 95.3 to 110 m (312.5 to 360 ft). The samples from intervals 95.3 m (312.5 ft), 102 m (335 ft), and 109.0 m (357.5 ft) were proposed for analysis (assumes top of interbed at 95.3 m (312.5 ft) bgs; adjusted intervals accordingly).	
Groundwater Samples			
299-E33-340	Pump or KABIS	Three samples were collected at the following intervals (bgs): 96 m (315 ft), 102.9 m (337.5 ft), and 110 m (360 ft) (assumed top of interbed aquifer at 95.3 m [312.5 ft]; adjusted intervals accordingly).	

Note: KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-9. Sediment and Groundwater Samples for Well 299-E33-341

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E33-341 is installed north of the BY Cribs to provide information regarding the northern extent of vadose zone contamination associated with the BY Cribs to characterize the thinly bedded, low-permeability (and possibly perching) layer observed during prior drilling in the vicinity. This well could potentially be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing technetium-99 plume (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			Grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 5 to 70 m (15 to 230 ft) bgs. Continuous split-spoon samples were collected at pre-determined intervals from 5 to 6.9 m (15 to 22.5 ft) bgs, 17 to 23 m (55 to 75 ft) bgs, 29 to 37 m (95 to 120 ft) bgs, 40 to 52 m (130 to 170 ft) bgs, 55 to 59 m (180 to 195 f)t bgs, and 64 to 71 m (210 to 233 ft) bgs. One groundwater sample was collected using a decontaminated 2 ft stainless-steel bailer at 70 m (230 ft) bgs. Exact depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-341 are presented in Appendix B of SGW-39626.
299-E33-341	Split spoon	Split-spoon samples collected continuously every 0.8 m (2.5 ft) over the intervals (bgs): 5 to 6.9 m (15 to 22.5 ft), 17 to 23 m (55 to 75 ft), 29 to 37 m (95 to 120 ft), 40 to 52 m (130 to 170 ft), 55 to 59 m (180 to 195 ft), and 64 to 69.3 m (210 to 227.5 ft).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 5 to 69.3 m (15 to 227.5 ft). Samples collected every 3 m (10 ft) were analyzed.	
	Split spoon	Split-spoon samples were collected continuously every 0.8 m (2.5 ft) over the intervals (bgs): 5 to 6.9 m (15 to 22.5 ft), 17 to 23 m (55 to 75 ft), 29 to 37 m (95 to 120 ft), 40 to 52 m (130 to 170 ft), 55 to 59 m (180 to 195 ft), and 64 to 69.3 m (210 to 227.5 ft).	
Saturated Zone Sediment Samples			
299-E33-341	Split spoon	Split-spoon samples collected at the following intervals: 69.3 to 70.9 m (227.5 to 232.5 ft) bgs. Assumed water table contact at 69.3 m (227.5 ft) bgs.	
	Grab quart jar	Grab samples collected over the intervals (bgs): 0.8 m (2.5 ft), 2 m (5 ft), and 7.5 (assuming water table contact at 69.3 m [227.5 ft] bgs, samples collected at approximately 70 m [230 ft], 70.9 m [232.5 ft] and 72 m [235 ft] bgs).	
Groundwater Samples			
299-E33-341	Pump or KABIS	Two samples were collected once basalt was reached.	

Table B-9. Sediment and Groundwater Samples for Well 299-E33-341

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval

Notes: Depth to groundwater is 69 m (227 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-10. Sediment and Groundwater Samples for Well 299-E33-342

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E33-342 is positioned south of Well 299-E33-38 and north of the BY Tank Farm to provide vertical extent of moisture in the vadose zone that is possibly linked with the high chloride concentrations reported in wells in this area. Location also will aid in identifying possible perched or high-moisture zones that may influence lateral spreading of contamination near the northern portion of Tank 241-BY-106. The location also is designed to investigate possible deep contamination from the BY Cribs. This well potentially could be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing uranium plume (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			
299-E33-342	Split spoon	Split-spoon samples collected continuously every 0.8 m (2.5 ft) over the intervals (bgs): 6 to 6.9 m (20 to 22.5 ft), 21 to 26 m (70 to 85 ft), 30 to 37 m (100 to 120 ft), 41 to 46 m (135 to 150 ft), 47 to 52 m (155 to 170 ft), 56 to 59 m (185 to 195 ft), and 64 to 71 m (210 to 232.5 ft). Eleven sample intervals were planned for analysis based on soil recovery, soil type, and preliminary contaminant concentrations.	
	Split spoon	Collected from three split-spoon samples from the intervals (bgs): 24 to 25.1 m (80 to 82.5 ft), 50 to 51.1 m (165 to 167.5 ft), and 58 to 58.7 m (190 to 192.5 ft).	

Table B-10. Sediment and Groundwater Samples for Well 299-E33-342

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 6 to 71 m (20 to 232.5 ft). Samples collected at every 3 m (10 f)t interval were analyzed. Additional analysis was planned to be completed based on initial results and additional intervals were analyzed as needed.	Grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 6 to 73.9 m (20 to 242.5 ft) bgs except in intervals where no recovery was achieved. Continuous split-spoon samples were collected at predetermined intervals at 6 m (20 f)t bgs, 21 to 26 m (70 to 85 ft) bgs, 30 to 37 m (100 to 120 ft) bgs, 41 to 46 m (135 to 150 ft) bgs, 47 to 52 m (155 to 170 ft) bgs, 56 to 59 m (185 to 195 ft) bgs, and 64 to 72 m (210 to 235 ft) bgs. One groundwater sample was collected using a decontaminated KABIS sampler at 74 m (242 ft) bgs. A second groundwater sample was not collected due to amount of water in the aquifer. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-342 are presented in Appendix C of SGW-39626.
Saturated Zone Sediment Samples			
299-E33-342	Split spoon	Split-spoon samples collected over intervals (bgs): groundwater surface to 0.8 m (2.5 ft), and 2.3 to 3 m (7.5 to 10 ft) (assuming water table contact at 71 m [234 ft] bgs, samples were collected at approximately 71 to 72.4 m [234 to 237.5 ft] and 73.9 and 75 m [242.5 to 245 ft] bgs).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval: 71 to 75 m (234 to 245 ft) (assuming water table contact at 71 m [234 ft] bgs).	
Groundwater Samples			
299-E33-342	Pump or KABIS	Two samples were planned for collection of groundwater. One at the first split-spoon interval and the other where basalt was reached.	

Notes: Depth to groundwater is 72 m (236 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-11. Sediment and Groundwater Samples for Well 299-E33-343

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 299-E33-343 is positioned between existing Wells 299-E33-41 and 299-E33-18 to provide additional information on lateral extent and source of localized uranium contamination in the vadose zone and depth and character of low-permeability strata that might influence vertical and lateral spreading (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			Grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 18 to 78 m (60 to 255 ft) bgs. Continuous split-spoon samples were collected at pre-determined intervals from 20 to 26 m (65 to 85 ft) bgs, 30 to 44 m (100 to 145 ft) bgs, 47 to 53 m (155 to 175 ft) bgs, and 62 to 76 m (205 to 250 ft) bgs; one split-spoon sample was also collected at 77 m (253 ft) bgs. One groundwater sample was collected using a decontaminated 1 m (2 ft) stainless-steel bailer at 77 m (252 ft) bgs. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-343 are presented in Appendix D of SGW-39626.
299-E33-343	Split spoon	Split-spoon samples collected every 0.8 m (2.5 ft) over the intervals (bgs): 20 to 26 m (65 to 85 ft), 30 to 44m (100 to 145 ft), 47 to 53 m (155 to 175 ft), and 62 to 77.0 m (205 to 252.5 ft).	
	Split spoon	Samples taken from split-spoons from 68.4 to 69 m (224.5 to 227 ft), 71.8 to 73 m (235.5 to 238 ft), and 75.4 to 76 m (247.5 to 250 ft) intervals. Intervals were preliminary and may change based on field-screening results.	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 18 to 77.0 m (60 to 252.5 ft). Samples collected every 3 m (10 ft) were analyzed.	
Saturated Zone Sediment Samples			
299-E33-343	Split spoon	Split-spoon samples were collected over the intervals (bgs): 77.0 to 78 m (252.5 to 255 ft) and 78 to 79.0 m (257 to 259.5 ft) (estimated water table contact at 77 m [252 ft] bgs).	
	Grab quart jar	Grab samples collected every 2.5 ft over the interval (bgs): 77.0 to 79 m (252.5 to 260 ft). The samples from intervals 77.0 m (252.5 ft) and 78.5 m (257.5 ft) were proposed for PNNL analysis.	
Groundwater Samples			
299-E33-343	Pump or KABIS	Sample collected at interval (bgs): 78 m (255 ft) (estimated water table contact at 77 m [252 ft] bgs).	
	Pump or KABIS	Sample collected at interval (bgs): 78 to 79.1 m (257 to 259.5 ft).	

Table B-11. Sediment and Groundwater Samples for Well 299-E33-343

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval

Notes: Depth to groundwater is 77 m (252 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*; and SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-12. Sediment and Groundwater Samples for Wells 299-E33-344/299-E33-345

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Wells 299-E33-344/299-E33-345 are positioned east of Well 299-E33-18 and west of the 216-B-7A Crib to provide information on lateral migration and source of vadose zone contaminants (particularly uranium) near the 216-B-7A Crib and the B Tank Farm and allow depth-discrete groundwater samples in the aquifer to evaluate vertical contaminant distribution. This well potentially could be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing uranium plume (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			
299-E33-344/ 299-E33-345	Split spoon	Split-spoon samples collected every0.8 m (2.5 ft) over the intervals (bgs): 12 to 14.4 m (40 to 47.5 ft), 18 to 26 m (60 to 85 ft), and 57.2 to 77.0 m (187.5 to 252.5 ft). Two sample intervals were planned to be analyzed based on soil recovery, soil type, and preliminary contaminant concentrations.	
	Split spoon	Collected from three split-spoon samples from the intervals (bgs): 22 to 23 m (72.5 to 75 ft), 61 to 61.7 m (200 to 202.5 ft), and 72 to 72.4 m (235 to 237.5 ft).	

Table B-12. Sediment and Groundwater Samples for Wells 299-E33-344/299-E33-345

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) between interval 12 to 77.0 (42 to 252.5 ft) bgs. Samples collected every 3 m (10 ft) were analyzed.	For 299-E33-344, grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 12 to 72 m (40 to 235 ft) bgs. Continuous split-spoon samples were collected at predetermined intervals from 12 to 14.4 m (40 to 47.5 ft) bgs, 18 to 26 m (60 to 85 ft) bgs, and 57.2 to 72.4 m (187.5 to 237.5 ft) bgs. One groundwater sample was collected using a decontaminated 1 m (2 ft) plastic bailer at 69.3 m (227.5 ft) bgs. A perched water zone was described from 69 to 72 m (225 to 237 ft) bgs. Because drilling did not terminate within the basalt, a second groundwater sample was not collected and a second borehole was drilled (C6226). Collection depths and HEIS database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-344 are presented in Appendix E of SGW-39626. For Well 299-E33-345, grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 72.4 to 79 m (237.5 to 260 ft) bgs as a continuation of the sampling originally planned for Well 299-E33-344. Continuous split-spoon samples were collected at predetermined intervals from 72.4 to 78.5 m (237.5 to 257.5 ft) bgs. One groundwater sample was collected using a decontaminated 1 m (2 ft) bailer at 79 m (258 ft) bgs. Exact depths and HEIS database numbers for grab, split-spoon, and groundwater samples collected from 299-E33-345 are presented in Appendix F of SGW-39626.
Perched Water Zone/Saturated Zone Sediment Samples			
299-E33-344/ 299-E33-345	Split spoon	Two split-spoon samples were collected over the intervals 78 to 78.5 m (255 to 257.5 ft) and 80.3 81 m (263.5 to 266 ft) bgs (estimated water table contact at 77 m m [253 ft] bgs).	
	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) between the interval of 78 m (255 ft) to the bottom of the borehole.	
Groundwater Samples			
299-E33-344/ 299-E33-345	Pump or KABIS	Sample collected at interval 78.5 m (257.5) ft bgs and at the top of basalt.	
	Pump or KABIS	Samples will be collected at intervals 81 m (266 ft) bgs and top of basalt.	

Notes: Depths to groundwater are 69 m (225 ft) and 77 m (253 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples were analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

HEIS = Hanford Environmental Information System

1

Table B-13. Sediment and Groundwater Samples for Well 699-48-50B

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 699-48-50B is located north of Well 299-E33-26 and south of Well 699-49-55A to provide northern definition of uranium plume (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			Grab samples were collected from the unsaturated zone every 0.8 m (2.5 ft) starting at 57 m (186 ft) bgs to the basalt surface. A total of four split-spoon samples were attempted, though only three obtained sample recovery: the final split-spoon attempt encountered basalt; therefore, no sample recovery was achieved. The two samples collected from within the unsaturated zone were from 59.0 to 60 m (193.5 to 196 ft) bgs and 60.5 to 61 m (198.5 to 201 ft) bgs. One sample was collected within the saturated zone from 63 to 63.8 m (207 to 209.4 ft) bgs. Groundwater samples at Well 699-48-50B were collected after the well was completed due to the shallow aquifer. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 699-48-50B are presented in Appendix B of SGW-34034.
699-48-50B	Grab quart jar	Every 0.8 m (2.5 ft) over the interval 6 m (20 ft) above groundwater to groundwater surface (estimated at 63 m [206 ft] bgs). Samples from 3.8 to 0.8 (12.5 to 2.5 ft) above groundwater surface were analyzed.	
	Split spoon	3.8 to 3 m (12.5 to 10 ft) and 2.3 to 2 m (7.5 to 5 ft) above groundwater surface.	
Saturated Zone Sediment Samples			
699-48-50B	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) bgs.	
	Split spoon	Split-spoon samples were collected at intervals 0 to 0.8 m (0 to 2.5 ft), 0.8 to 2 m (2.5 to 5 ft), and 2 to 2.3 m (5 to 7.5 ft) below groundwater surface.	
Groundwater Samples			
699-48-50B	Pump or KABIS	At basalt surface.	

Notes: Depth to groundwater is 63 m (208 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-34034, *Borehole Summary Report for the Installation of Three Groundwater Wells in the 200-BP-5 Operable Unit, FY 2007*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-14. Sediment and Groundwater Samples for Well 699-50-56

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 699-50-56 is located between Wells 699-49-55A and 699-52-57 to resolve contaminant concentrations in the technetium-contoured plume in this area. This well also may help identify an erosional channel in the basalt for potential northern groundwater flow (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			

Table B-14. Sediment and Groundwater Samples for Well 699-50-56

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
699-50-56	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval 6 m (20 ft) above groundwater to groundwater surface (groundwater estimated at 46 m [151 ft] bgs); samples from 3.8 m (12.5 ft), 2.3 m (7.5 m) and 0.8 m (2.5 ft) above groundwater for analysis.	Grab samples were collected every 0.8 m (2.5 ft) over the interval 40 m to 46 m (131 ft to the 151 ft) bgs. Three split-spoon samples were collected in the saturated zone over the interval 46 to 48.3 m (151 to 158.5 ft) bgs. One groundwater sample was collected once the basalt surface was reached. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 699-50-56 are presented in Appendix C of SGW-34034.
Saturated Zone Sediment Samples			
699-50-56	Split spoon	Split-spoon samples were collected at intervals 0.3 to 0.8 m (1 to 2.5 ft), 0.8 to 2 m (2.5 to 5 ft), and 2 to 2.3 m (5 to 7.5 ft) below groundwater surface.	
Groundwater Samples			
699-50-56	Pump or KABIS	At basalt surface.	

Notes: Depth to groundwater is 164 ft bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit.*

SGW-34034, *Borehole Summary Report for the Installation of Three Groundwater Wells in the 200-BP-5 Operable Unit, FY 2007.*

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-15. Sediment and Groundwater Samples for Well 699-52-55

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 699-52-55 is installed south of Well 699-53-55 to resolve contaminant concentrations in the technetium-contoured plume in this area and determine aquifer hydraulic properties. A primary requirement for this well is to determine vertical variability of technetium and nitrate contamination. This well also is linked with Well C5862 and is planned to be used for a pump test to determine the potential capture zone for technetium-99. Other possible benefits from this proposed well include providing additional control for the basalt surface, determining the concentrations of other radionuclide and chemical contaminants, and providing additional numerical results to refine statistical measurements for modeling risk of contaminant migration in the future (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			

Table B-15. Sediment and Groundwater Samples for Well 699-52-55

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
699-52-55	Grab quart jar	Grab samples collected every 0.8 m (2.5 ft) over the interval (bgs): 44 to 52.6 m (145 to 172.5 ft). Samples from 50 to 52.6 m (165 to 172.5 ft) bgs were analyzed.	A total of 12 grab samples were collected every 0.8 m (2.5 ft) beginning at 44 to 53 m (145 ft to 175 ft) bgs, 10 samples were collected in the unsaturated zone and 2 samples were collected in the saturated zone. One split-spoon sample was attempted near the top of the unconfined aquifer from 53 to 53.8 m (174 to 176.5 ft) bgs. A large cobble was encountered during the split-spoon attempt, damaging the split-spoon, preventing the removal of the shoe. No groundwater samples were collected. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 699-52-55 are presented in Appendix B of SGW-37834.
Saturated Zone Sediment Samples			
699-52-55	Split spoon	Split-spoon samples collected over the intervals (bgs): 53 to 53.5 m (173 to 175.5 ft), 55 to 56.2 m (182 to 184.5), and 58.1 to 59 m (190.5 to 193 ft) (estimated water table contact at 53 m [173 ft] bgs).	
	Split spoon	Split-spoon samples collected over the intervals (bgs): 53 to 53.4 m (173 to 175.5) and 55 to 56.2 m (182 to 184.5 ft).	
	Grab quart jar	Grab samples collected at the following depths (bgs): 53 m (175 ft), 55 m (180 ft), 56 m (185 ft), and 58 m (190 ft).	
Groundwater Samples			
699-52-55	Pump or KABIS	Samples collected at split-spoon intervals (bgs): 175.5, 184.5, and 193 (estimated water table contact at 53 m [173 ft] bgs).	

Notes: Depth to groundwater is 53 m (173 ft) bgs.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit.*

SGW-37834, *Borehole Summary Report for the Installation of Two Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, FY 2007.*

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

1

Table B-16. Sediment and Groundwater Samples for Well 699-52-55B

Sample Location	Sample Collection Method	Planned Sample Collection Interval*	Actual Sample Collection Interval
Well 699-52-55B is located upgradient of Well 699-53-55 to assess potential intercommunication between unconfined and confined aquifers (DOE/RL-2007-18, Table 5-2).			
Vadose Zone Sediment Samples			Grab samples for chemical analysis were collected every 0.8 m (2.5 ft) from 69 to 86.9 m (225 to 285 ft) bgs, except in intervals where no recovery was possible. Three split-spoon samples were collected: at 69 m (225 ft), 75.4 m (247.5 ft), and 84.6 m (277.5 ft) bgs. Three groundwater samples were collected using a submersible pump at 70 m (230 ft), 78 m (257 ft), and 86 m (283 ft) bgs. Collection depths and Hanford Environmental Information System database numbers for grab, split-spoon, and groundwater samples collected from 699-52-55B are presented in Appendix G of SGW-39626.
None required.			
Saturated Zone Sediment Samples (Confined Aquifer)			
699-52-55B	Split spoon	Split-spoon samples collected at intervals (bgs): 70 to 70.9 m (230 to 232.5 ft), 77.0 to 78 m (252.5 to 255 ft), and 86.1 to 87 m (282.5 to 285 ft) (assumed top of interbed at 230 ft bgs; adjusted intervals accordingly).	
	Grab quart jar	Grab samples collected every 2.5 ft over the interval (bgs): 230 to 287.5 (assumed top of interbed at 70 m [230 ft] bgs; adjusted intervals accordingly).	
Groundwater Samples			
699-52-55B	Pump or KABIS	Samples collected at intervals (bgs): 70.9 m (232.5 ft), 78 m (255 ft), and 87 m (285 ft) (assumed top of interbed at 70 m [230 ft] bgs; adjusted intervals accordingly).	

Notes: Unsaturated zone samples were not collected from Well C5862 due to the proximity to proposed Well C5861, where unsaturated samples were collected and analyzed.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Sources: DOE/RL-2007-18, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit*.

SGW-39626, *Borehole Summary Report for the Installation of Seven Groundwater Monitoring Wells in the 200-BP-5 Operable Unit, CY 2008*.

* The sample collection process was designed for comprehensive study of the unsaturated and saturated zone. Only a subset of these samples was analyzed. The determination of which samples were analyzed was based on sample recovery, sediment type, radiological field-screening results, borehole geophysical profiles, and contaminant concentrations.

bgs = below ground surface

Table B-17. Groundwater Sample Analytical Data

[Provided as a Microsoft Excel table on the attached compact disk.]

Table B-18. Soil Sample Analytical Data

[Provided as a Microsoft Excel table on the attached compact disk.]

Table B-19. Analytical Laboratory General Information

LAB_ CODE	LAB_NAME	CITY	STATE	COMMENTS	LOCATION_ CATEGORY
ESL	Environmental Sciences Laboratory	Richland	WA	—	OFFSITE
LVL	Lionville Laboratory Incorporated	Exton	PA	(Formerly RCRA LabNet)	OFFSITE
222-S	222-S Lab Operations	Richland	WA	—	HANFORD CONTROLLED
RLNP	Lionville Laboratory Incorporated	Exton	PA	(Formerly RCRA LabNet)	OFFSITE
WSCF	Waste Sampling & Characterization	Richland	WA	—	HANFORD CONTROLLED
STLSL	Severn Trent St. Louis	Earth City	MO	—	OFFSITE
STLRL	Severn Trent Incorporated, Richland	Richland	WA	—	OFFSITE
EBRLNE	Eberline Services	Richmond	CA	(Formerly TMA)	OFFSITE
TASL	TestAmerica St. Louis	Earth City	MO	—	OFFSITE
TARL	TestAmerica Incorporated, Richland	Richland	WA	—	OFFSITE

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Appendix C

Hydrostratigraphic and Geologic Cross Sections

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C1 Introduction

This appendix provides hydrostratigraphic and geologic cross sections and cross-section location maps for the 200-BP-5 Groundwater Operable Unit (OU).

The hydrostratigraphic unit cross section orientations and locations for the 200-BP-5 OU are provided in Figure C-1. Eight hydrogeologic cross sections (Figures C-2 through C-9) have been assembled to illustrate the 200-BP-5 OU near-field and far-field area hydrogeology. The scales are different on each section, as necessary, to illustrate the primary structural and hydrostratigraphic features, aquifer boundaries, and relative line length.

The geologic cross section orientations and locations for the 200-BP-5 OU are provided in Figure C-10. Five geologic cross sections (Figures C-11 through C-15) have been assembled to illustrate the geology north of the 200 East Area in the area of Gable Gap. The geologic cross sections were prepared by Pacific Northwest National Laboratory (PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*).

C2 Reference

PNNL-19702, 2010, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19702.pdf.

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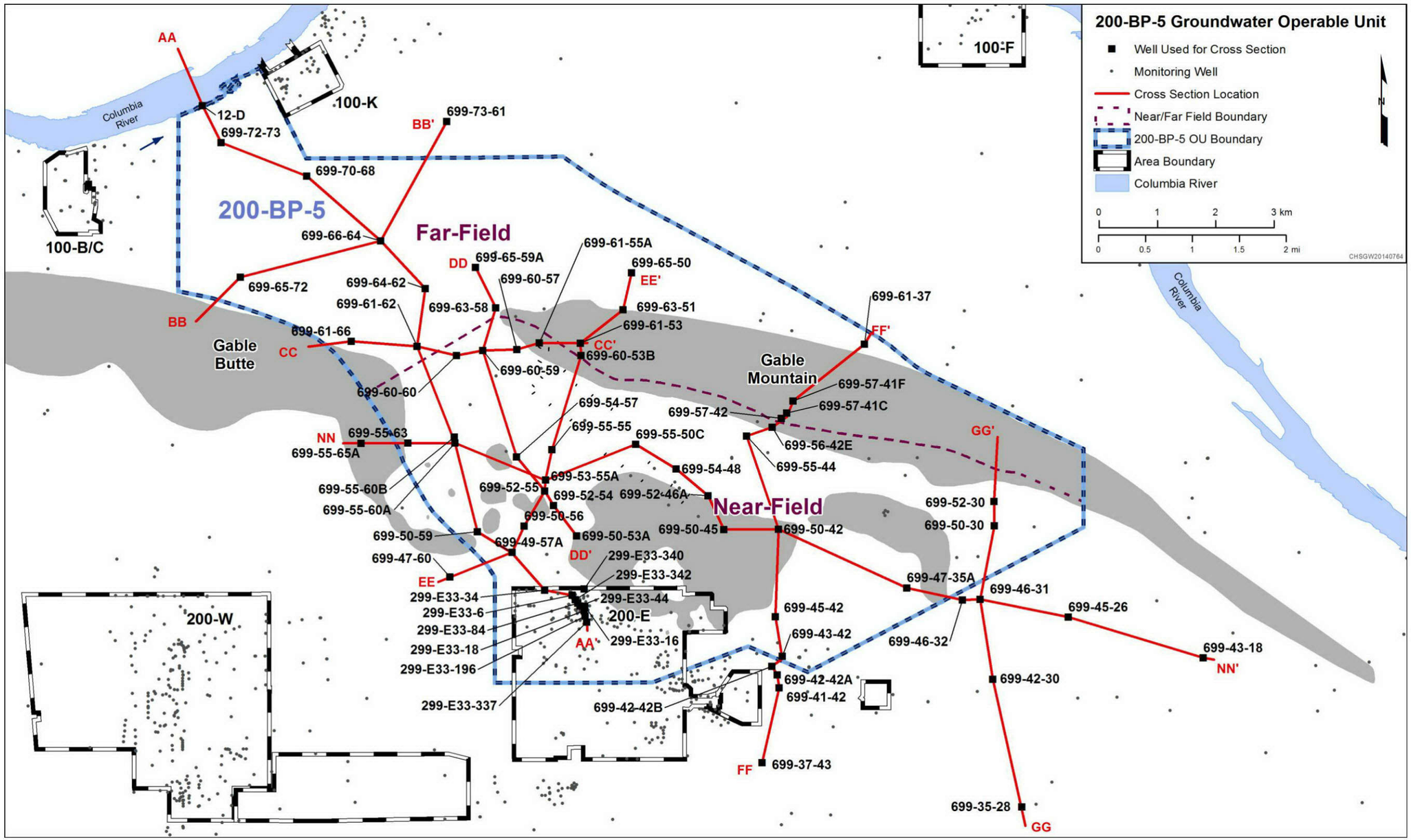
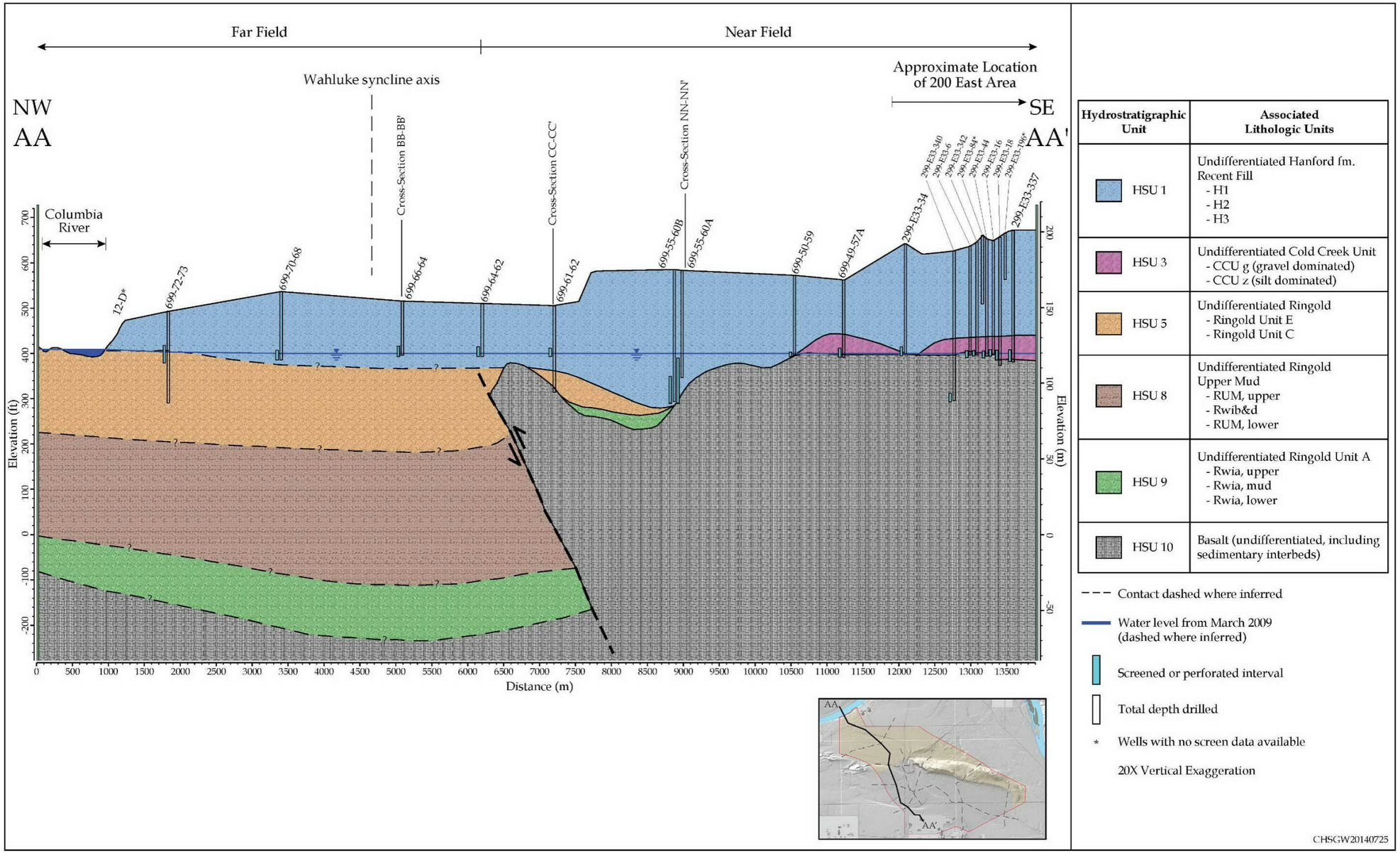


Figure C-1. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section Location Map



Hydrostratigraphic Unit	Associated Lithologic Units
HSU 1	Undifferentiated Hanford fm. Recent Fill - H1 - H2 - H3
HSU 3	Undifferentiated Cold Creek Unit - CCU g (gravel dominated) - CCU z (silt dominated)
HSU 5	Undifferentiated Ringold - Ringold Unit E - Ringold Unit C
HSU 8	Undifferentiated Ringold Upper Mud - RUM, upper - Rwib&d - RUM, lower
HSU 9	Undifferentiated Ringold Unit A - Rwia, upper - Rwia, mud - Rwia, lower
HSU 10	Basalt (undifferentiated, including sedimentary interbeds)

Contact dashed where inferred

Water level from March 2009 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Wells with no screen data available

20X Vertical Exaggeration

CHSGW20140725

Figure C-2. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section AA-AA'

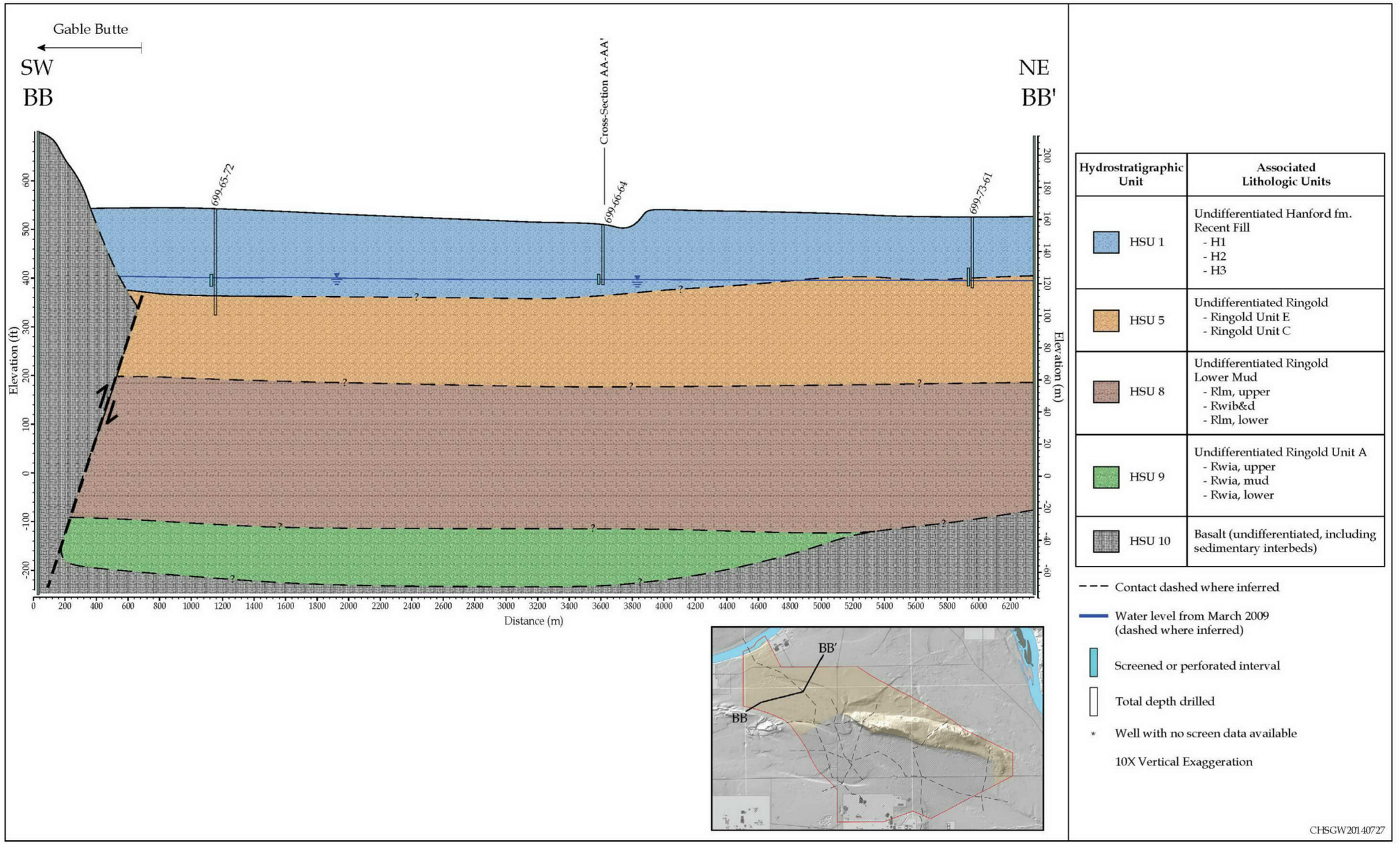


Figure C-3. 200-BP-5 Hydrostratigraphic Unit Cross-Section BB-BB'

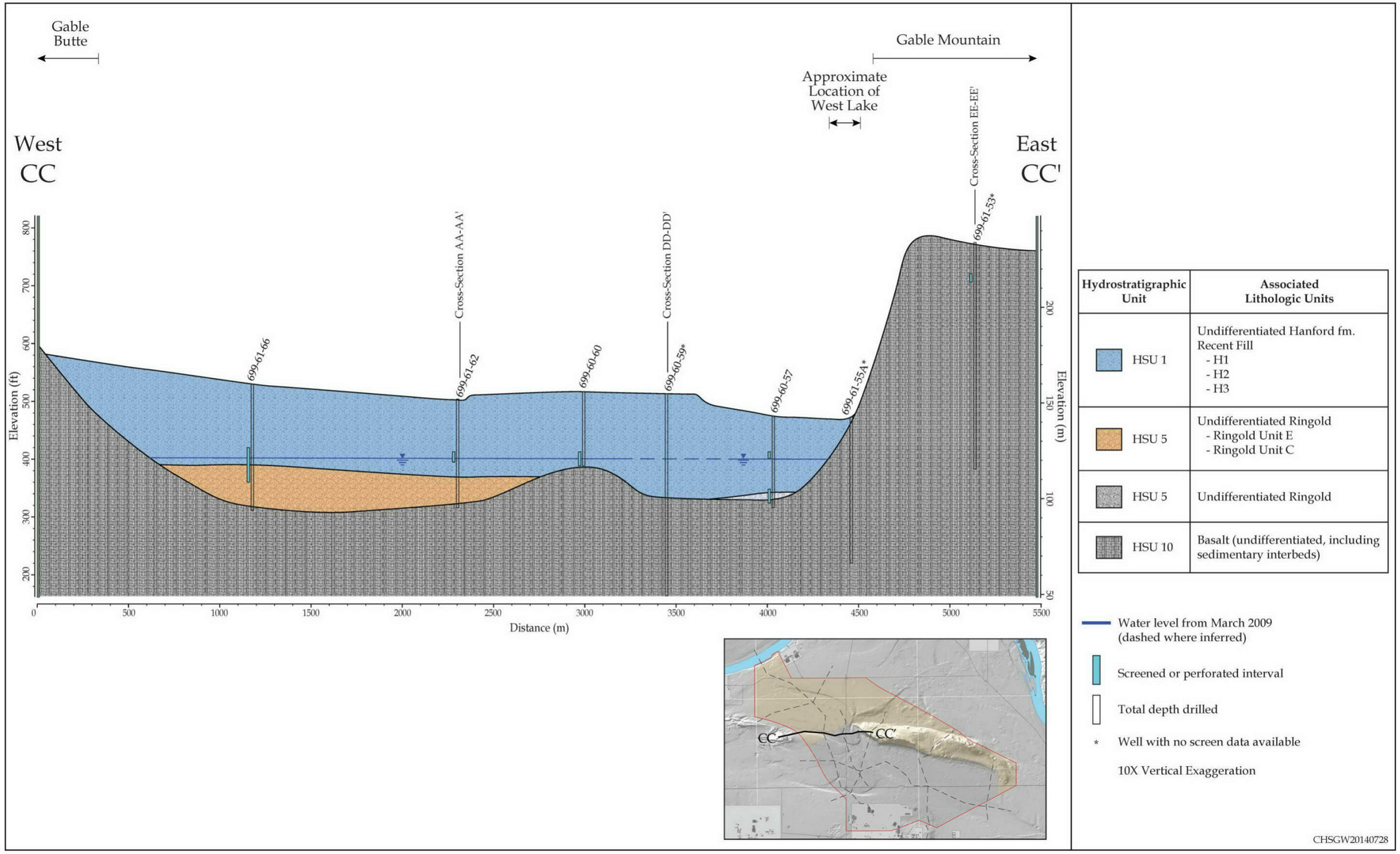


Figure C-4. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section CC-CC'

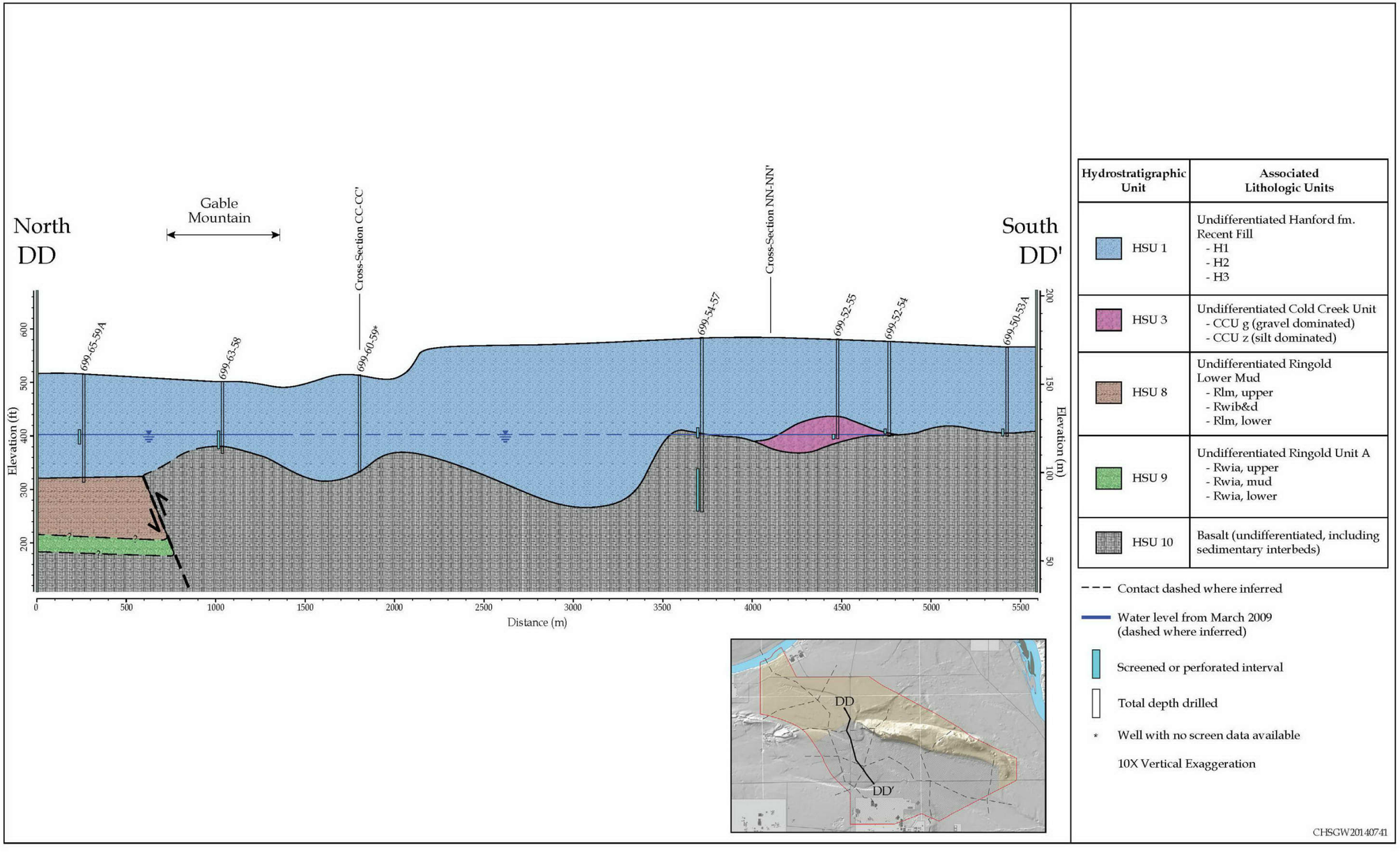


Figure C-5. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section DD-DD'

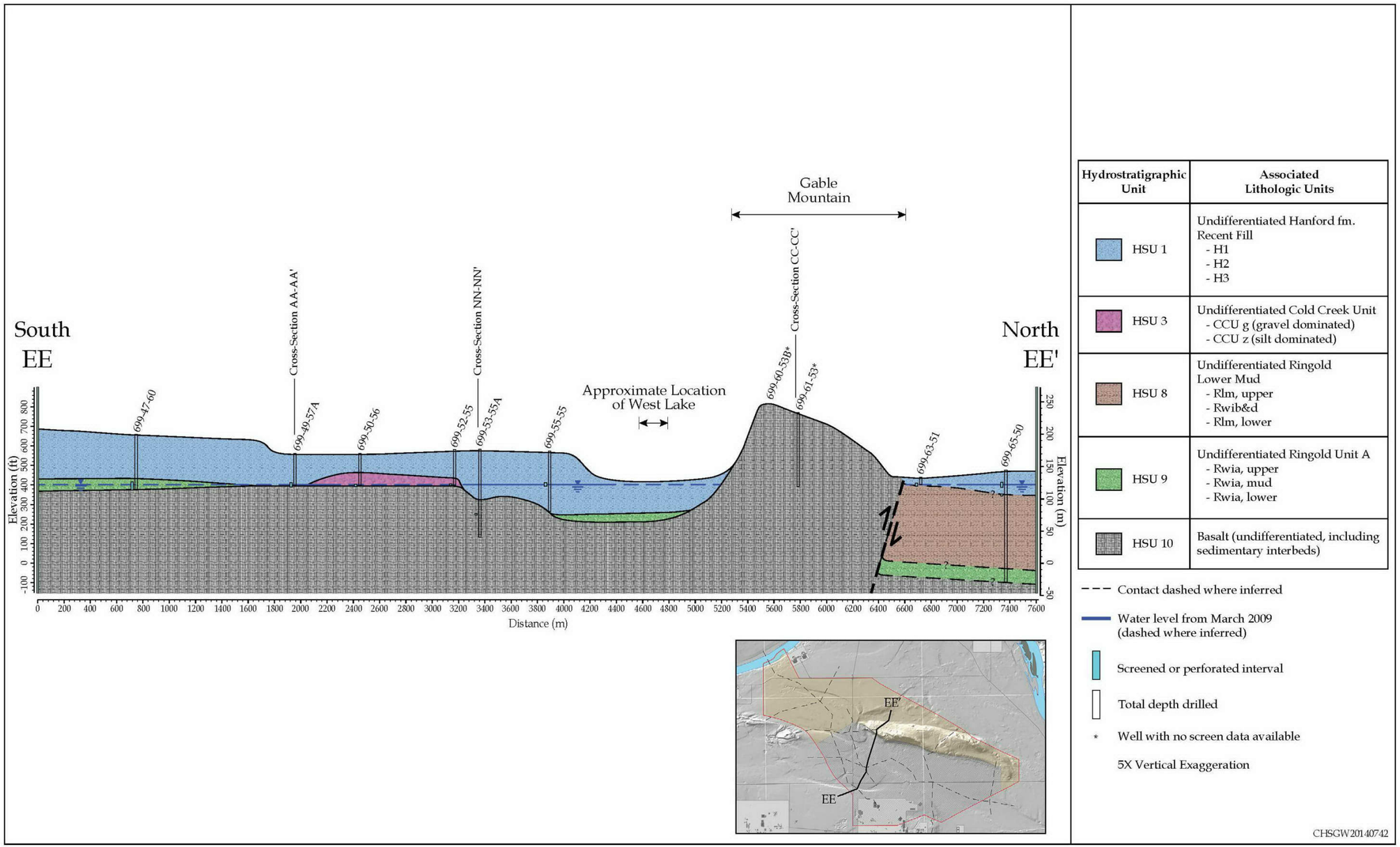
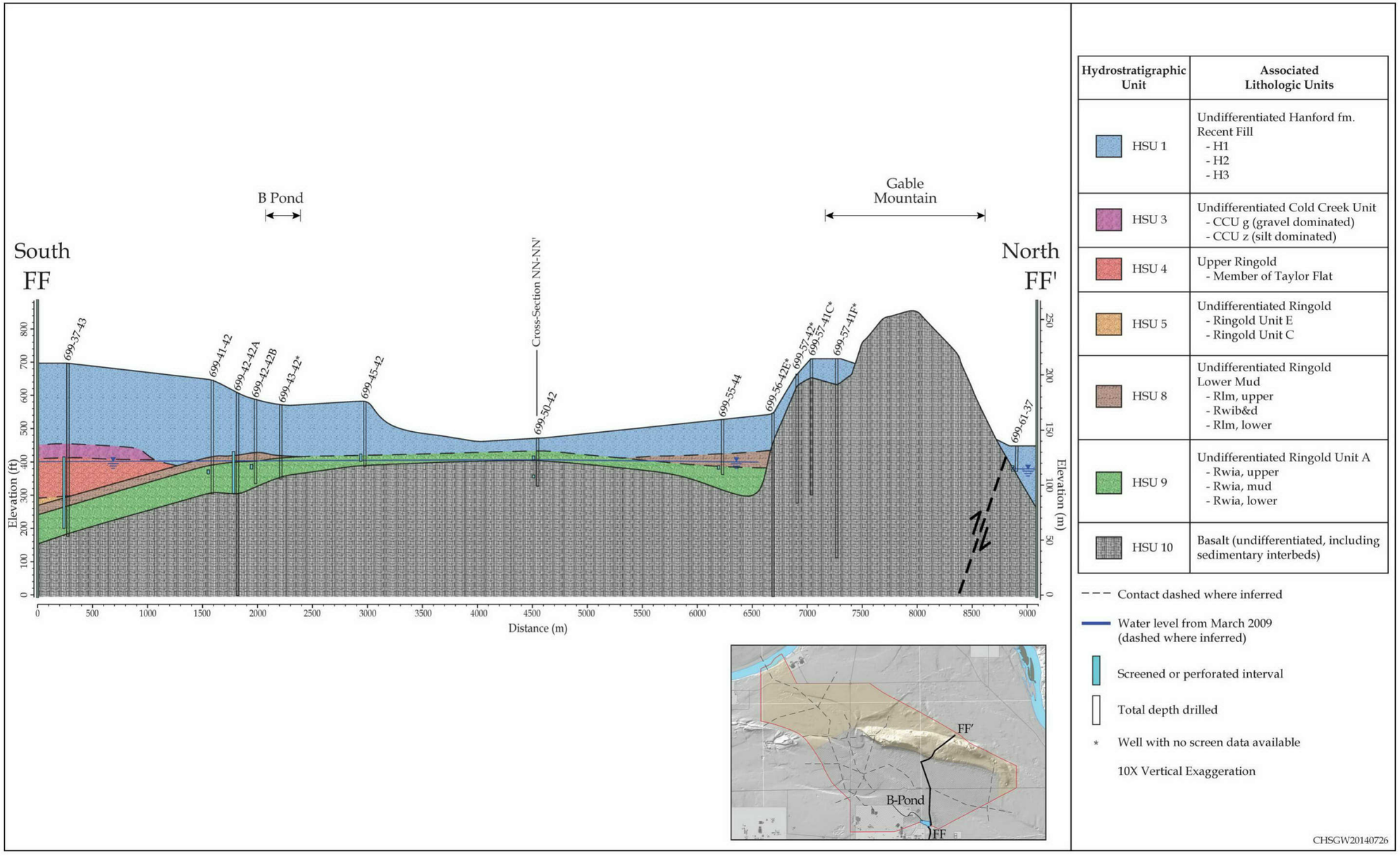


Figure C-6. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section EE-EE'



Hydrostratigraphic Unit	Associated Lithologic Units
HSU 1	Undifferentiated Hanford fm. Recent Fill - H1 - H2 - H3
HSU 3	Undifferentiated Cold Creek Unit - CCU g (gravel dominated) - CCU z (silt dominated)
HSU 4	Upper Ringold - Member of Taylor Flat
HSU 5	Undifferentiated Ringold - Ringold Unit E - Ringold Unit C
HSU 8	Undifferentiated Ringold Lower Mud - Rlm, upper - Rwib&d - Rlm, lower
HSU 9	Undifferentiated Ringold Unit A - Rwia, upper - Rwia, mud - Rwia, lower
HSU 10	Basalt (undifferentiated, including sedimentary interbeds)

Contact dashed where inferred

Water level from March 2009 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Well with no screen data available

10X Vertical Exaggeration

Figure C-7. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section FF-FF'

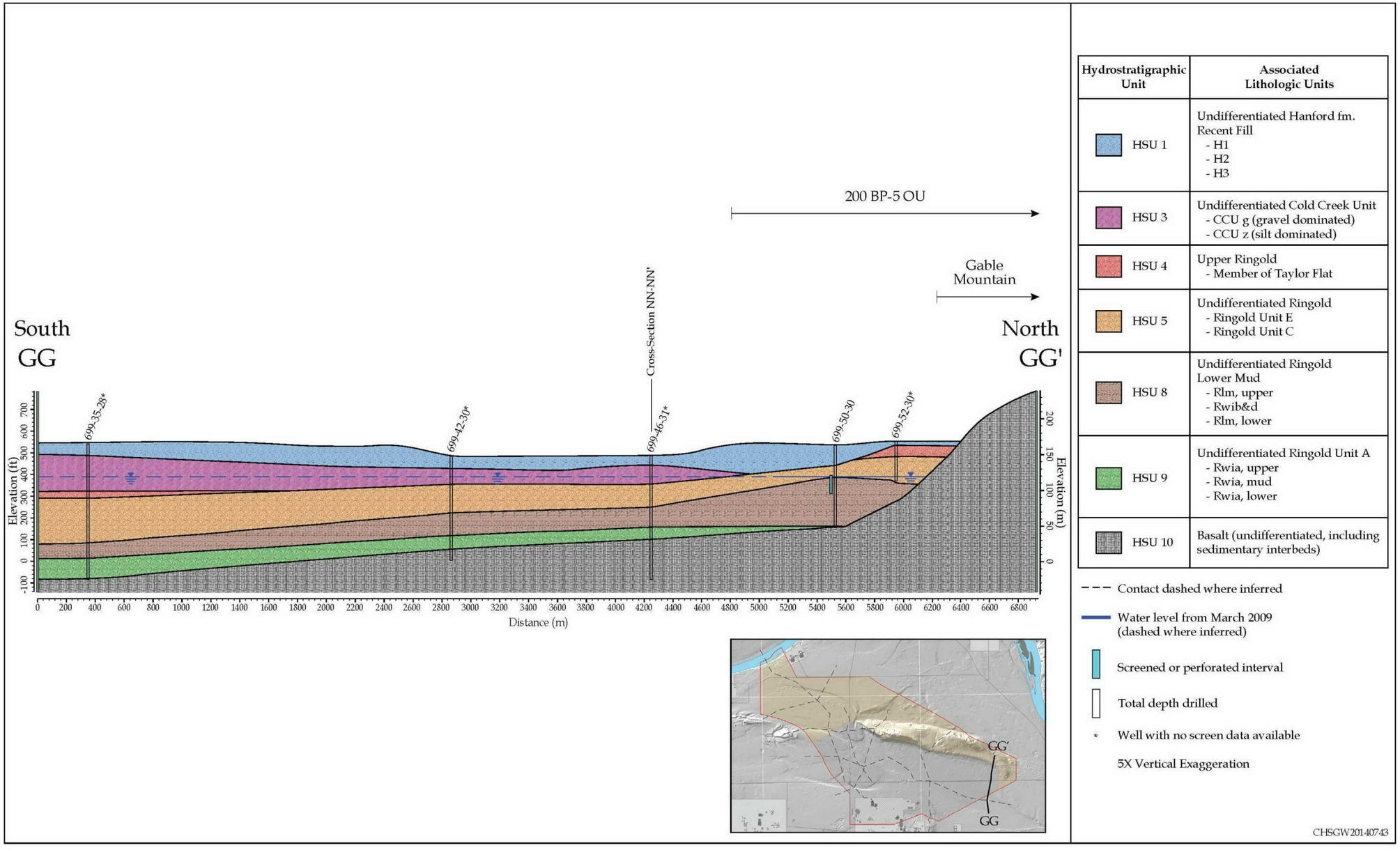
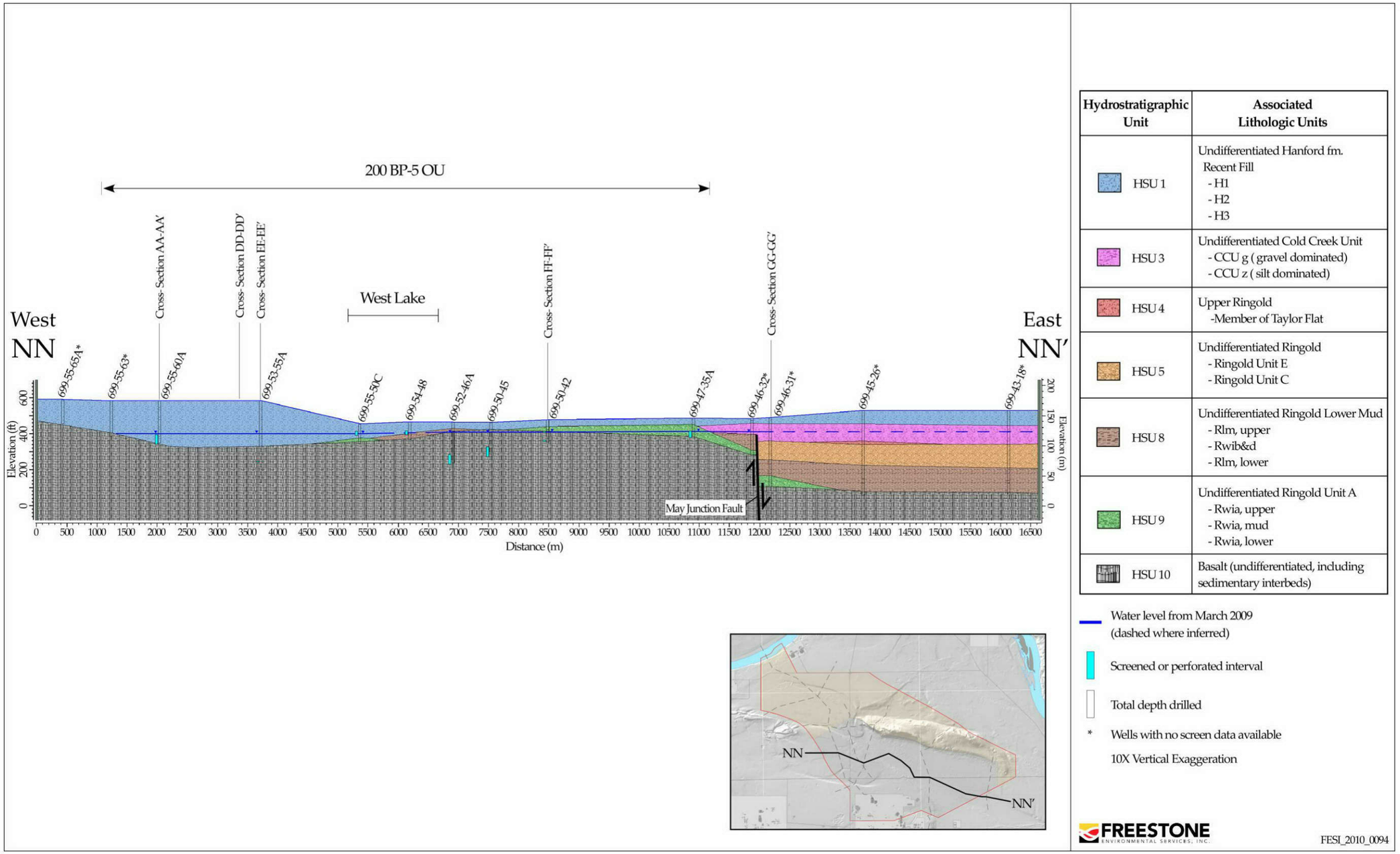


Figure C-8. 200-BP-5 OU Hydrostratigraphic Unit Cross-Section GG-GG'



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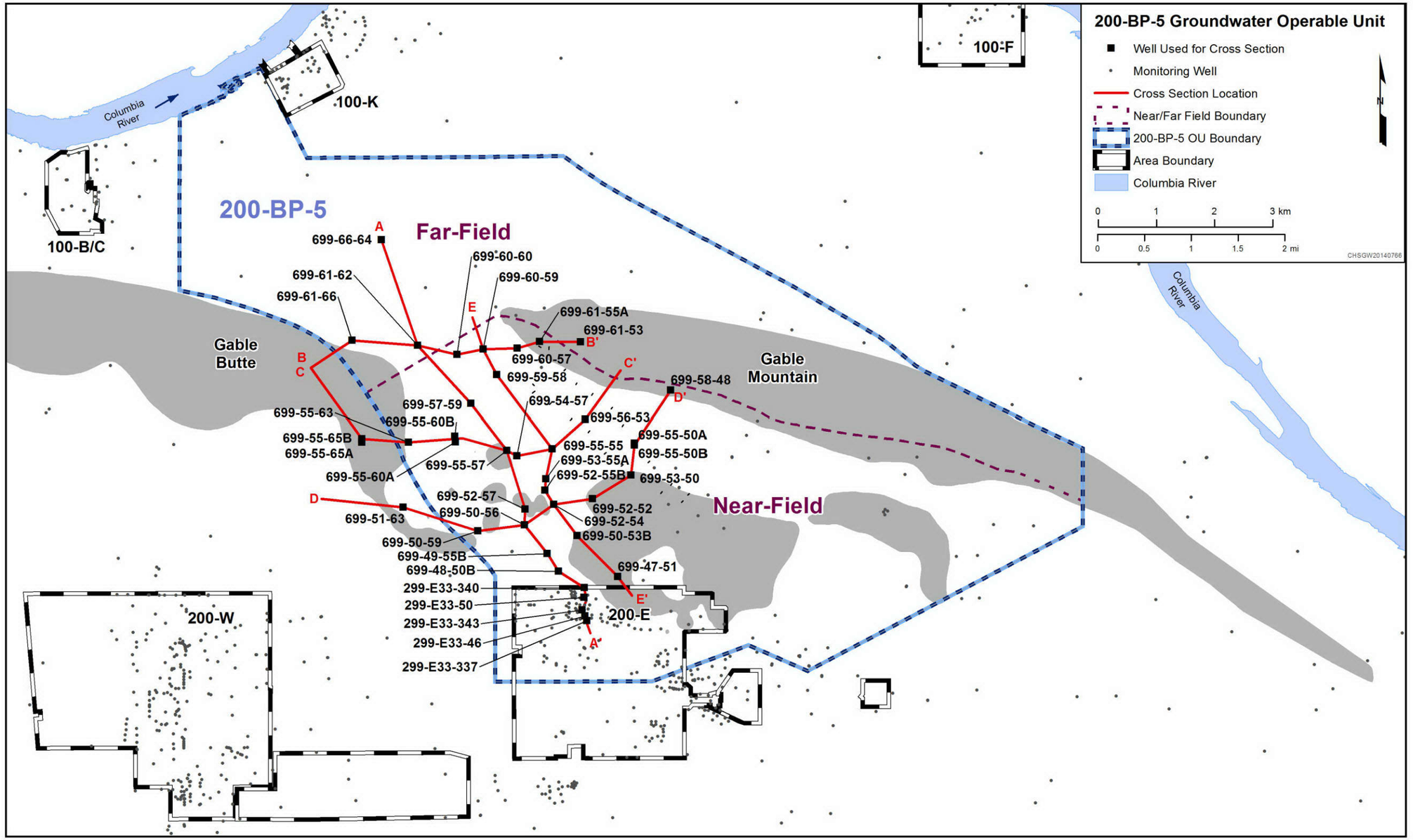

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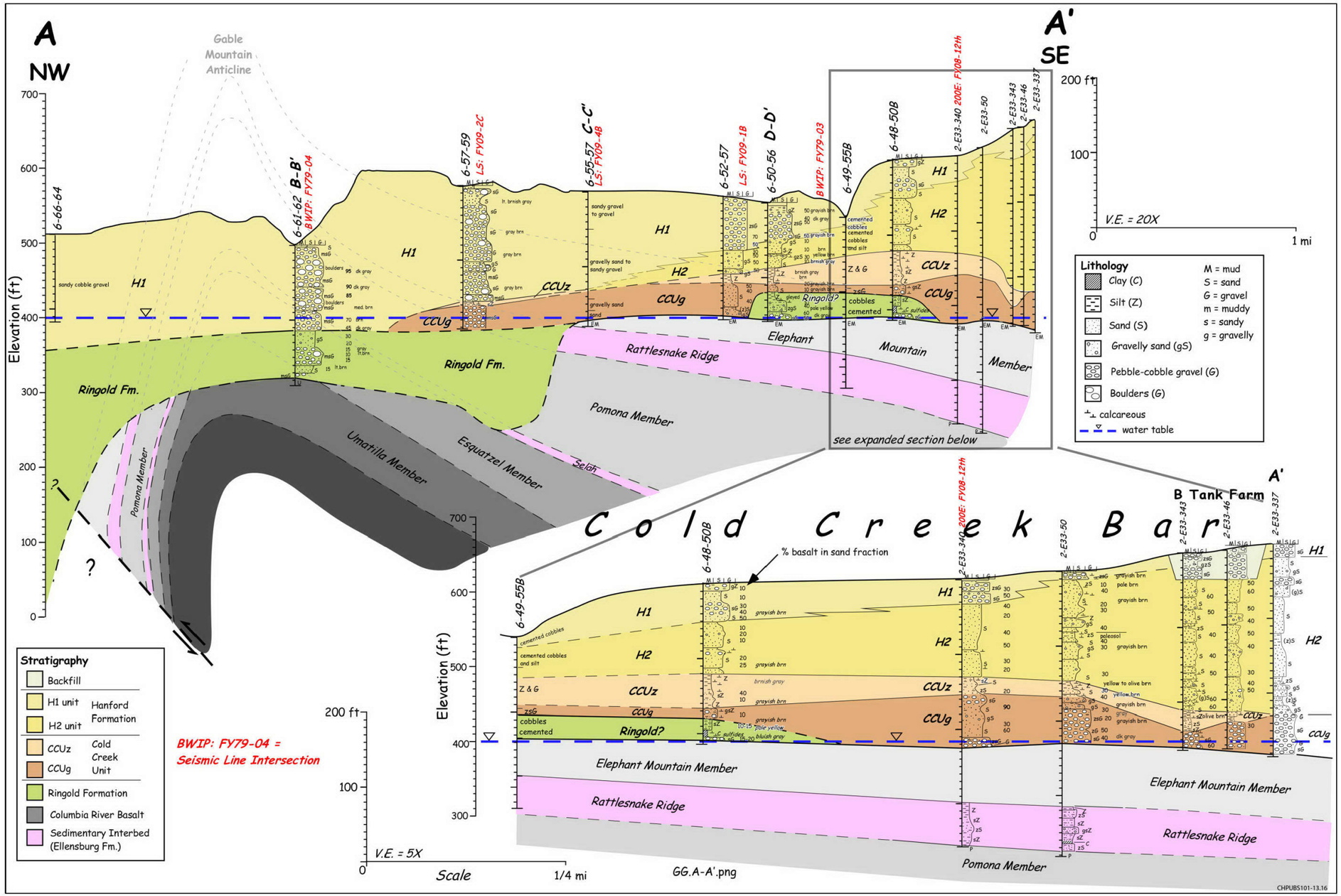

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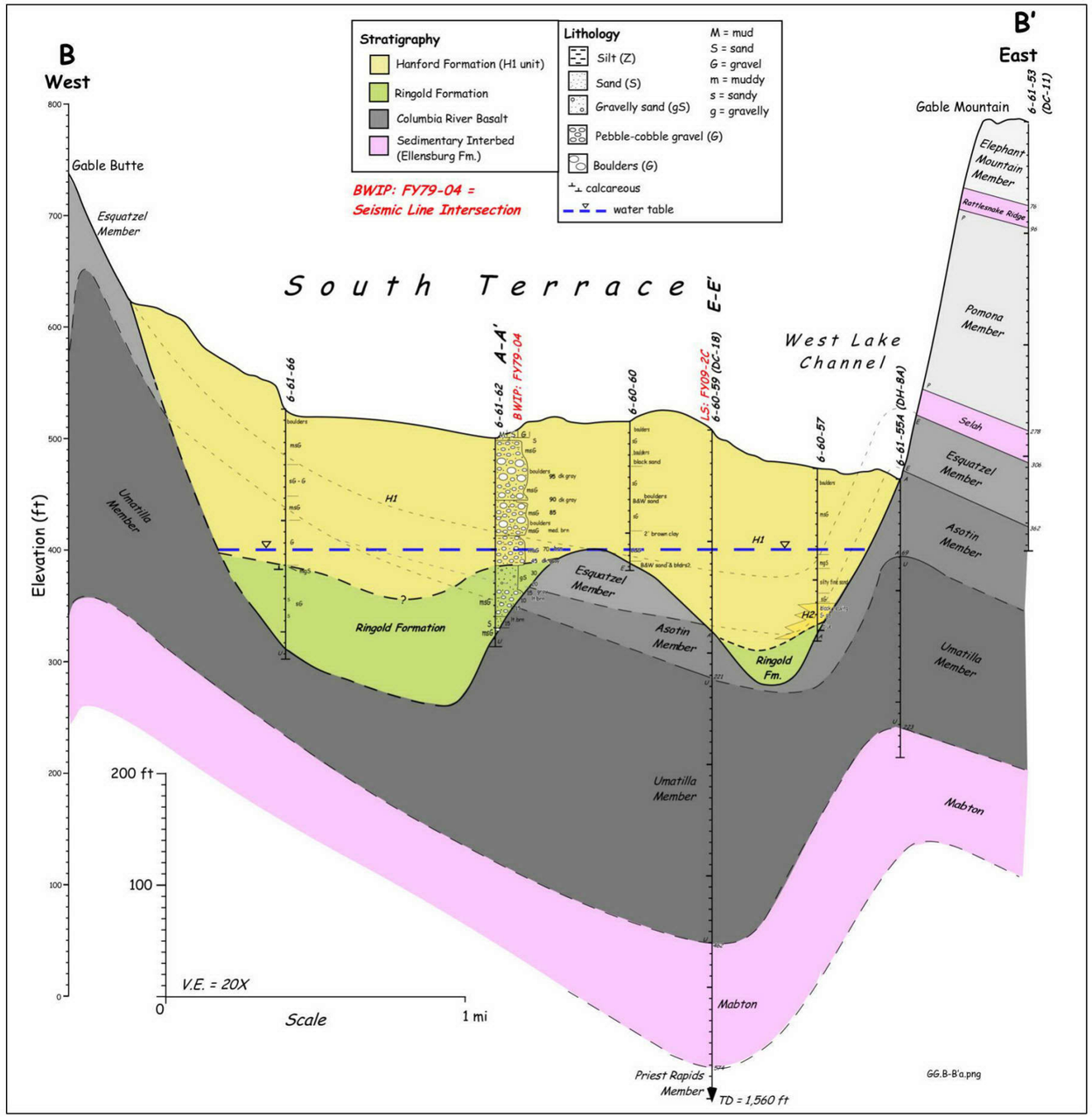

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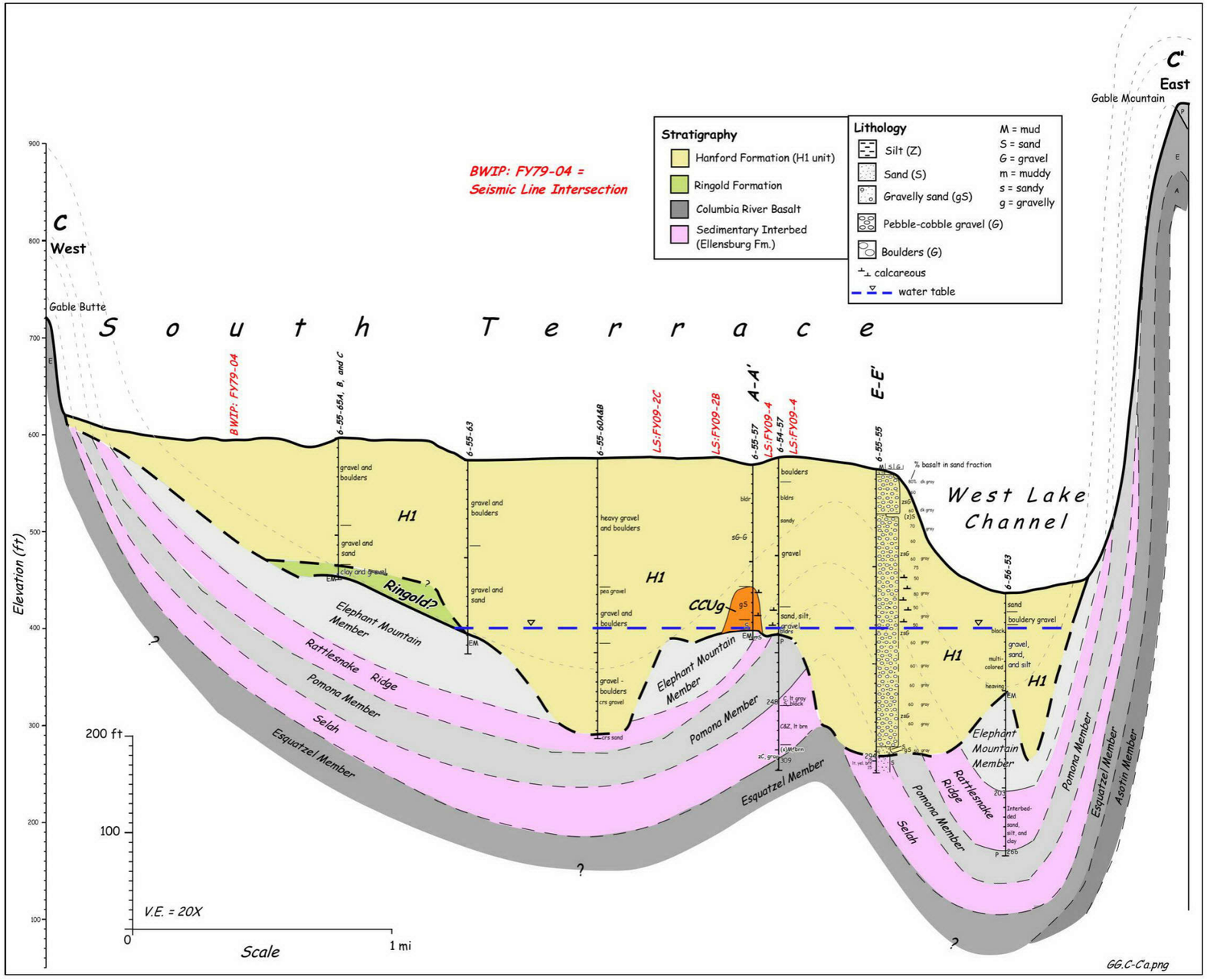


Figure C-13. 200-BP-5 OU Geologic Cross-Section C-C'

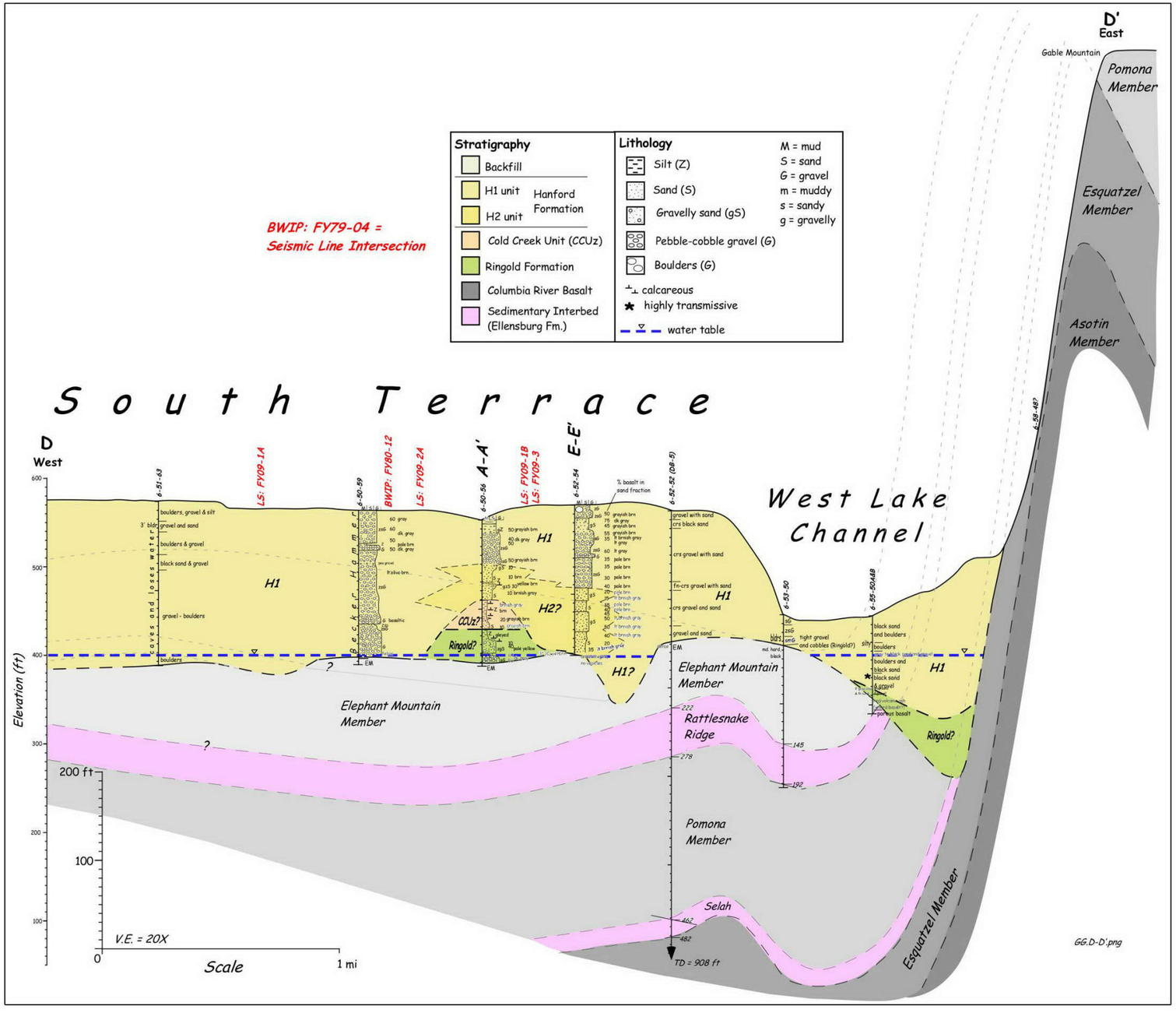
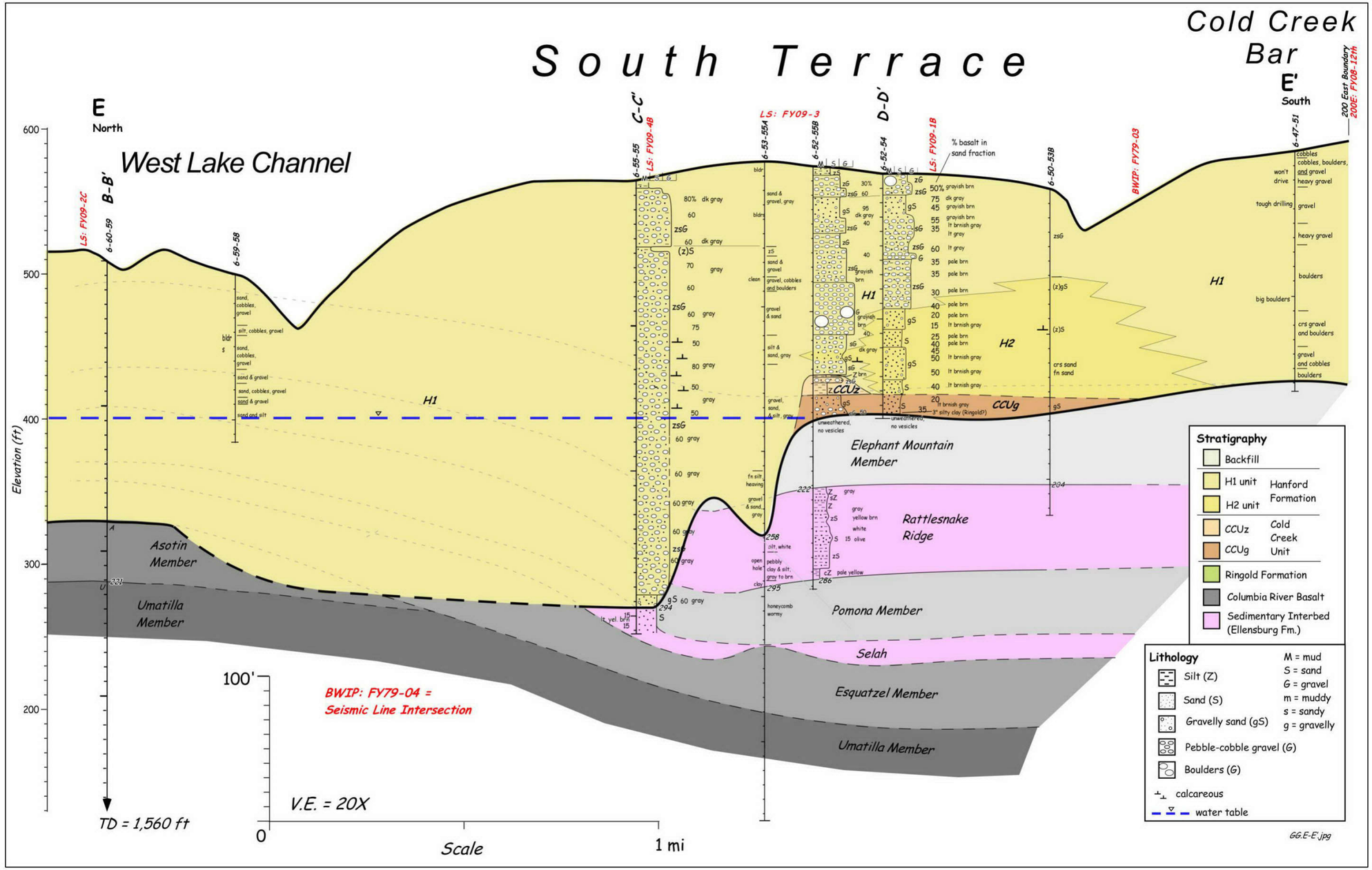


Figure C-14. 200-BP-5 OU Geologic Cross-Section D-D'



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Plume Cross Sections

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Table

Table D 1. Summary of 200-BP-5 OU Plume Cross Sections D-1

1

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D1 Introduction

This appendix includes 19 individual contaminant plume cross-section maps, assembled to illustrate the vertical distribution of contaminants in the 200-BP-5 Groundwater Operable Unit (OU). The six cross-section lines are L1, L2, L3, L4, L5, and L6. The vertical distribution of up to five contaminants is shown on each cross-section line (Table D-1). The orientations and locations of the six cross-section lines are provided in the Figure D-1, and Figures D-2 through D-20 include the individual cross-section maps.

Table D 1. Summary of 200-BP-5 OU Plume Cross Sections

Contaminant	Cross Section Line L1	Cross Section Line L2	Cross Section Line L3	Cross Section Line L4	Cross Section Line L5	Cross Section Line L6
Cyanide	—	—	—	—	—	D-2
Iodine-129	—	D-3	—	—	—	—
Nitrate	D-4	D-5	D-6	D-7	—	—
Technetium-99	D-8	D-9	D-10	D-11	—	D-12
Tritium	D-13	D-14	D-15	D-16	D-17	—
Uranium	D-18	D-19	D-20	—	—	—

Note: Table entries refer to figure numbers in this appendix.

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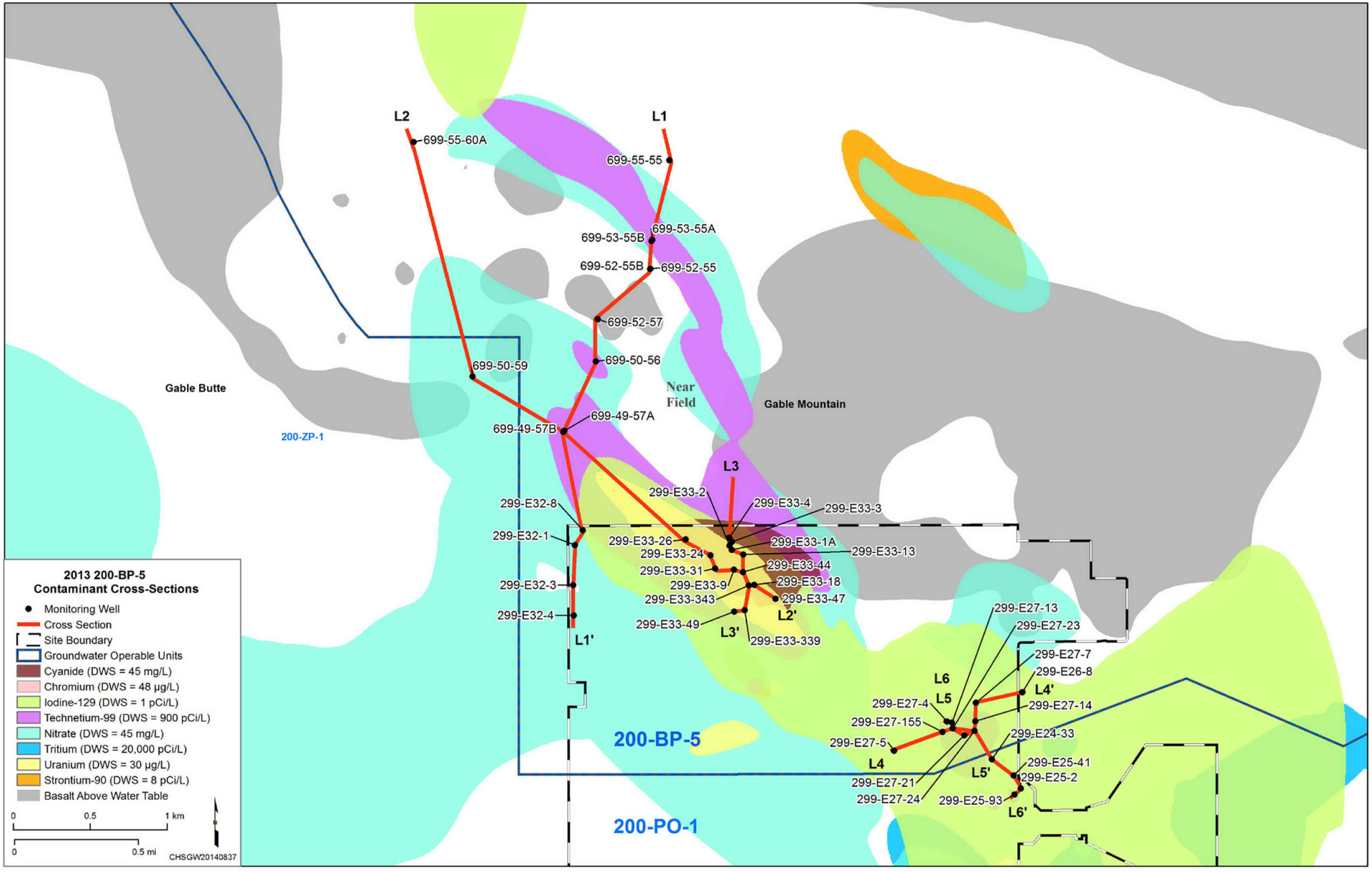


Figure D-1. 200-BP-5 OU Plume Cross-Section Location Map, with Major Contaminant Plumes

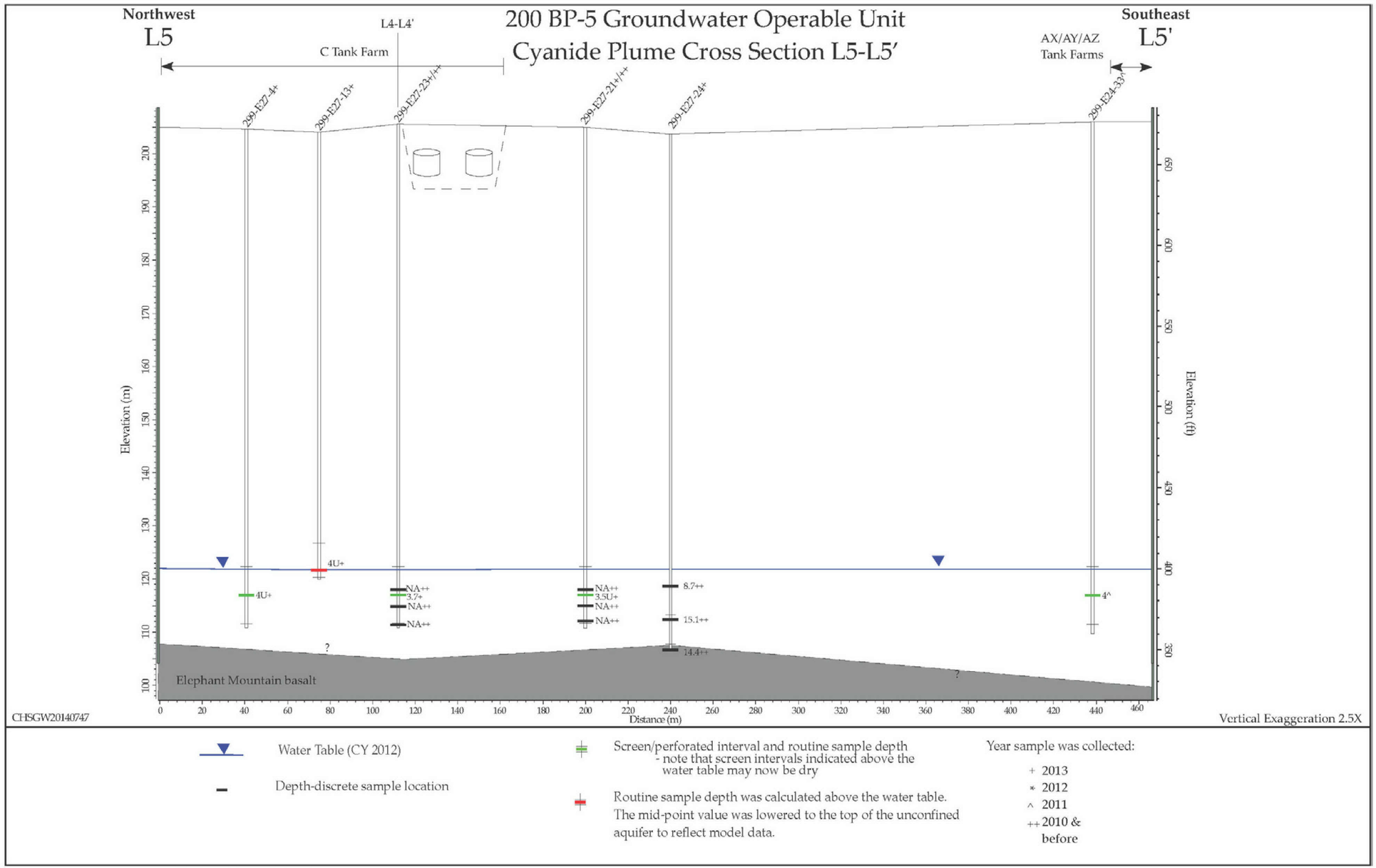


Figure D-2. 200-BP-5 OU L5-L5' Cyanide Plume Cross Section

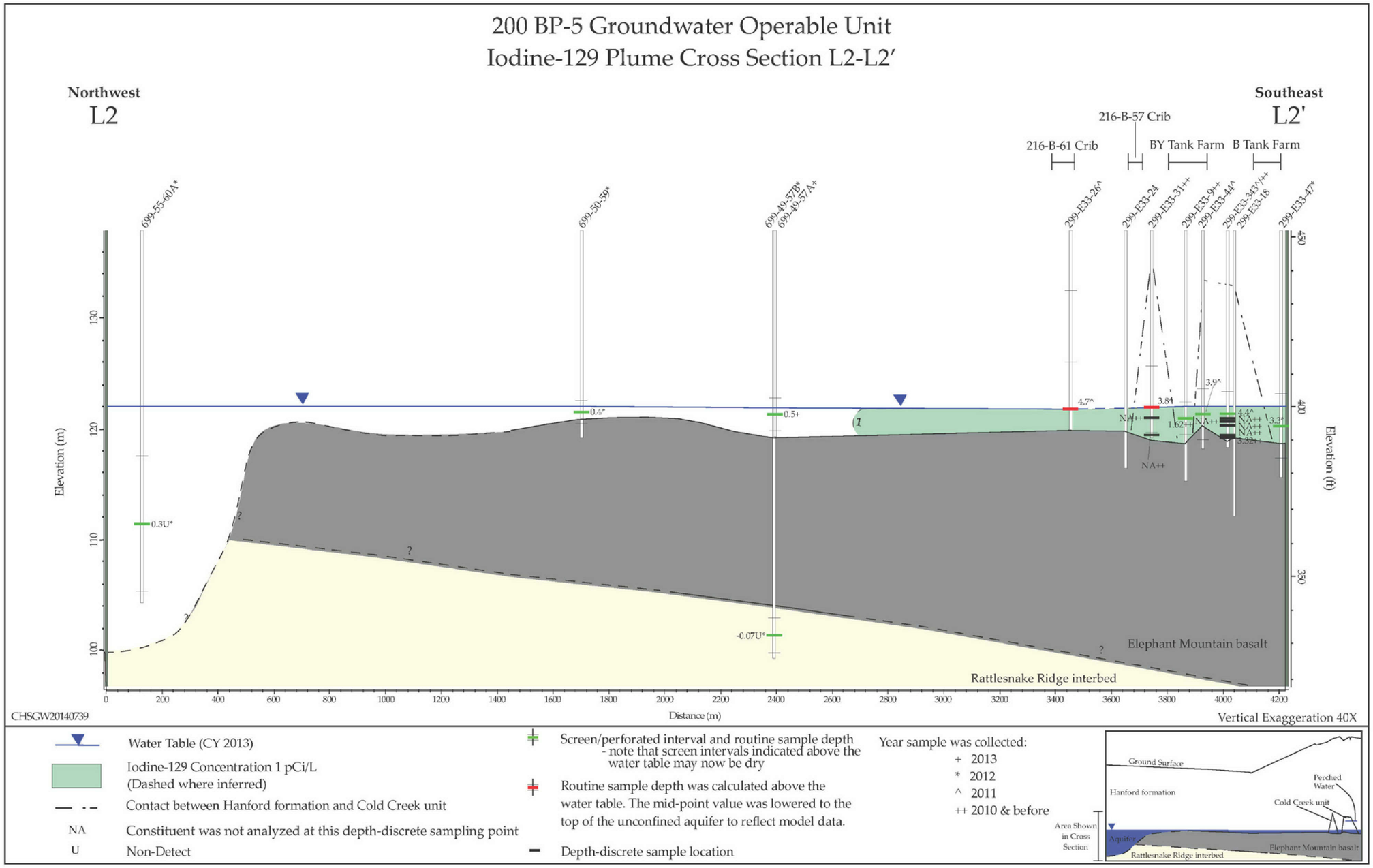


Figure D-3. 200-BP-5 OU L3-L3' Iodine-129 Plume Cross Section

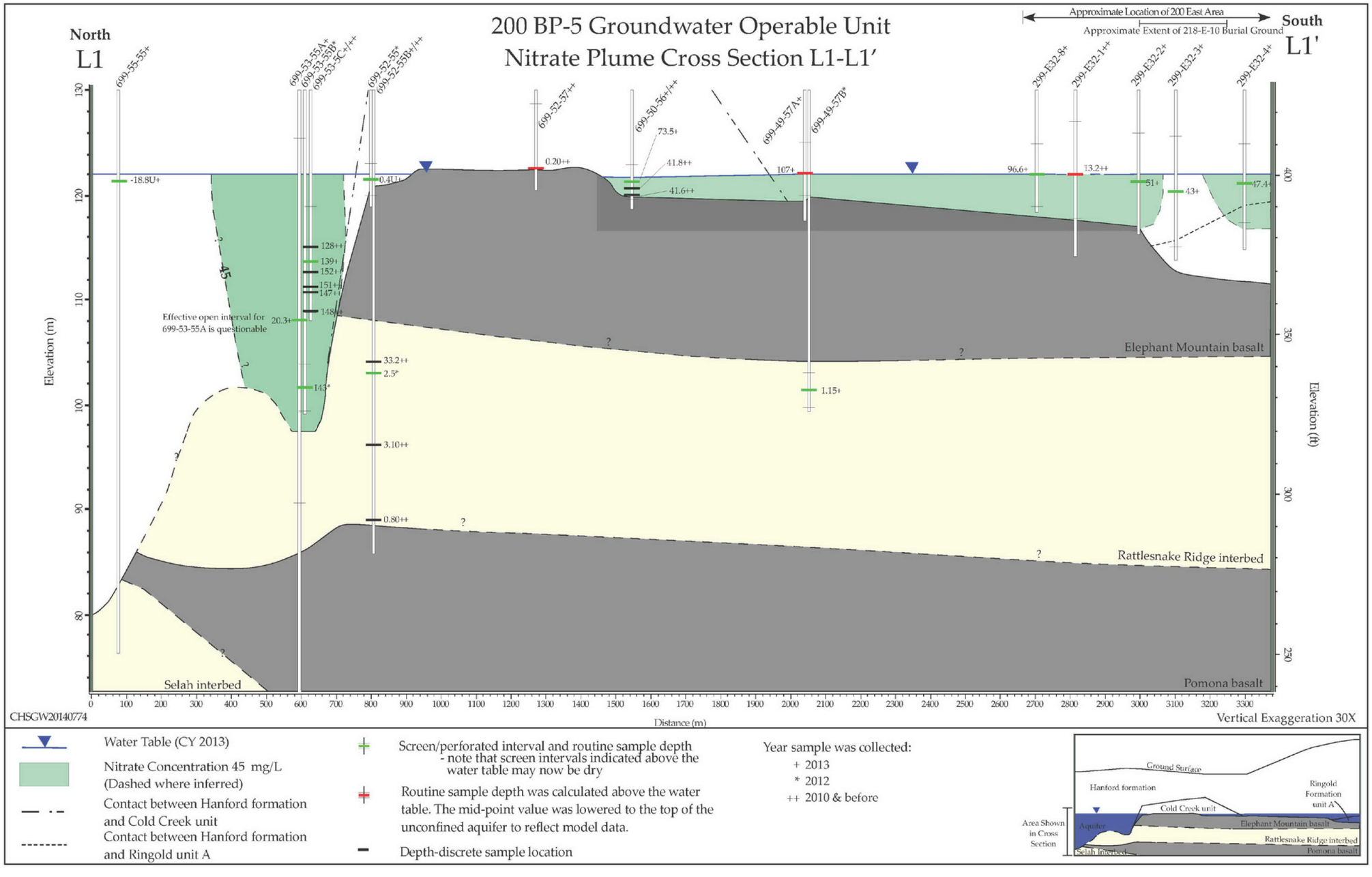


Figure D-4. 200-BP-5 OU L1-L1' Nitrate Plume Cross Section

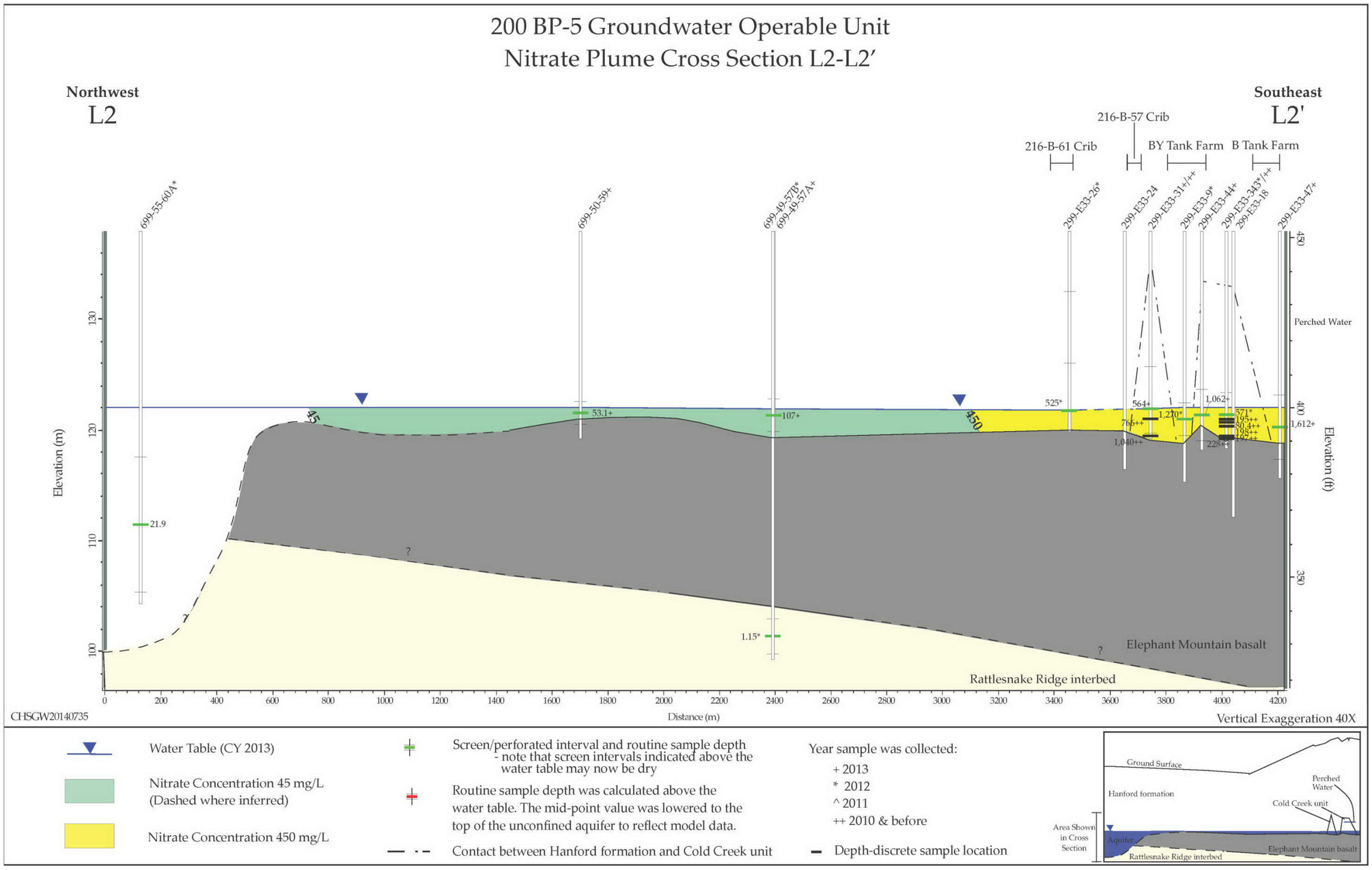
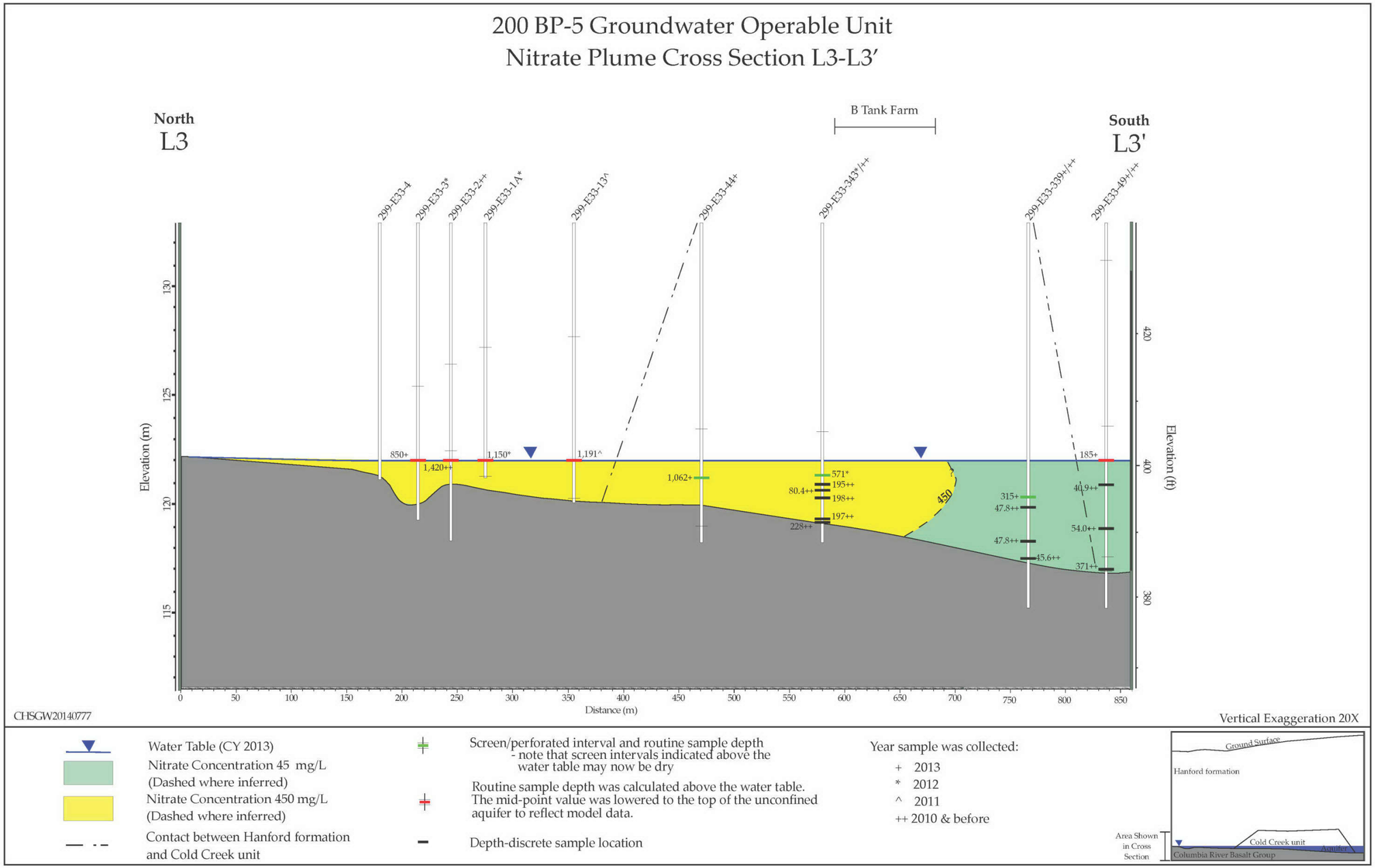


Figure D-5. 200-BP-5 OU L2-L2’ Nitrate Plume Cross Section



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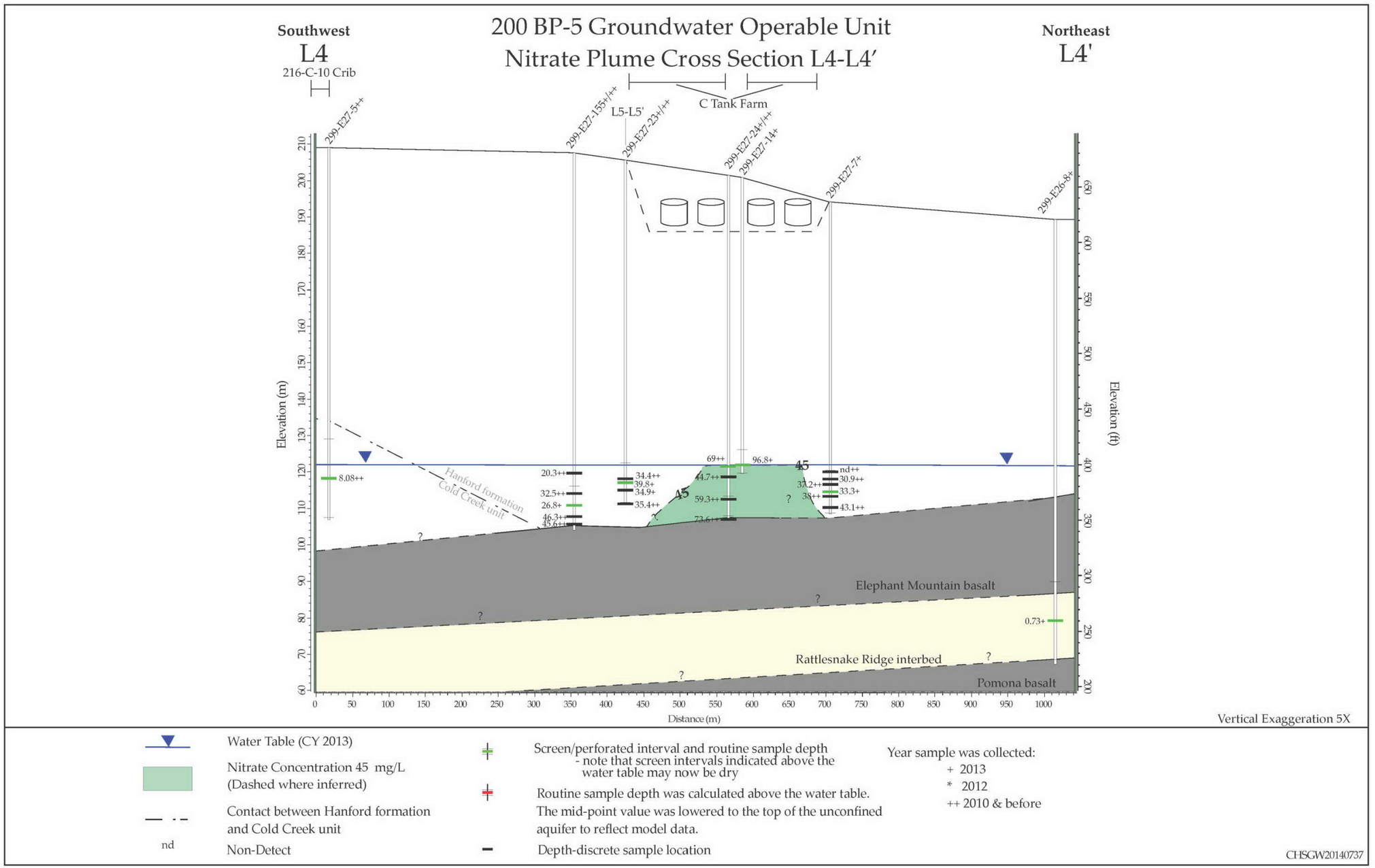


Figure D-7. 200-BP-5 OU L4-L4' Nitrate Plume Cross Section

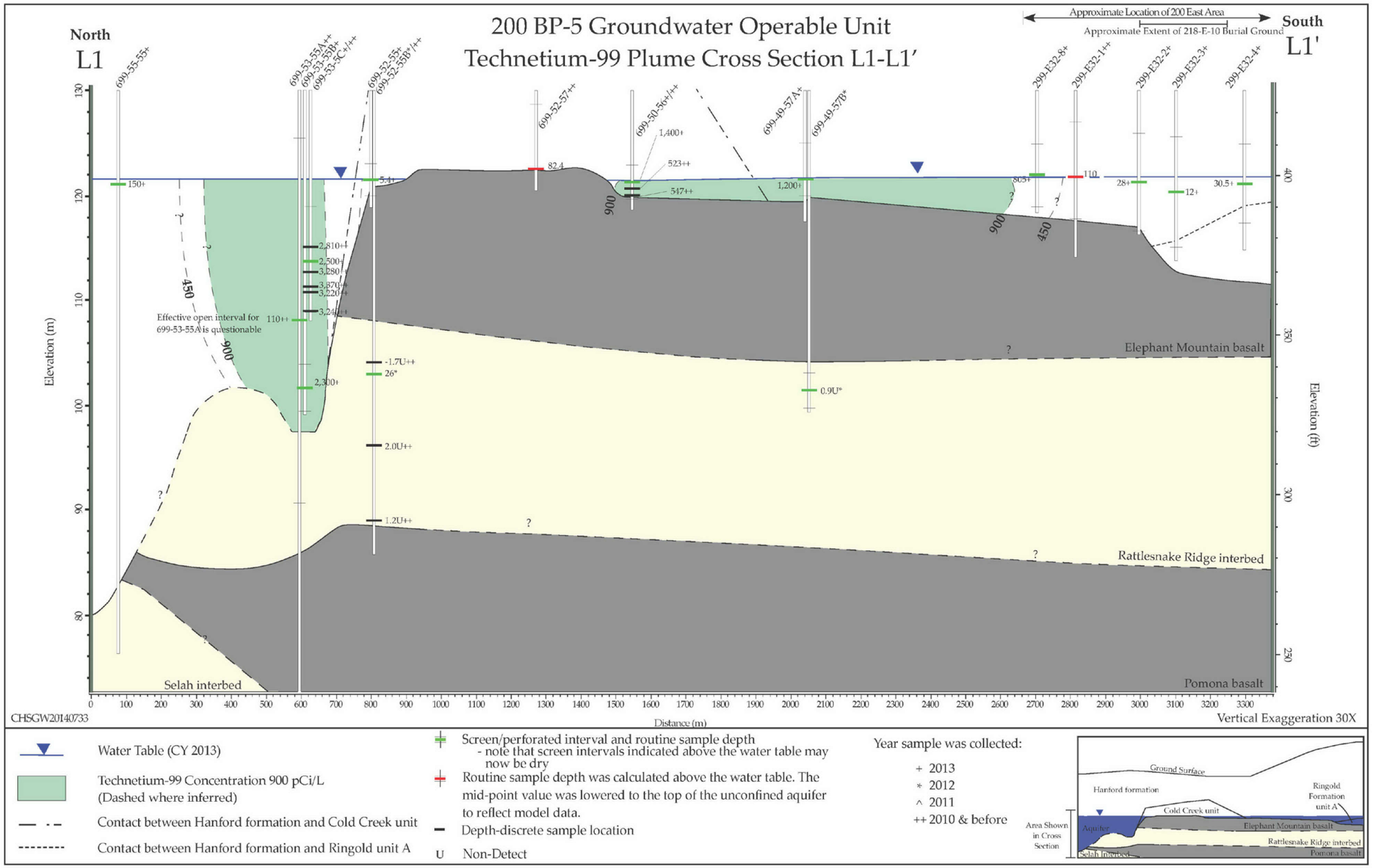


Figure D-8. 200-BP-5 OU L1-L1' Technetium-99 Plume Cross Section

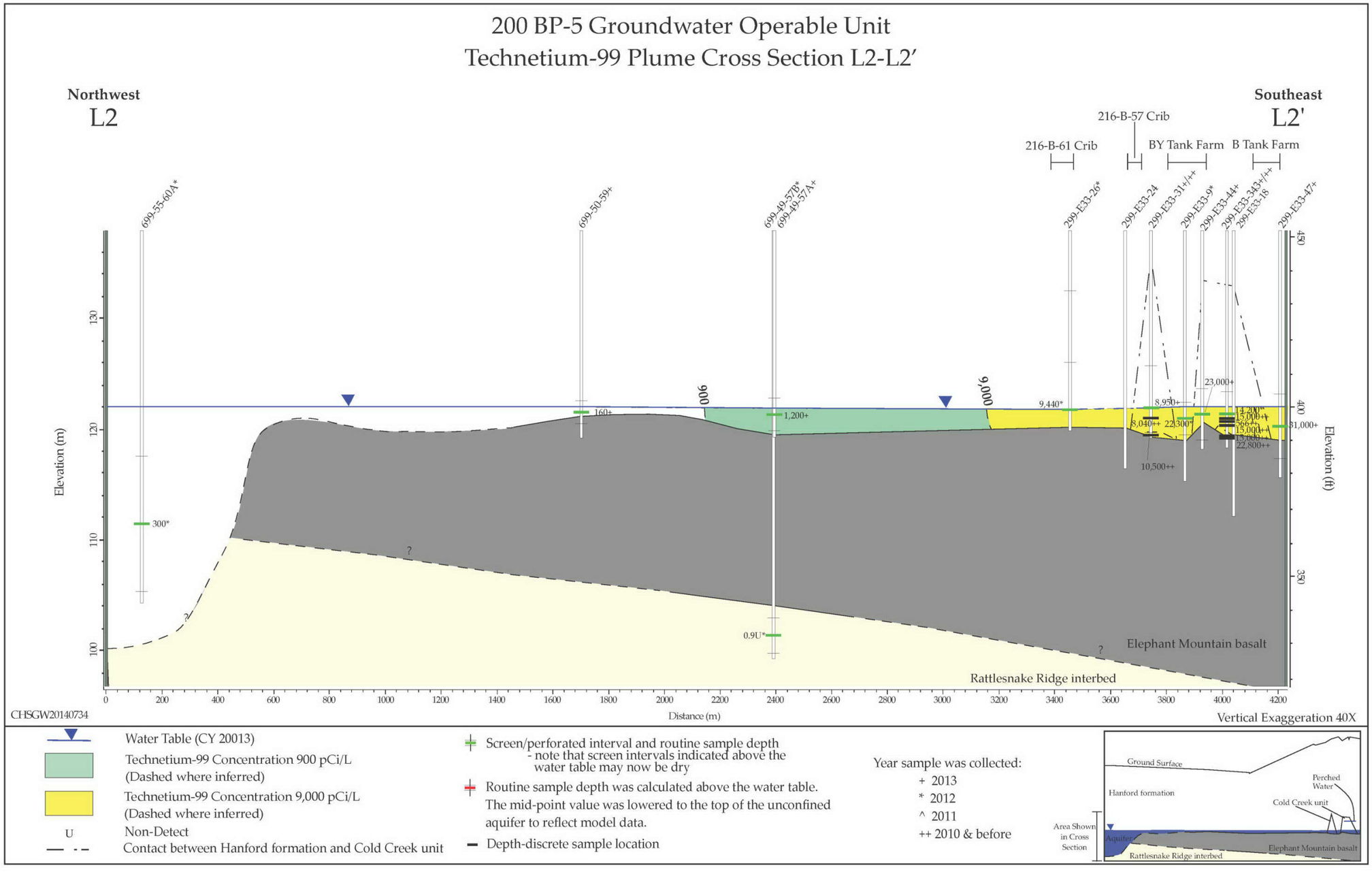


Figure D-9. 200-BP-5 OU L2-L2’ Technetium-99 Plume Cross Section

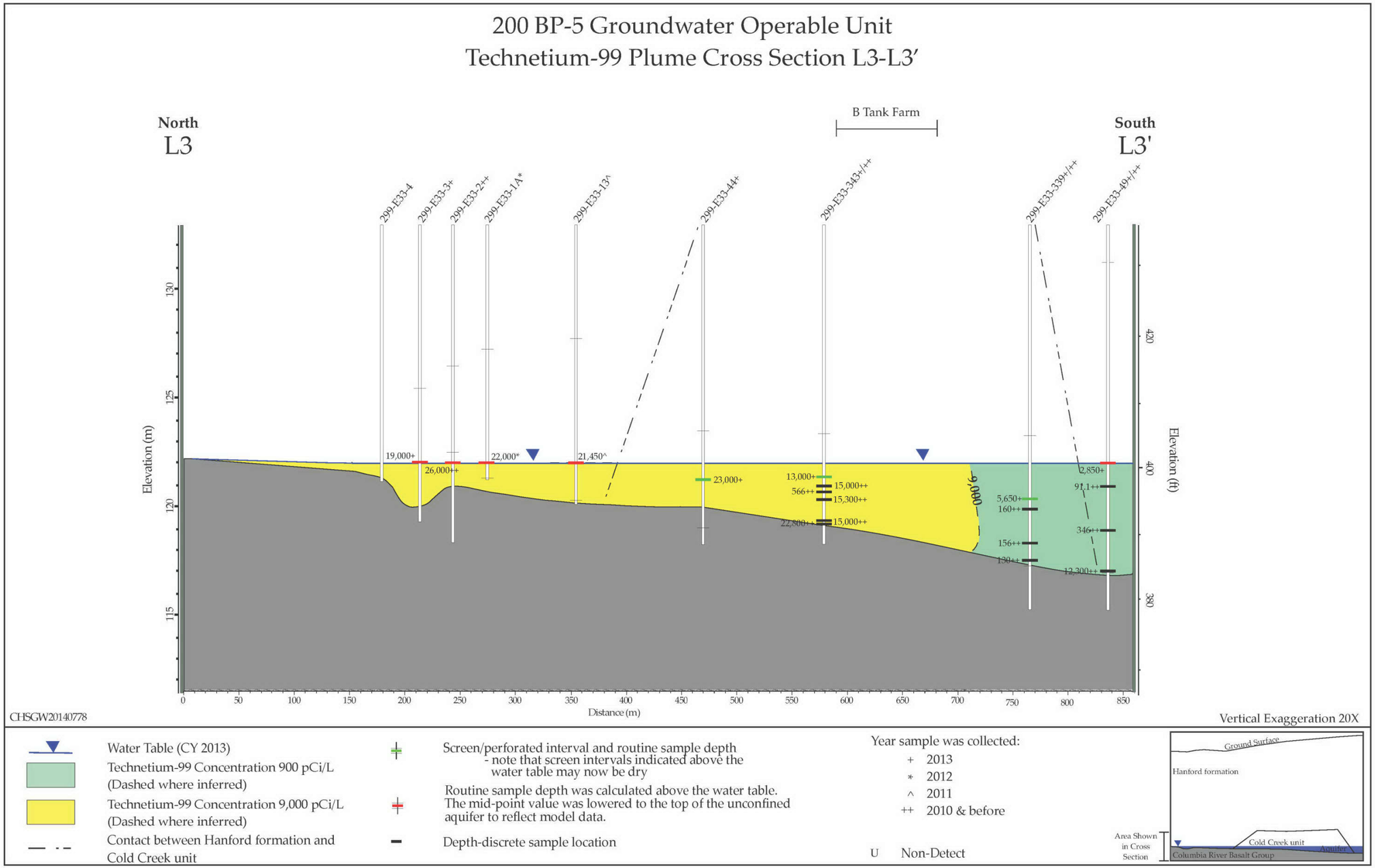
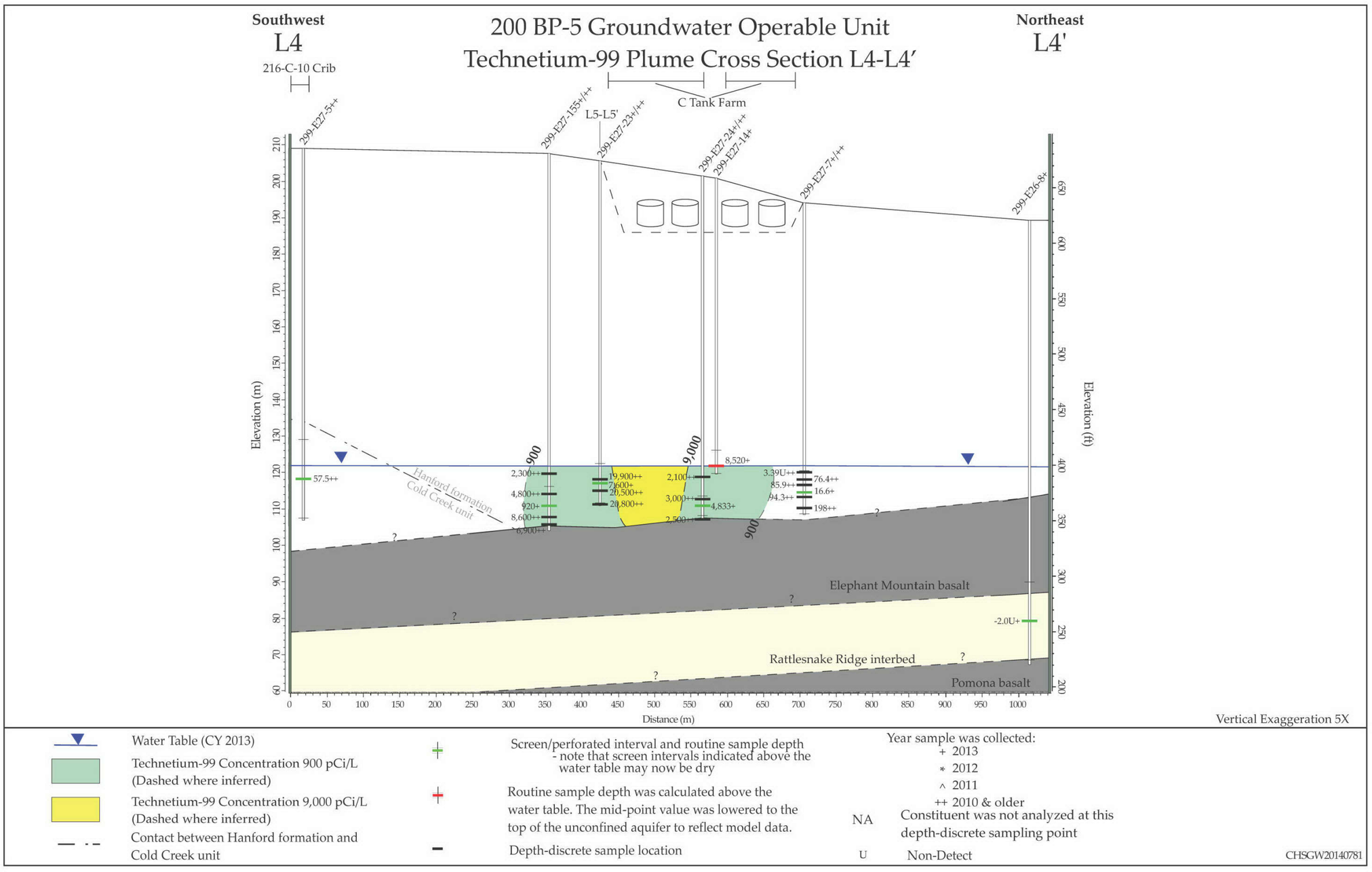


Figure D-10. 200-BP-5 OU L3-L3' Technetium-99 Plume Cross Section



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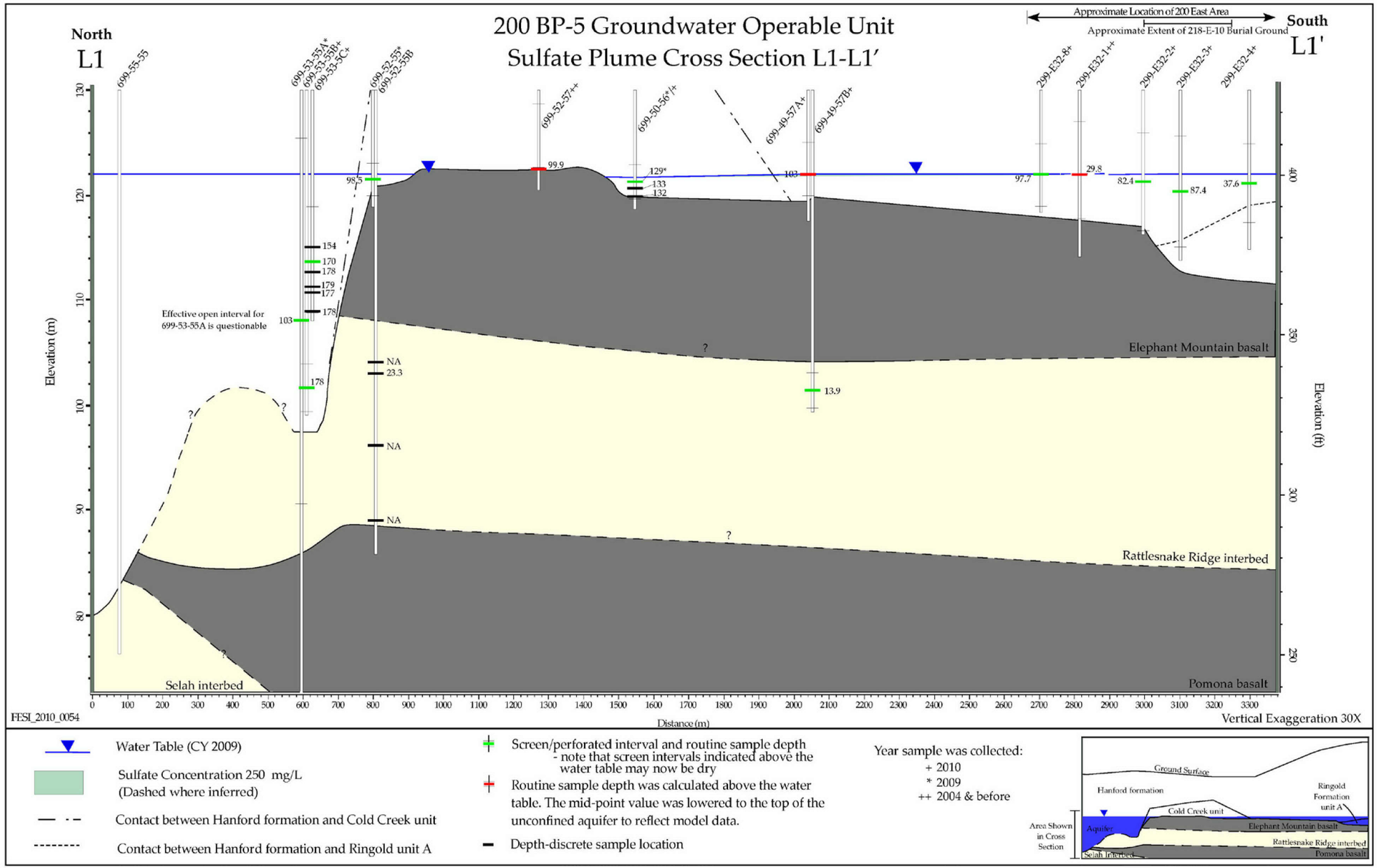

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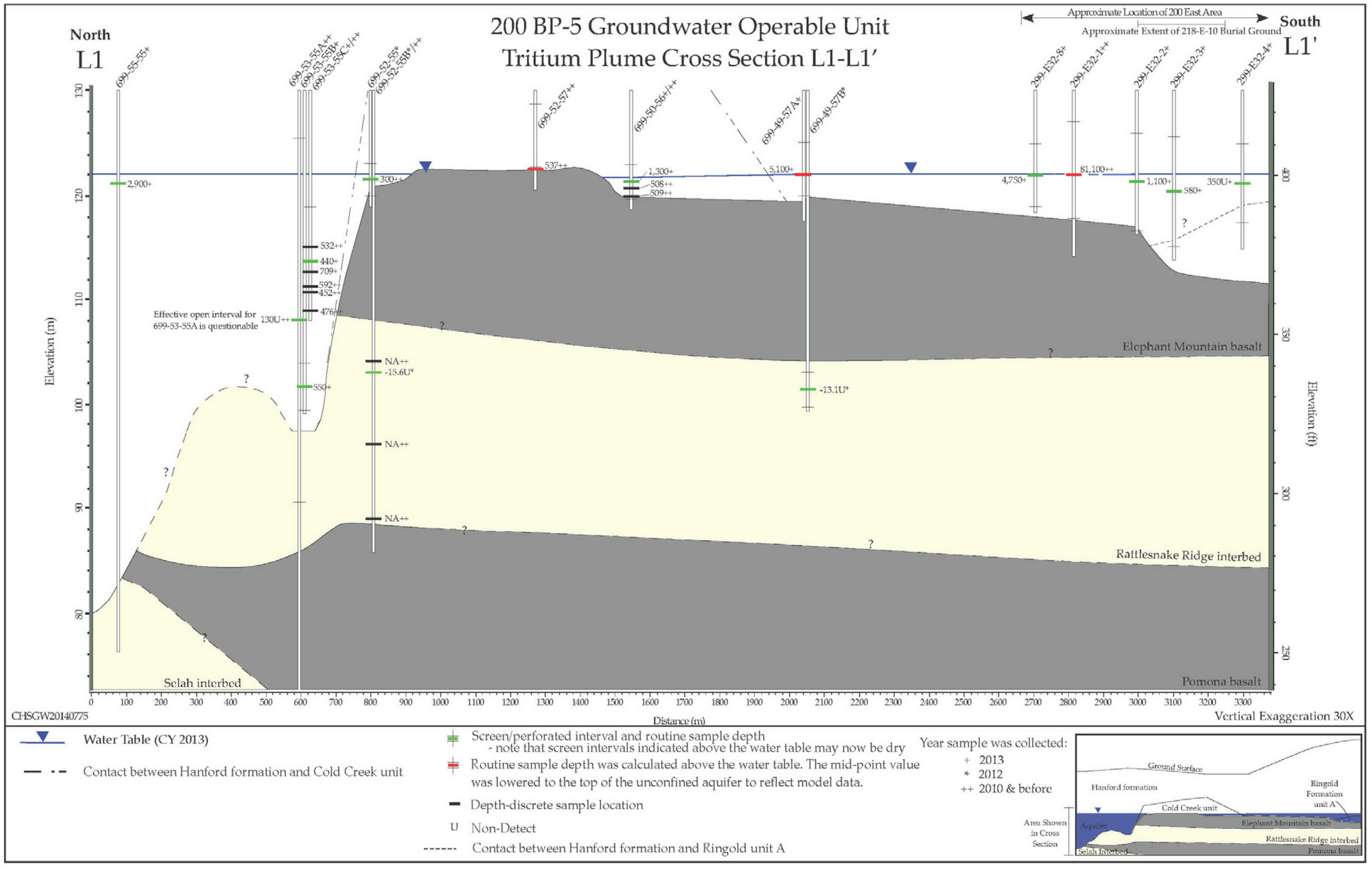


Figure D-13. 200-BP-5 OU L1-L1' Tritium-99 Plume Cross Section

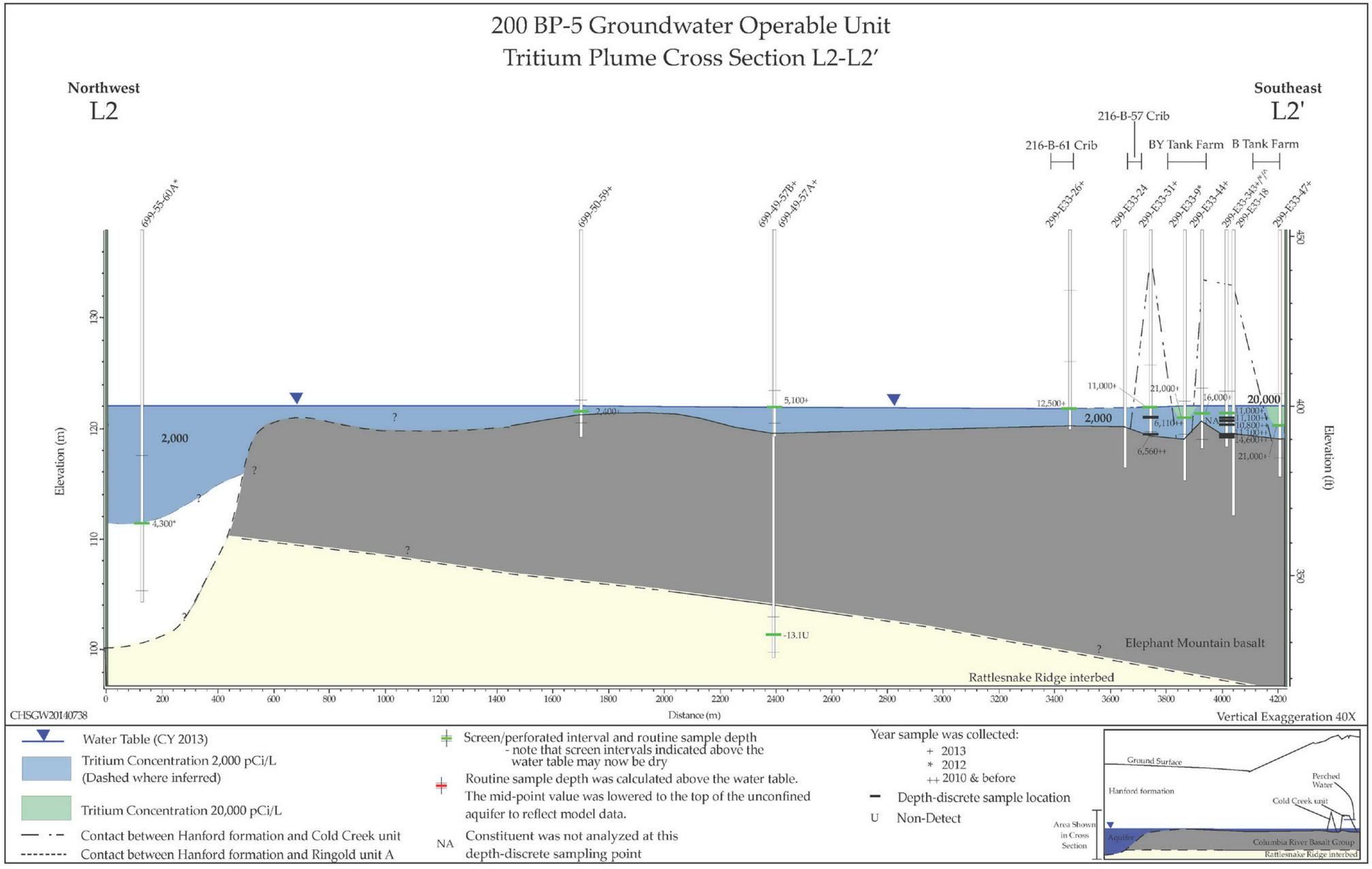
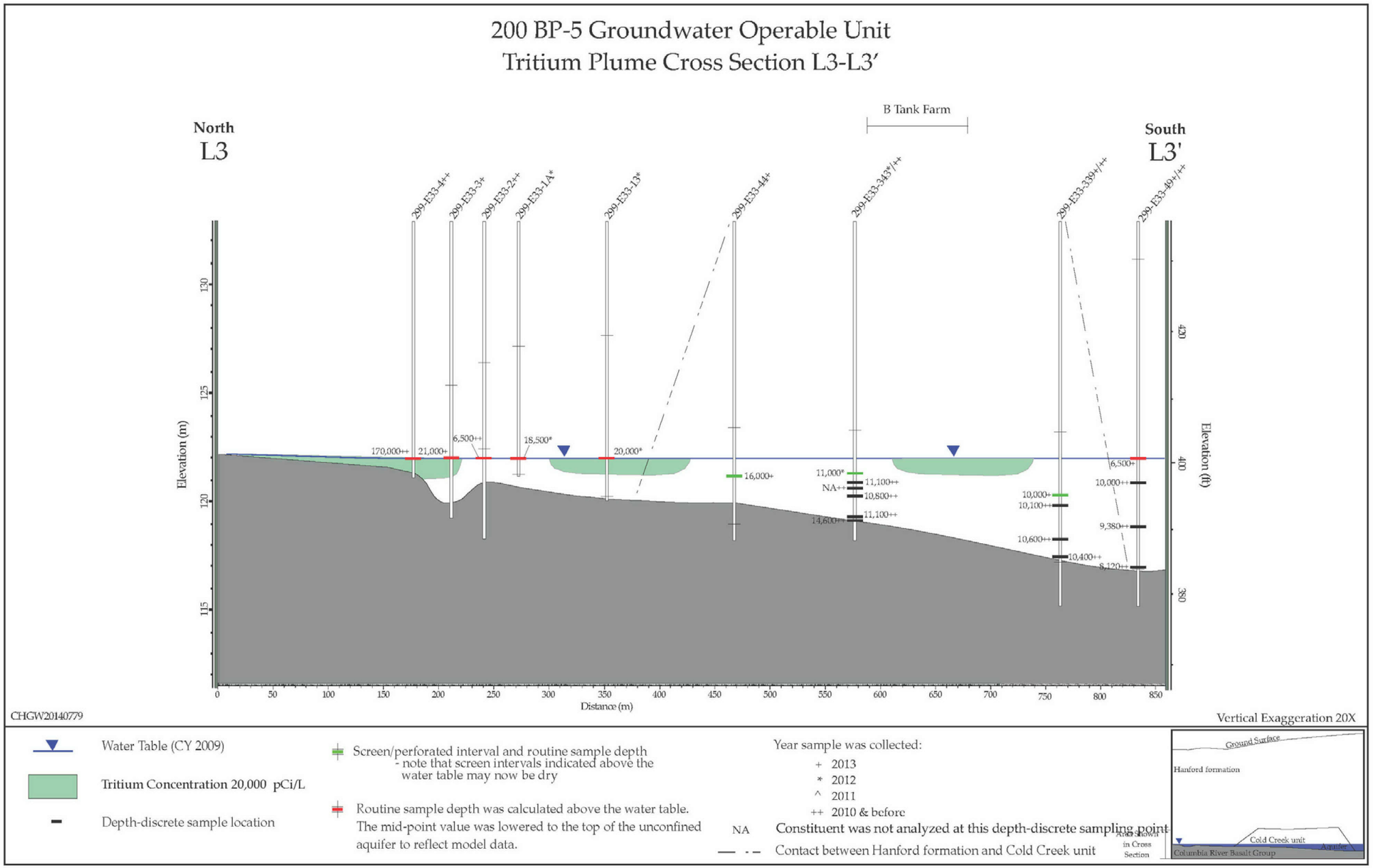


Figure D-14. 200-BP-5 OU L2-L2' Tritium Plume Cross Section



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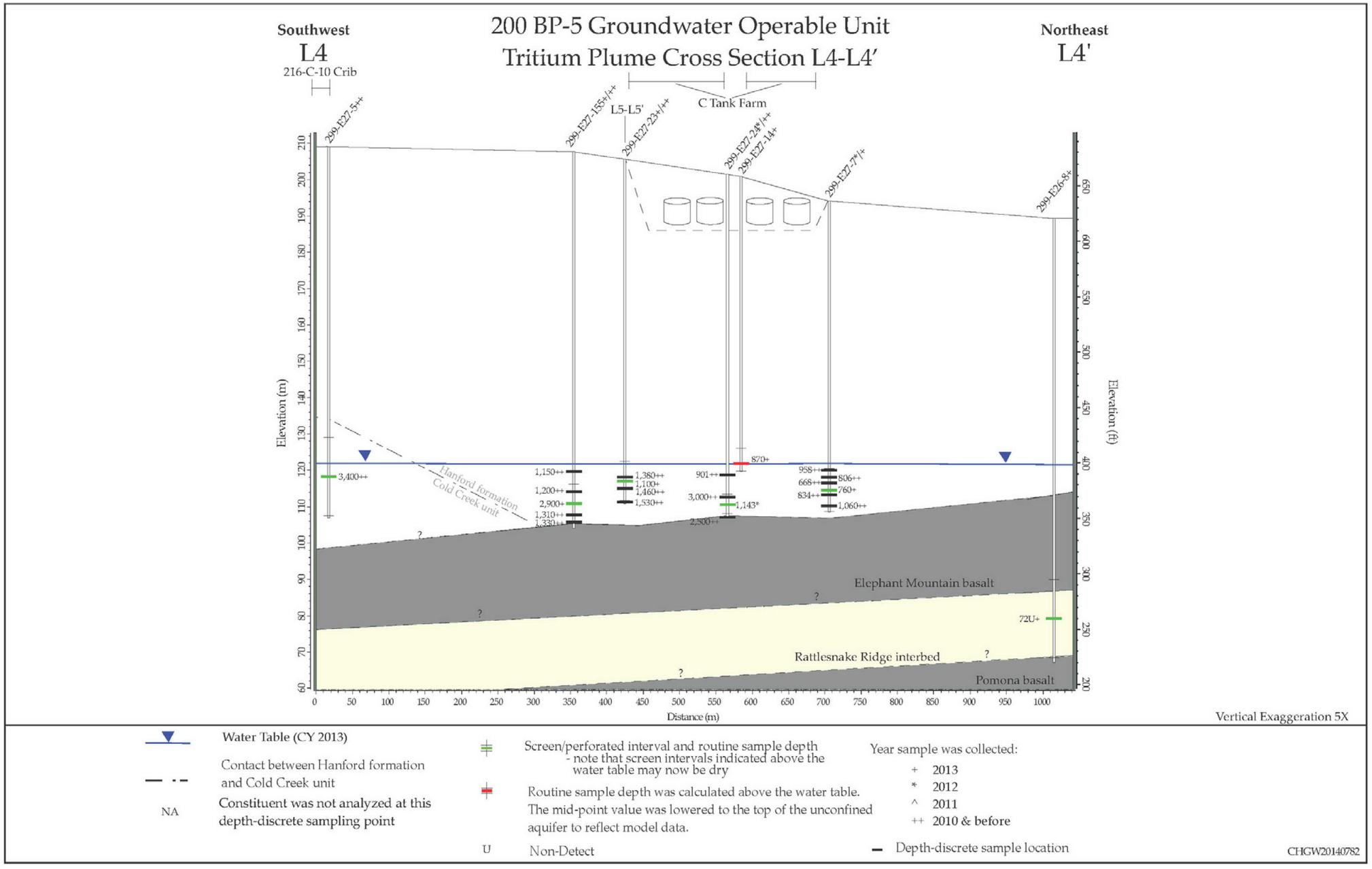

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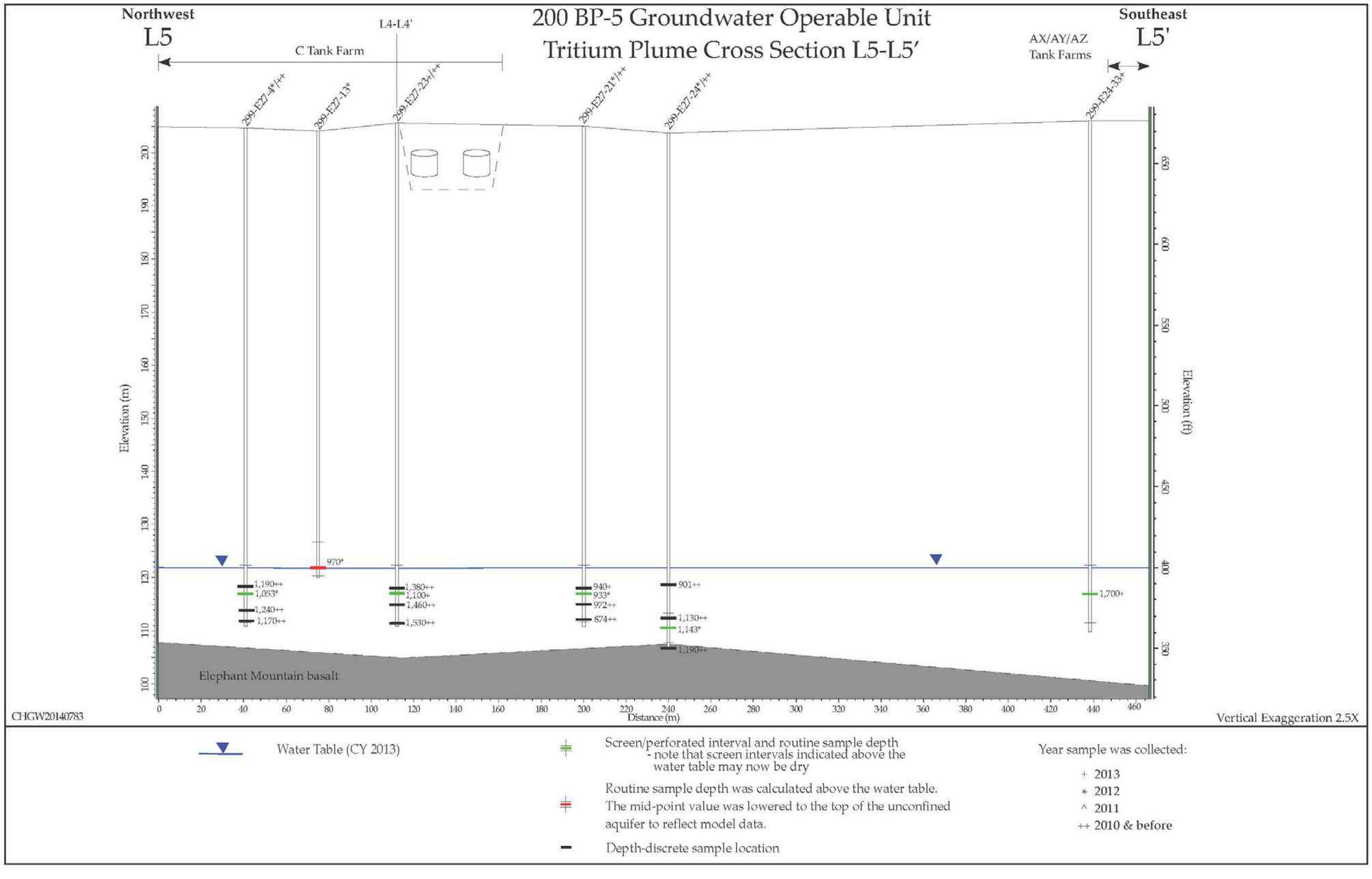

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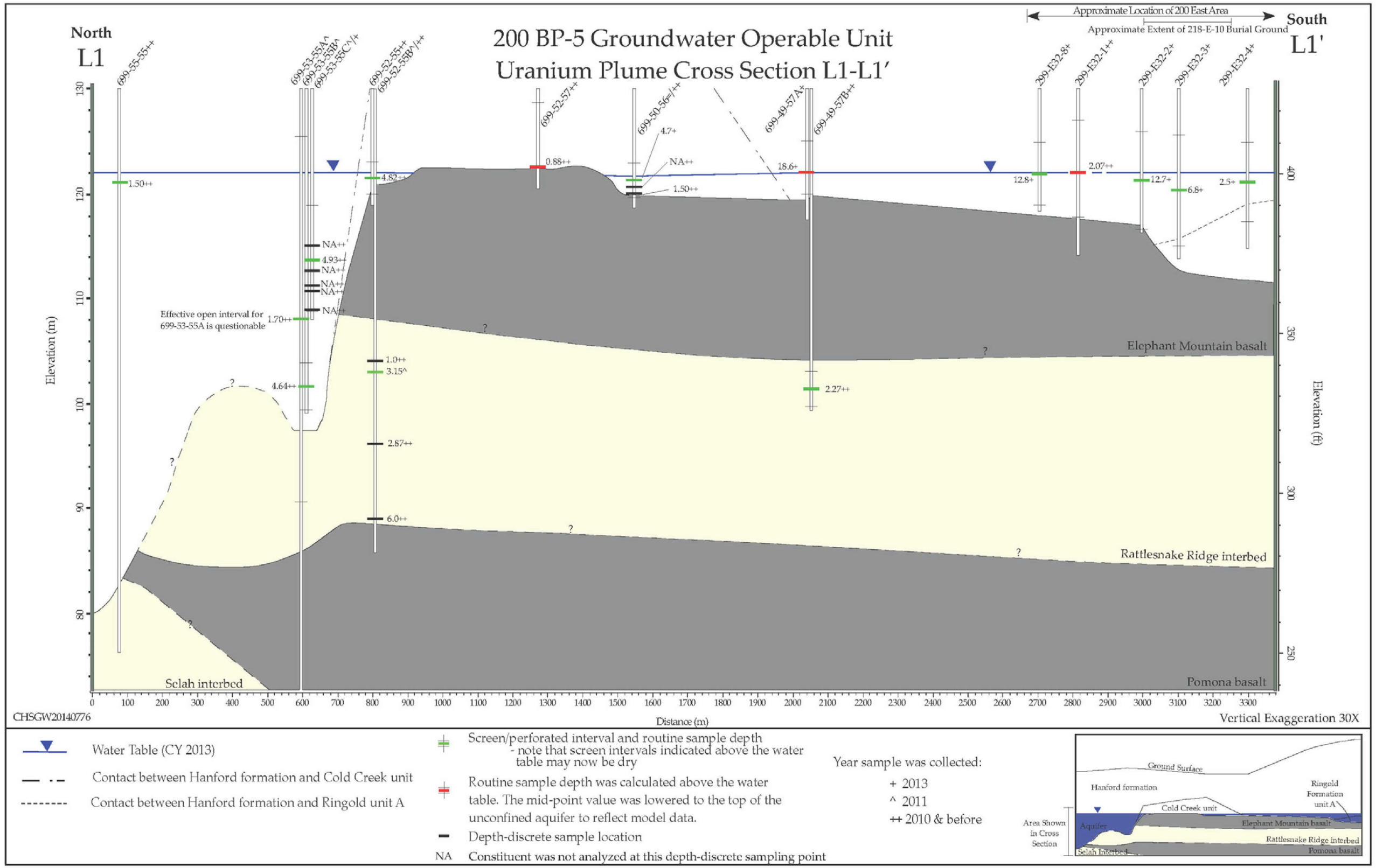
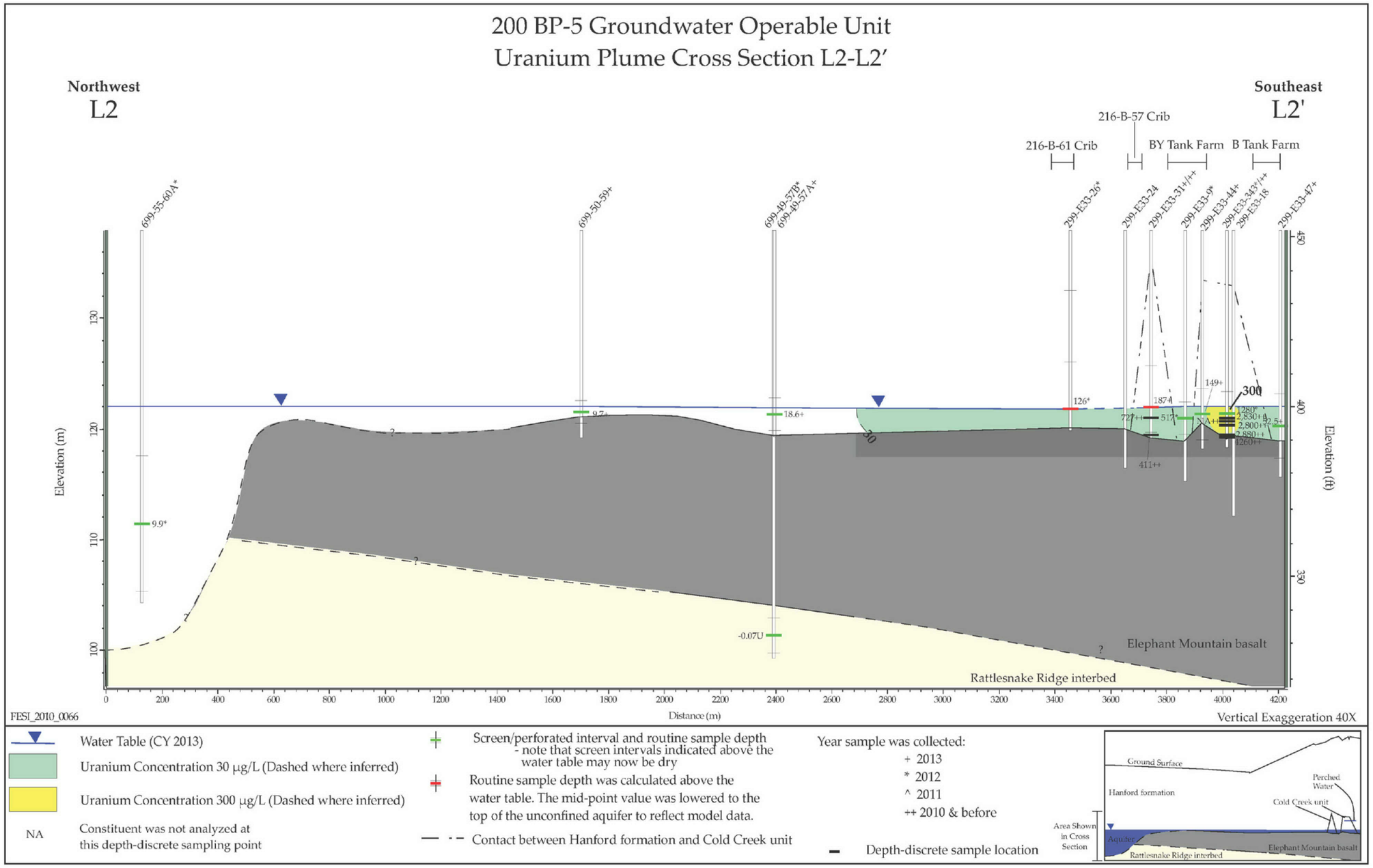


Figure D-18. 200-BP-5 OU L1-L1’ Uranium Plume Cross Section



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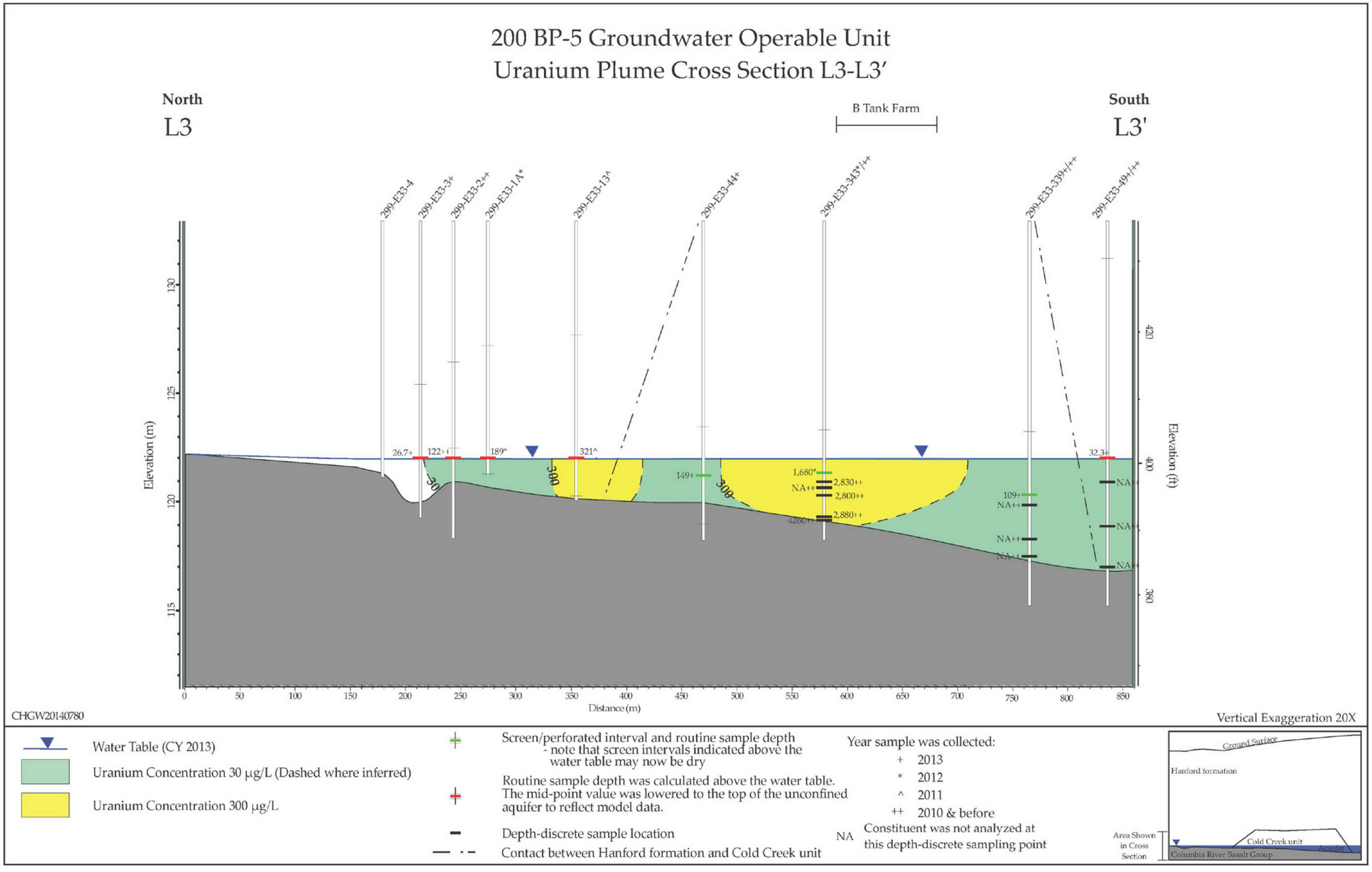

Figure D-20. 200-BP-5 OU L3-L3' Uranium Plume Cross Section

Appendix E

Groundwater Summary Statistics and Time Series

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Terms

CCC	criteria continuous concentration
ICP/AES	inductively coupled plasma/atomic emission spectroscopy
ICP/MS	inductively coupled plasma/mass spectrometry
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
MCL	maximum contaminant level
MCLG	maximum contaminant level guideline
OU	operable unit
WMA	waste management area

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E1 Introduction

This appendix contains figures (Figures E-1 through E-85) and tables (Tables E-1 through E-12), which provide additional information on groundwater summary statistics and time series for the 200-BP-5 Groundwater Operable Unit.

E2 References

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol22/xml/CFR-2010-title40-vol22-part141.xml.

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DOE/RL-96-61, 1997, *Hanford Site Background: Part 3, Groundwater Background*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D197226378.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A.

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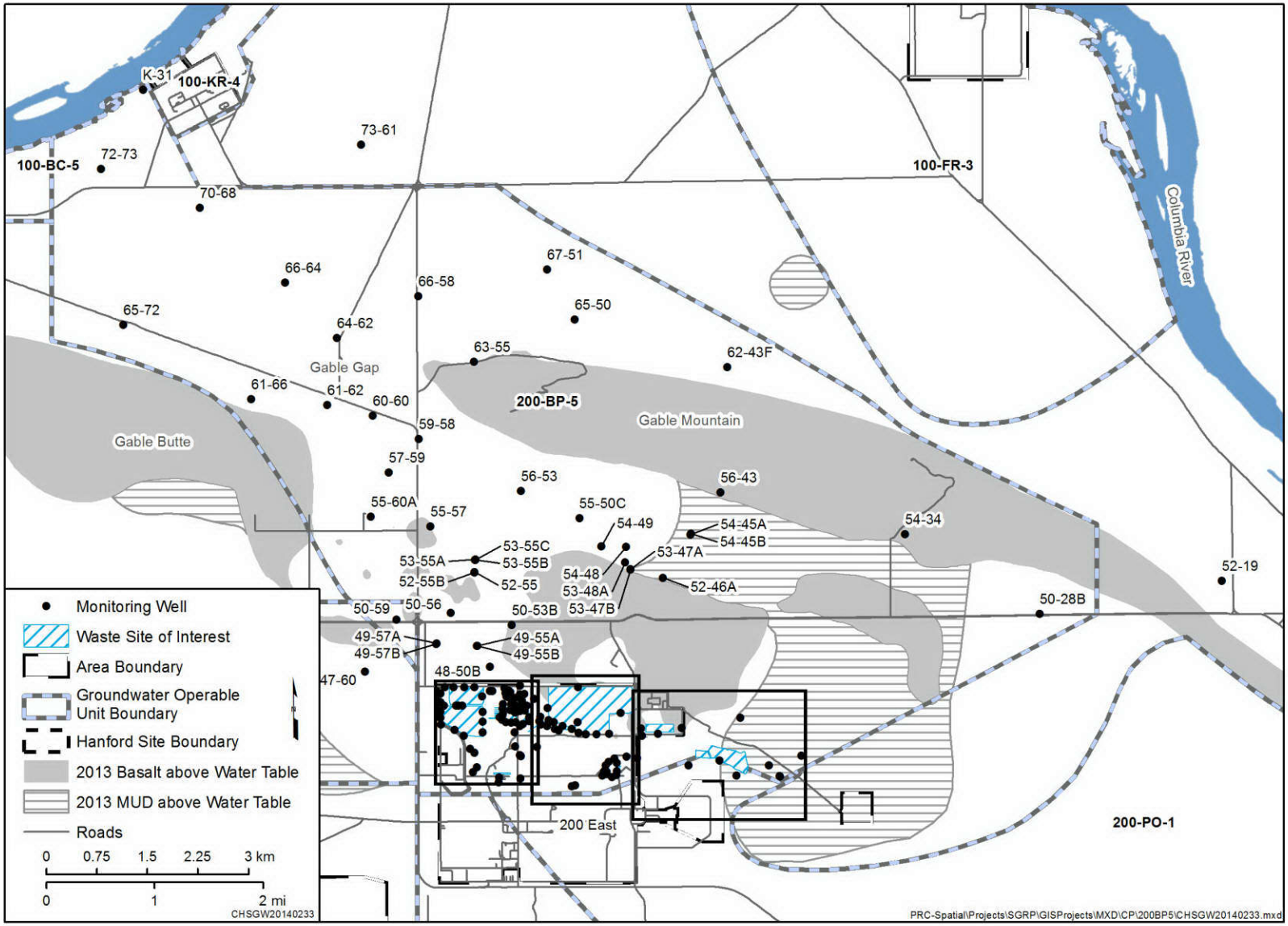

Figure E-1. Overview of 200-BP-5 OU and Monitoring Wells Located in the Far-Field Area

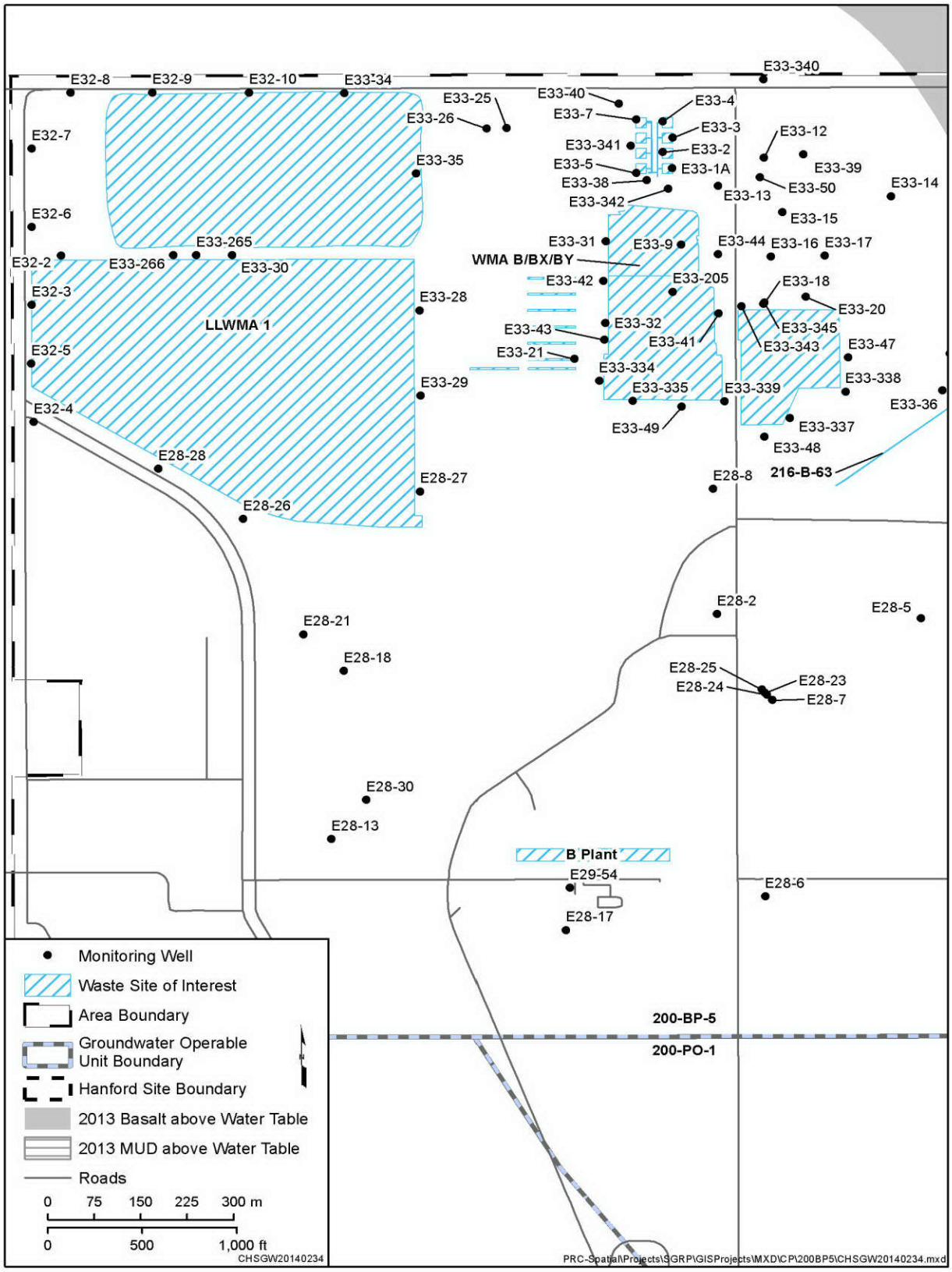

Figure E-2. Monitoring Wells Located in LLWMA-1 and WMA B-BX-BY Tank Farms

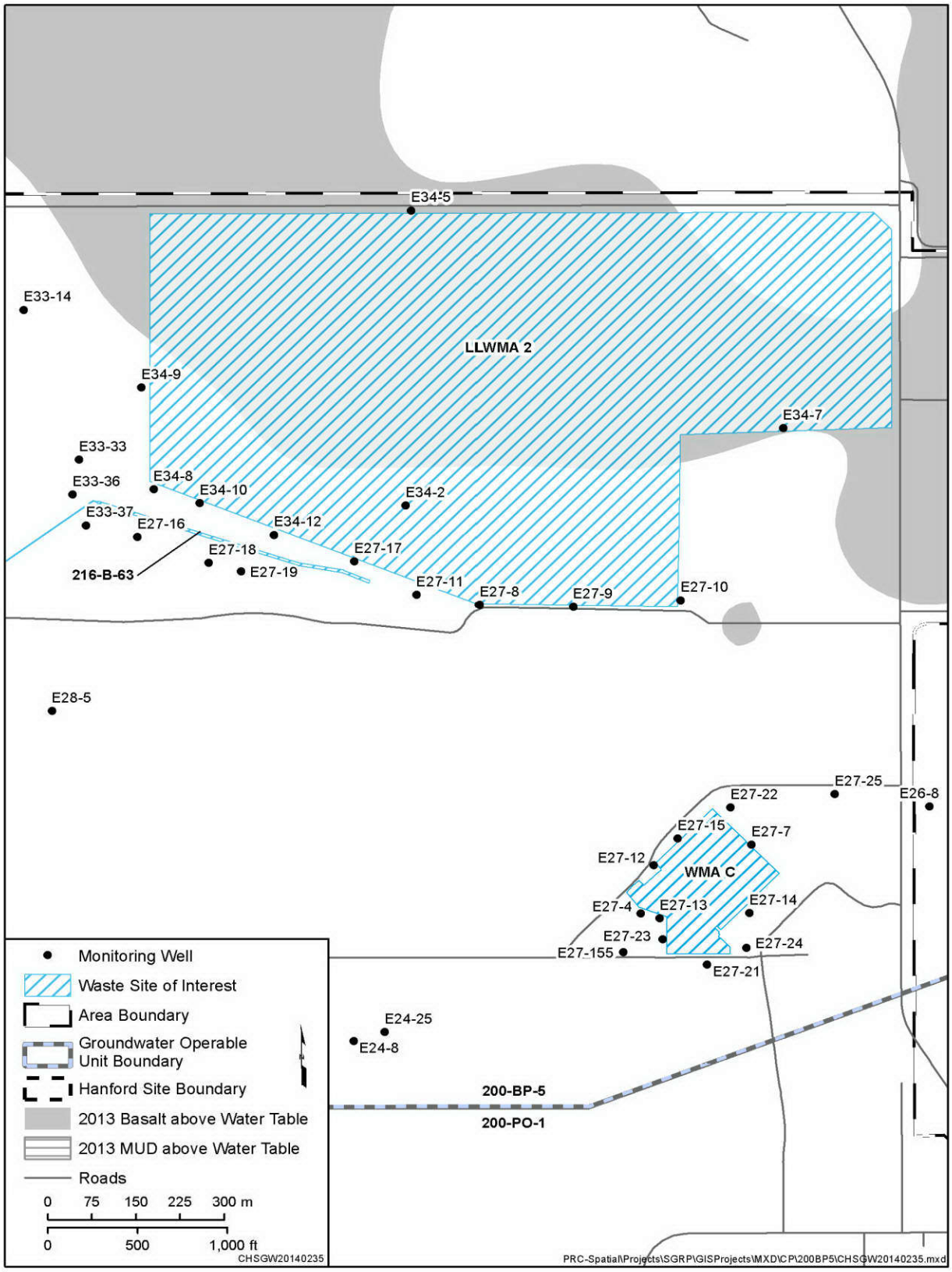

Figure E-3. Monitoring Wells Located in LLWMA-2 and 216-B-63 Trench

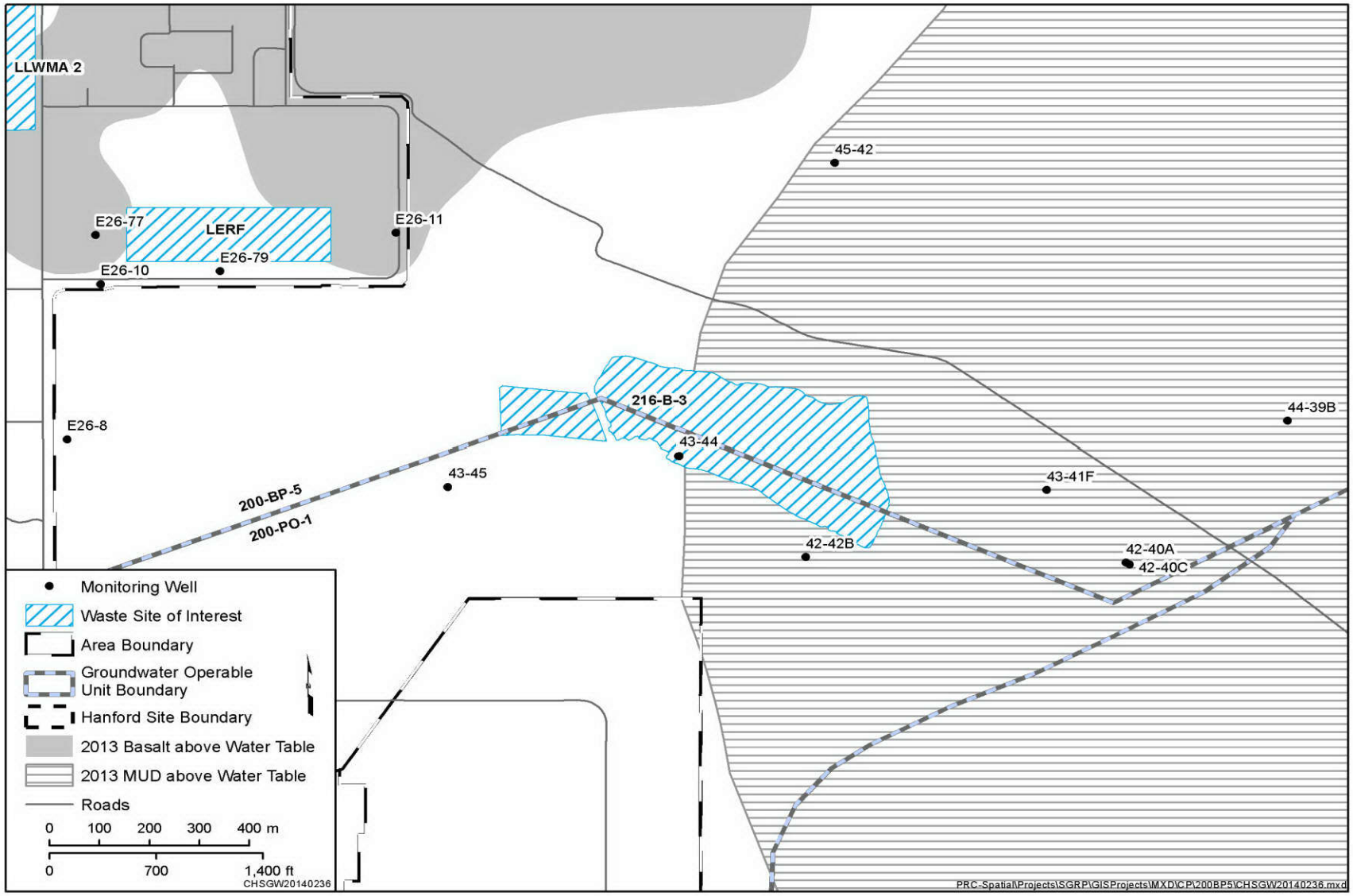

Figure E-4. Monitoring Wells Located in LERF

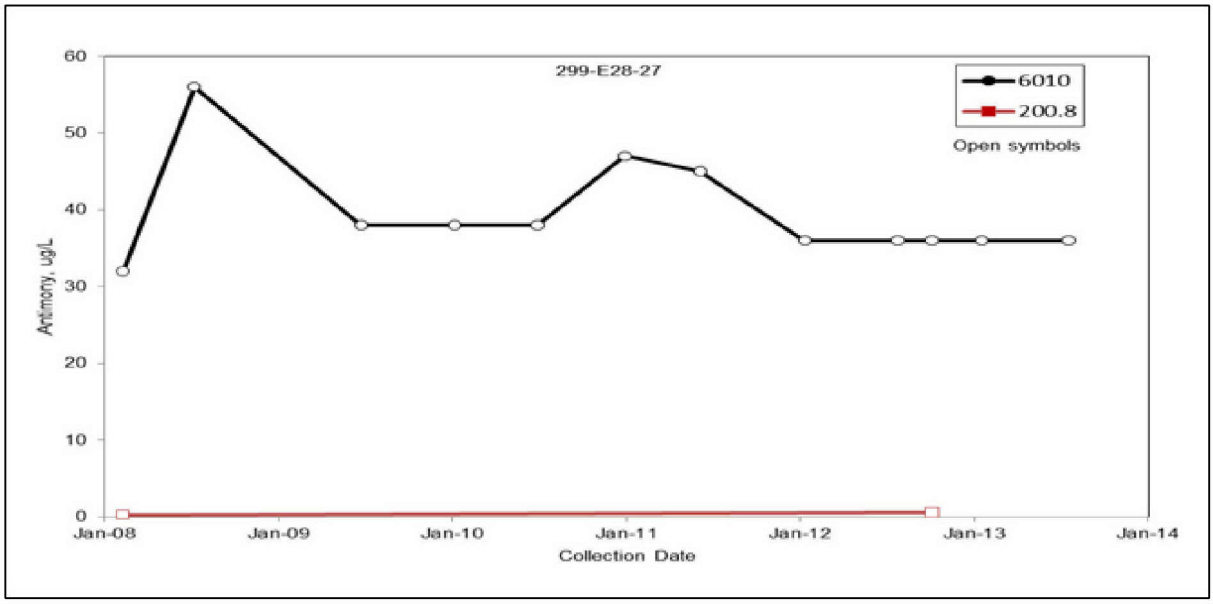

Figure E-5. Antimony Concentrations in Well 299-E28-27 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

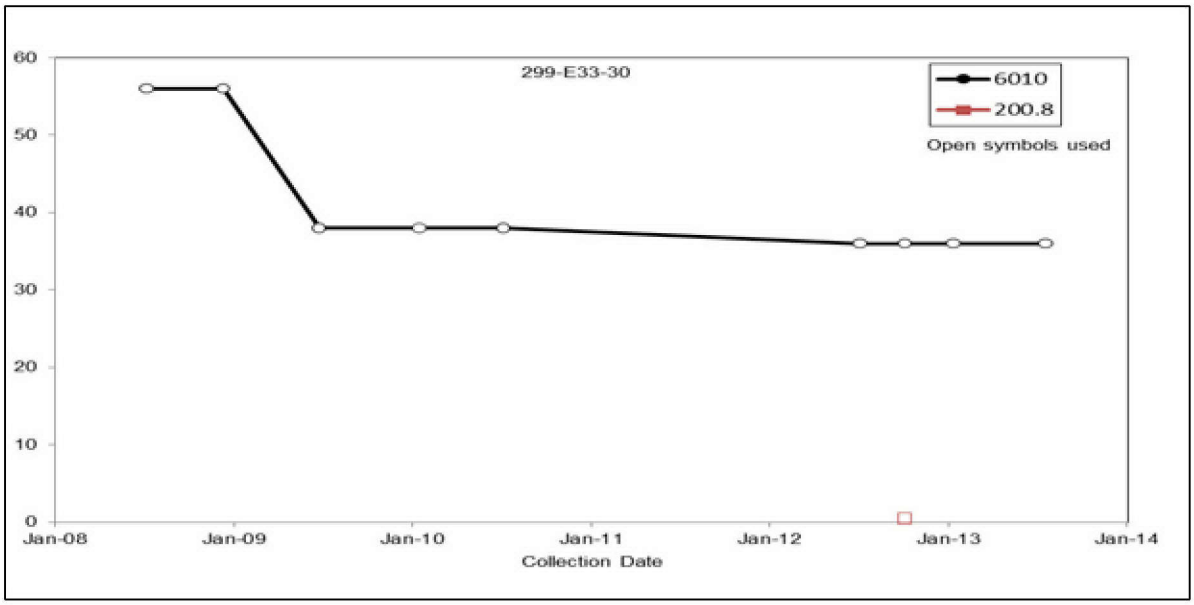

Figure E-6. Antimony Concentrations in Well 299-E33-30 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

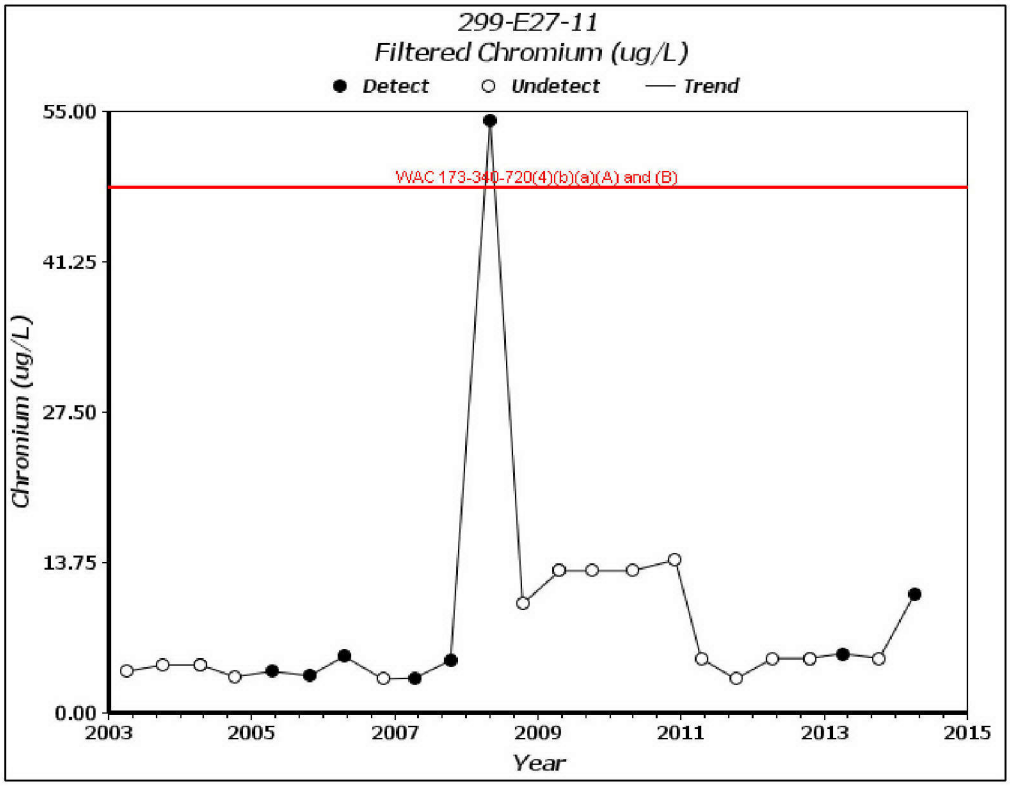

Figure E-7. Dissolve Chromium Concentrations in Well 299-E27-11

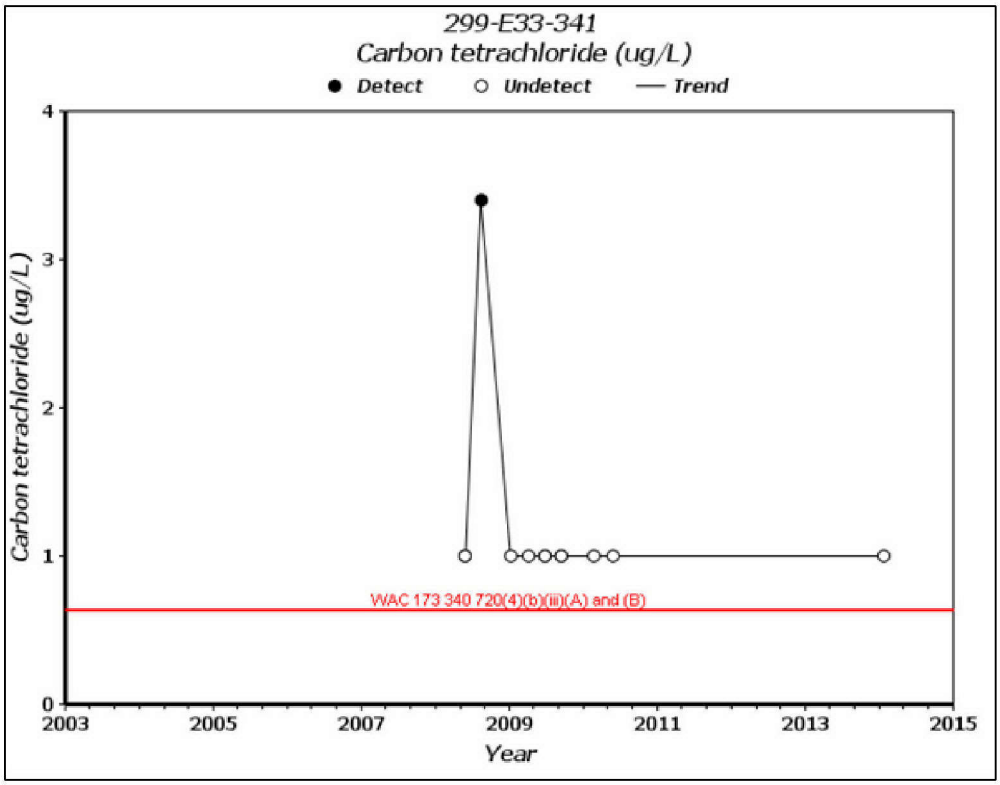

Figure E-8. Carbon Tetrachloride Concentrations in Well 299-E33-341

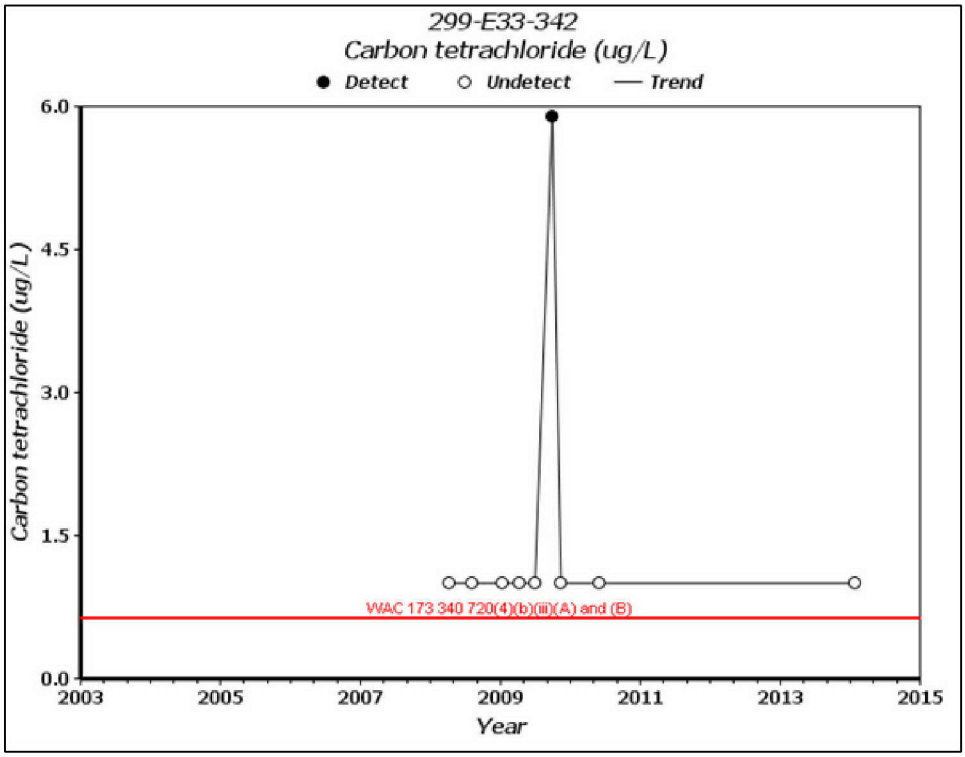

Figure E-9. Carbon Tetrachloride Concentrations in Well 299-E33-342

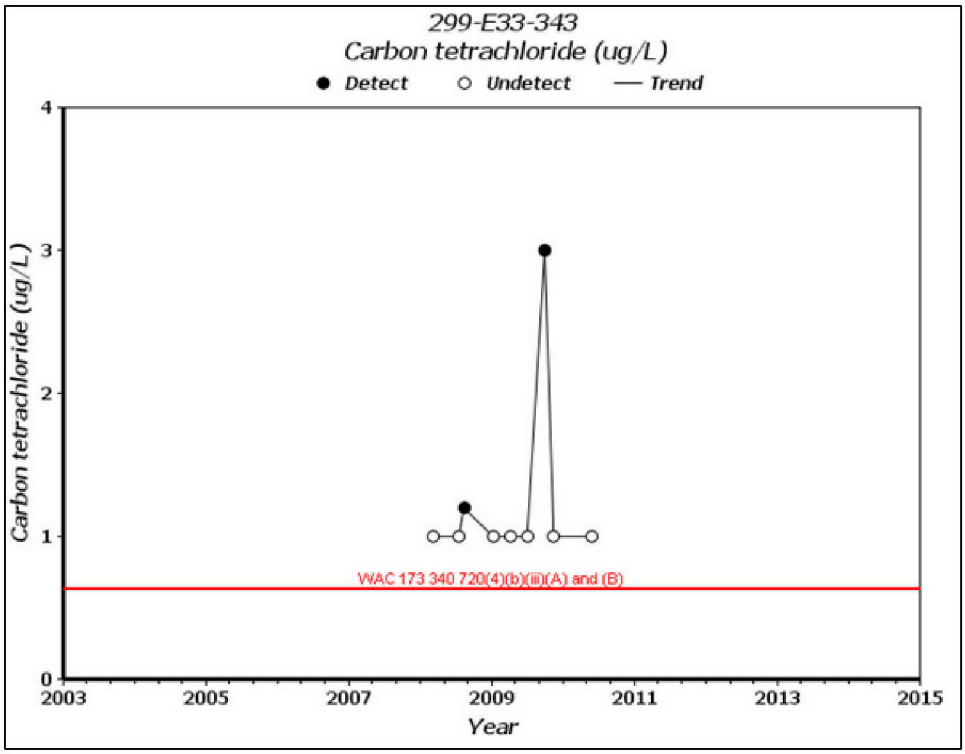

Figure E-10. Carbon Tetrachloride Concentrations in Well 299-E33-343

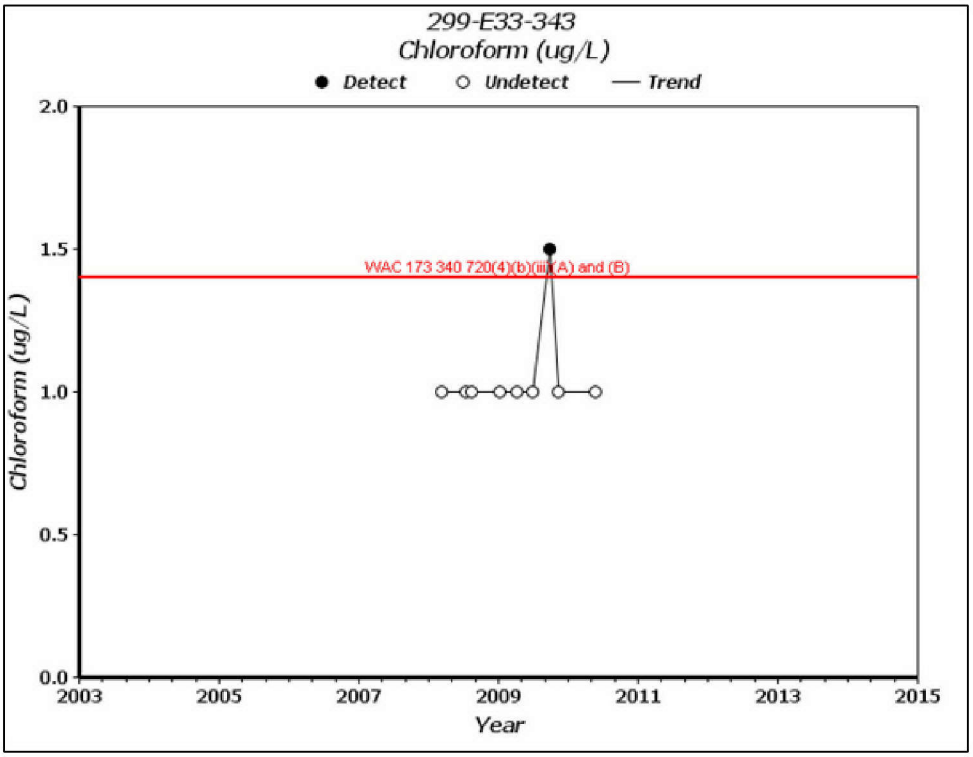

Figure E-11. Chloroform Concentrations in Well 299-E33-343

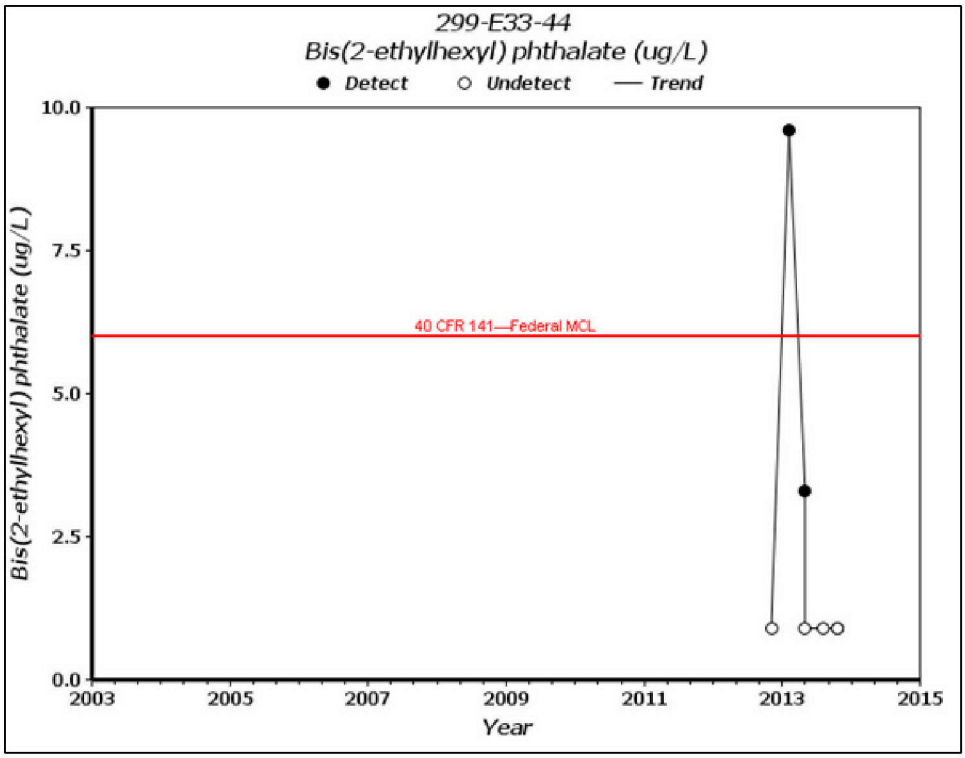

Figure E-12. Bis(2-ethylhexyl) phthalate Concentrations in Well 299-E33-44

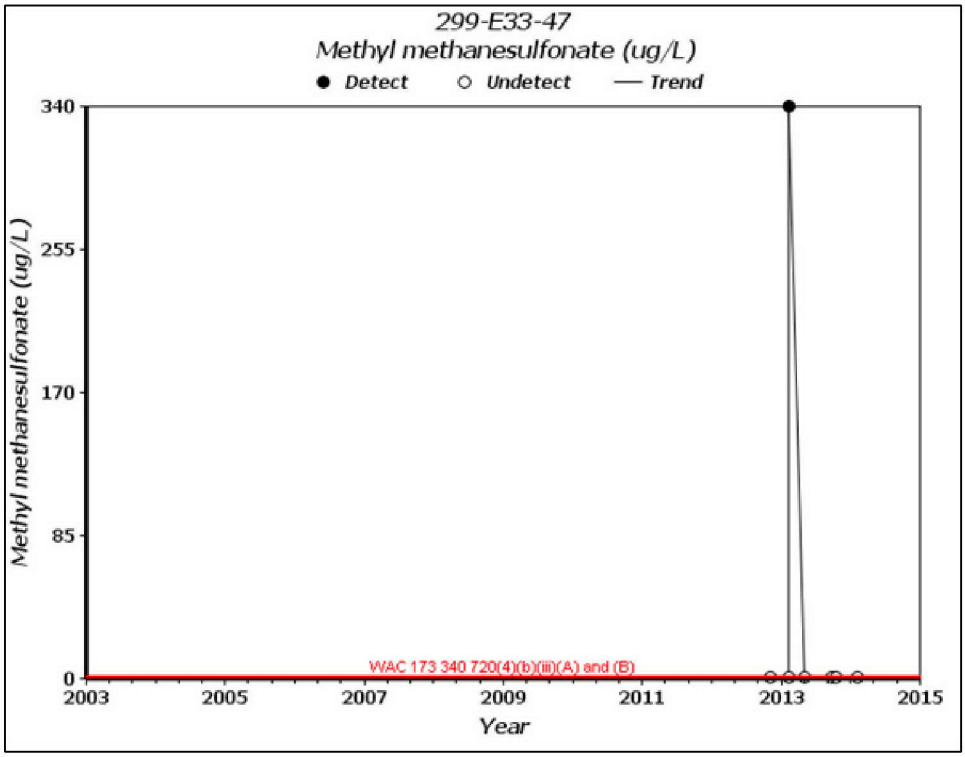

Figure E-13. Methyl Methanesulfonate Concentrations in Well 299-E33-47

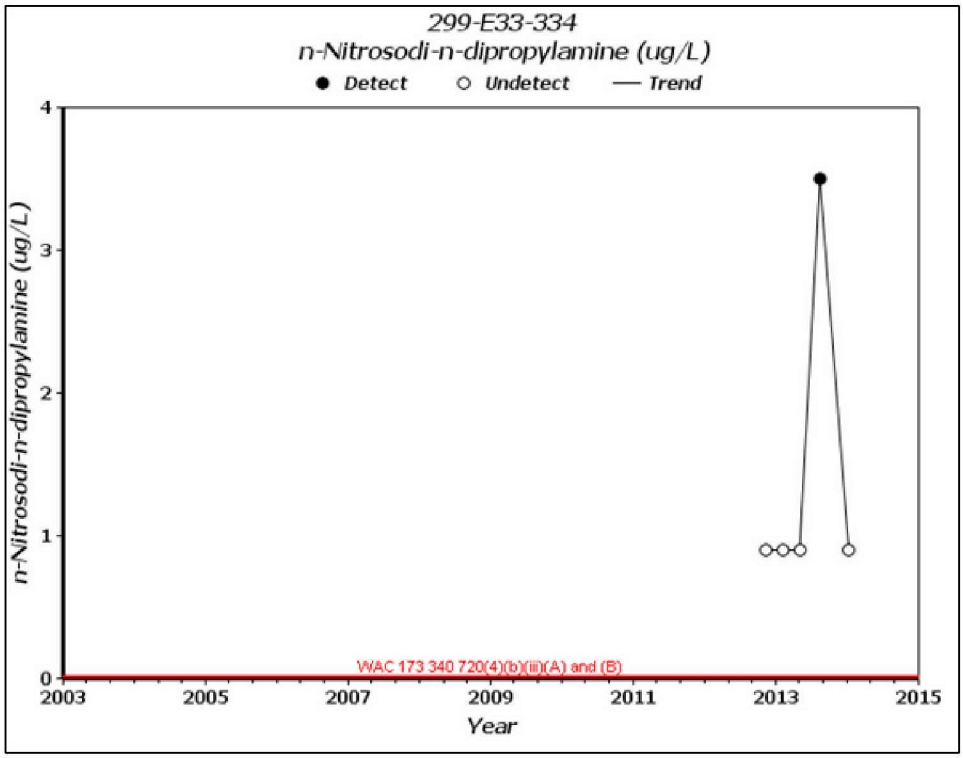

Figure E-14. n-Nitrosodi-n-dipropylamine Concentrations in Well 299-E33-334

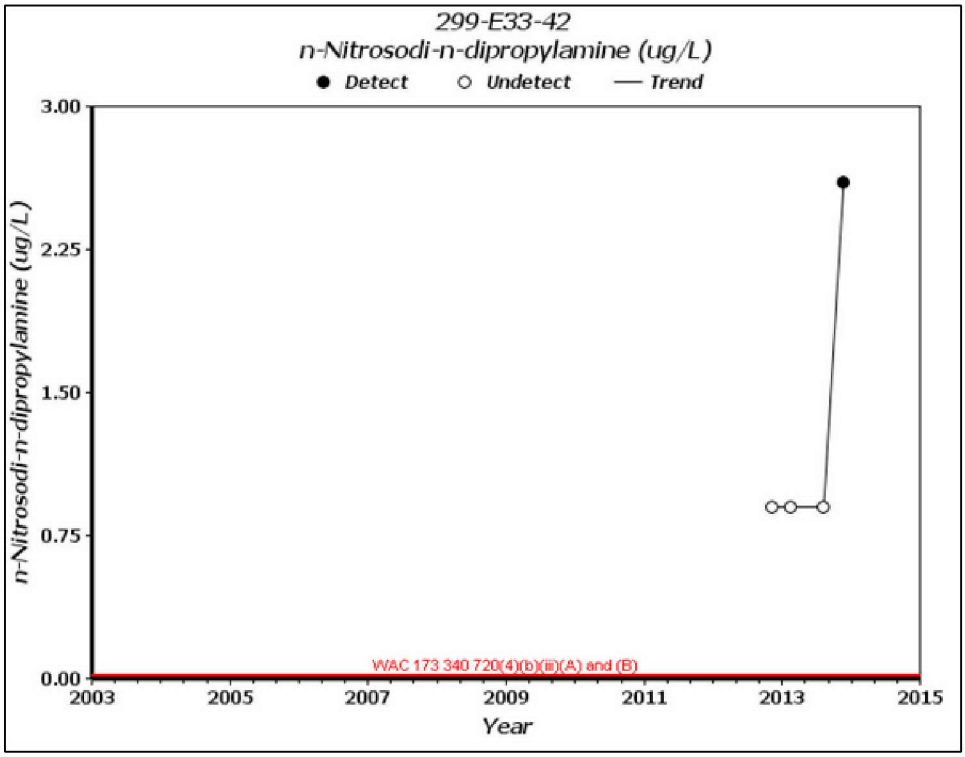

Figure E-15. n-Nitrosodi-n-dipropylamine Concentrations in Well 299-E33-42

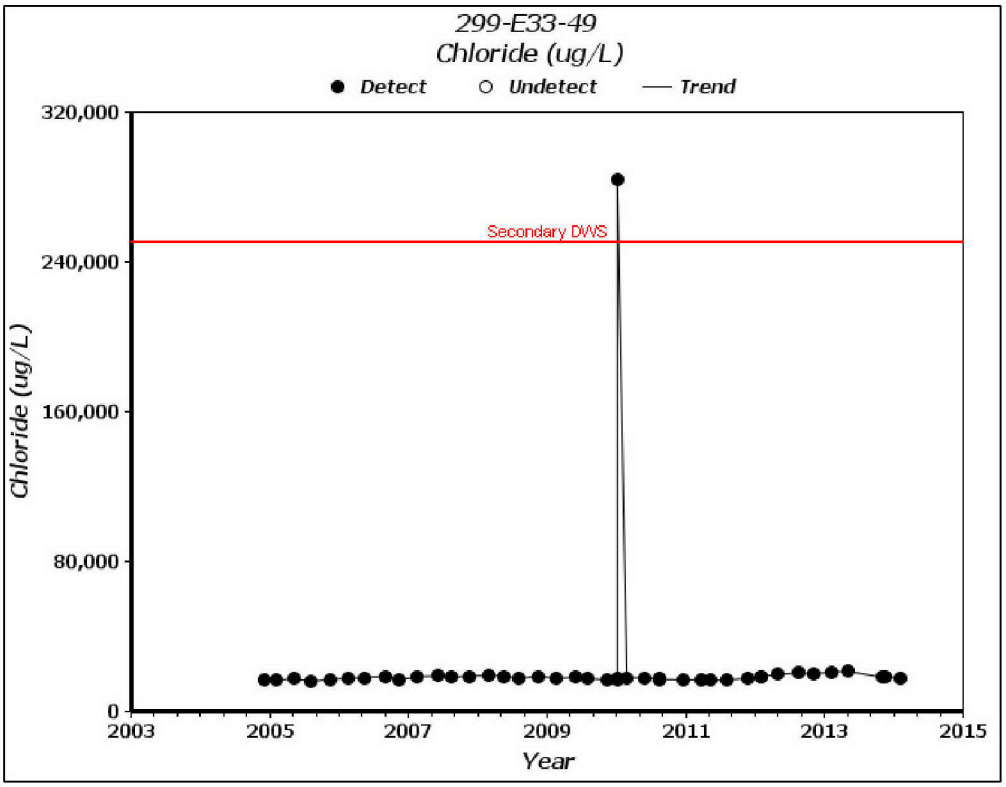

Figure E-16. Chloride Concentrations in Well 299-E33-49

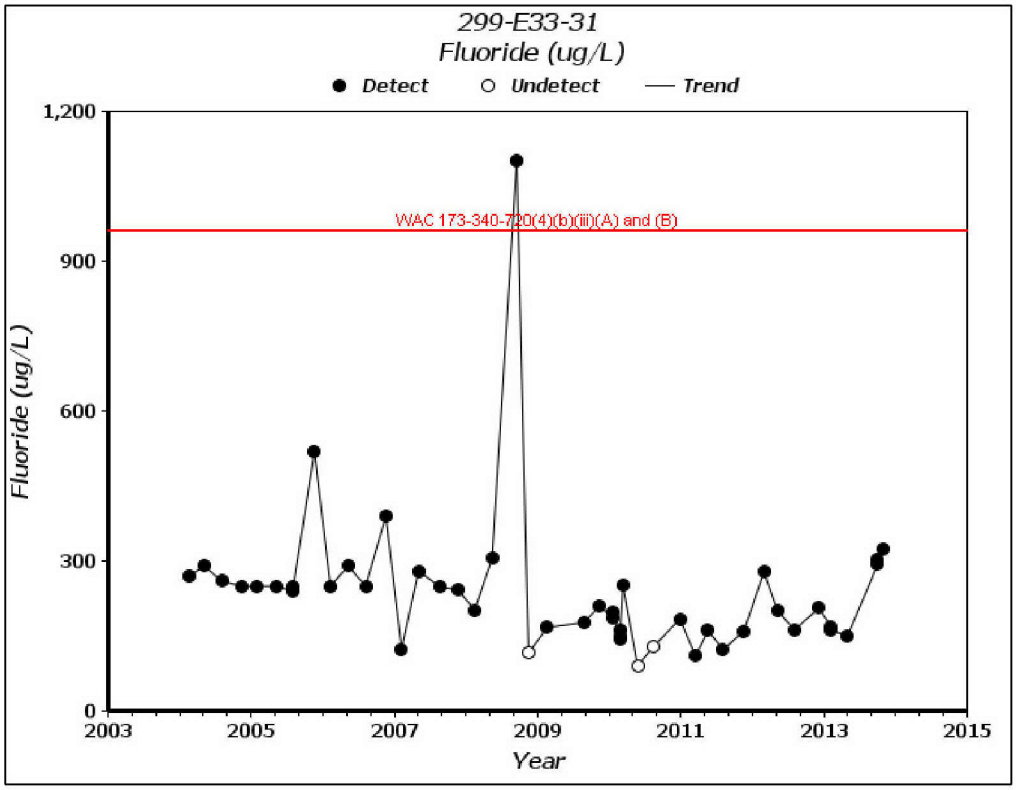

Figure E-17. Fluoride Concentrations in Well 299-E33-31

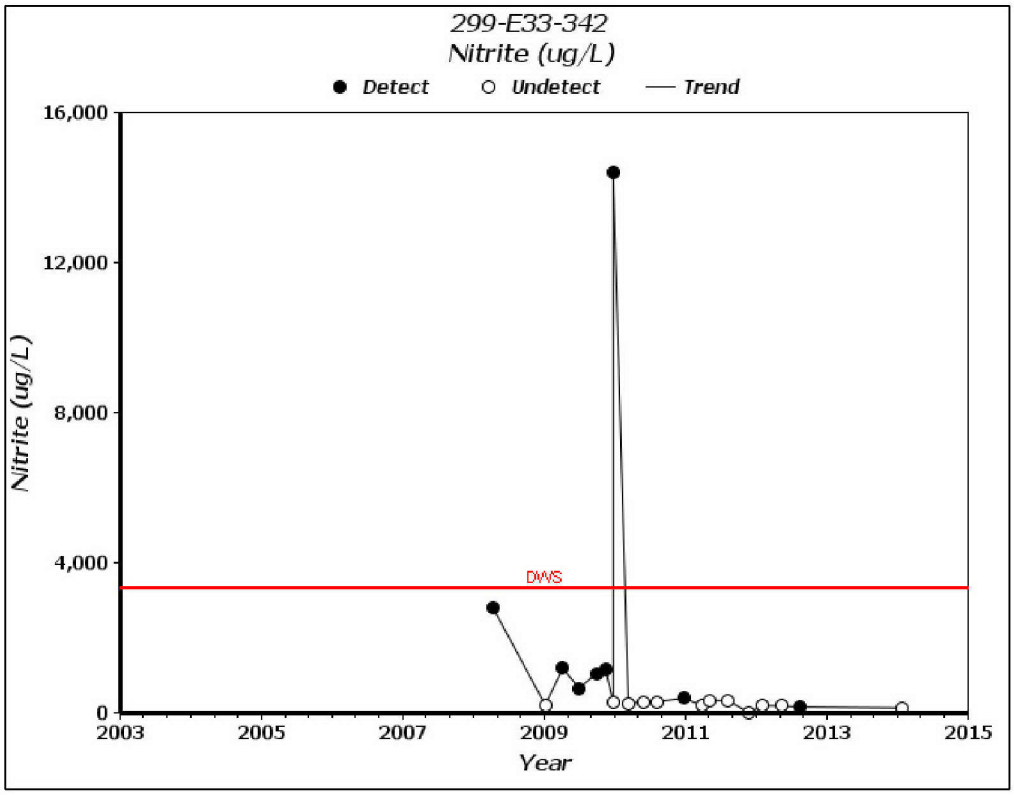

Figure E-18. Nitrite Concentrations in Well 299-E33-342

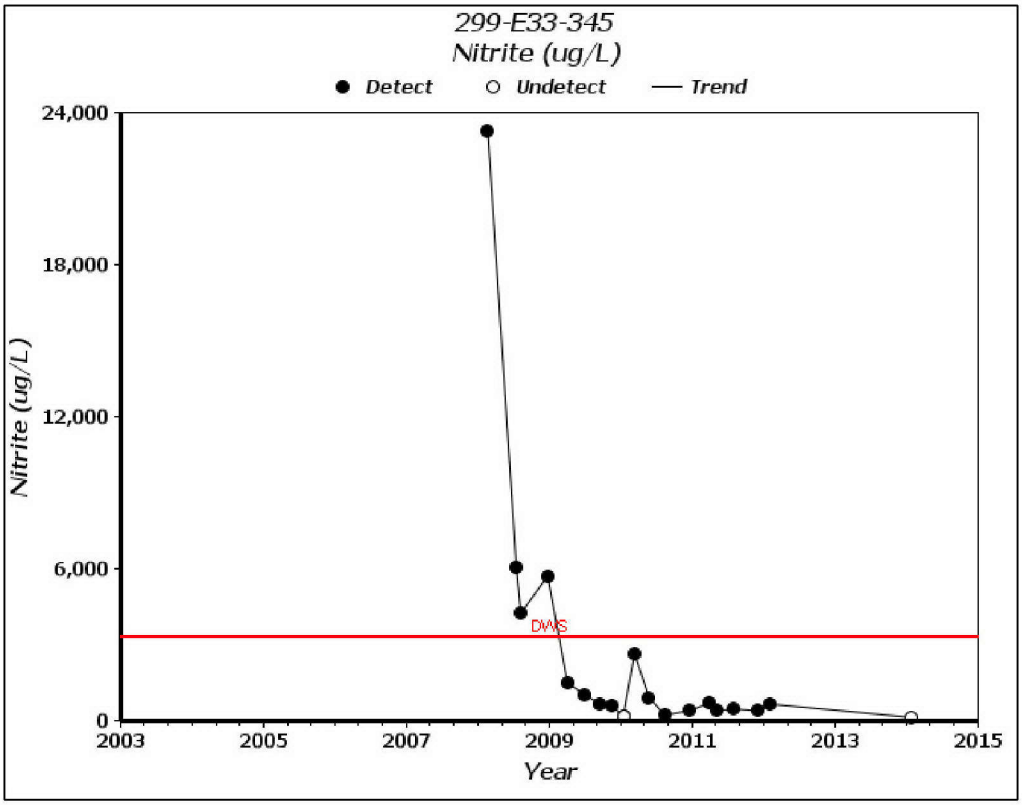

Figure E-19. Nitrite Concentrations in Well 299-E33-345

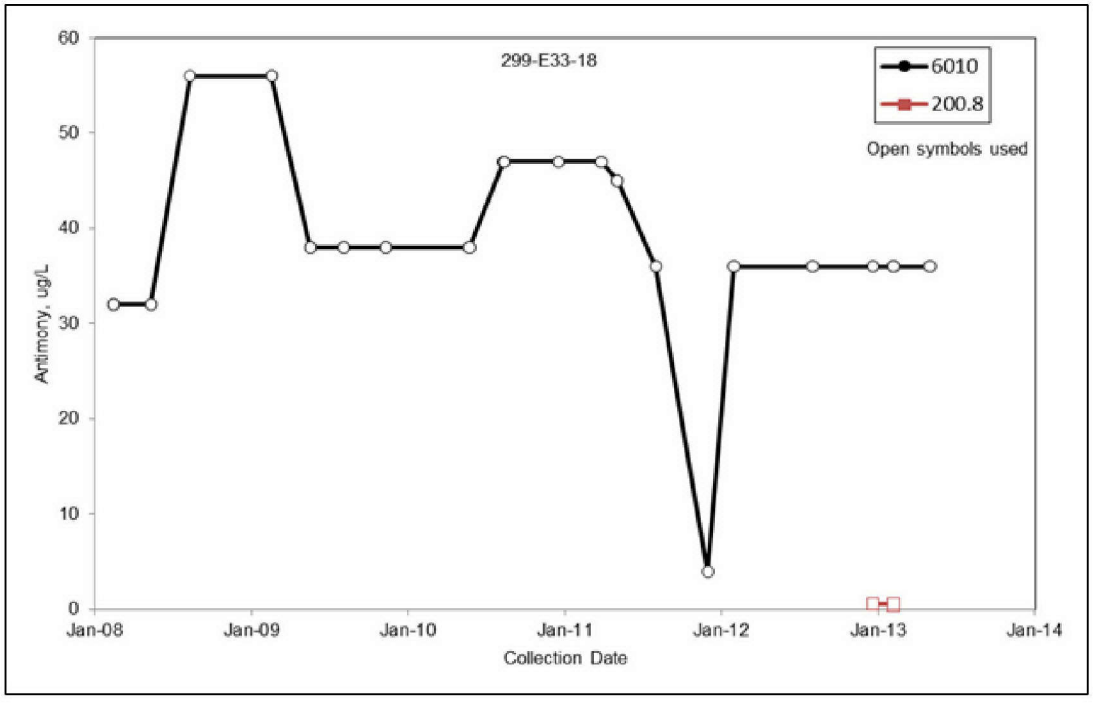

Figure E-20. Antimony Concentrations in Well 299-E33-18 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

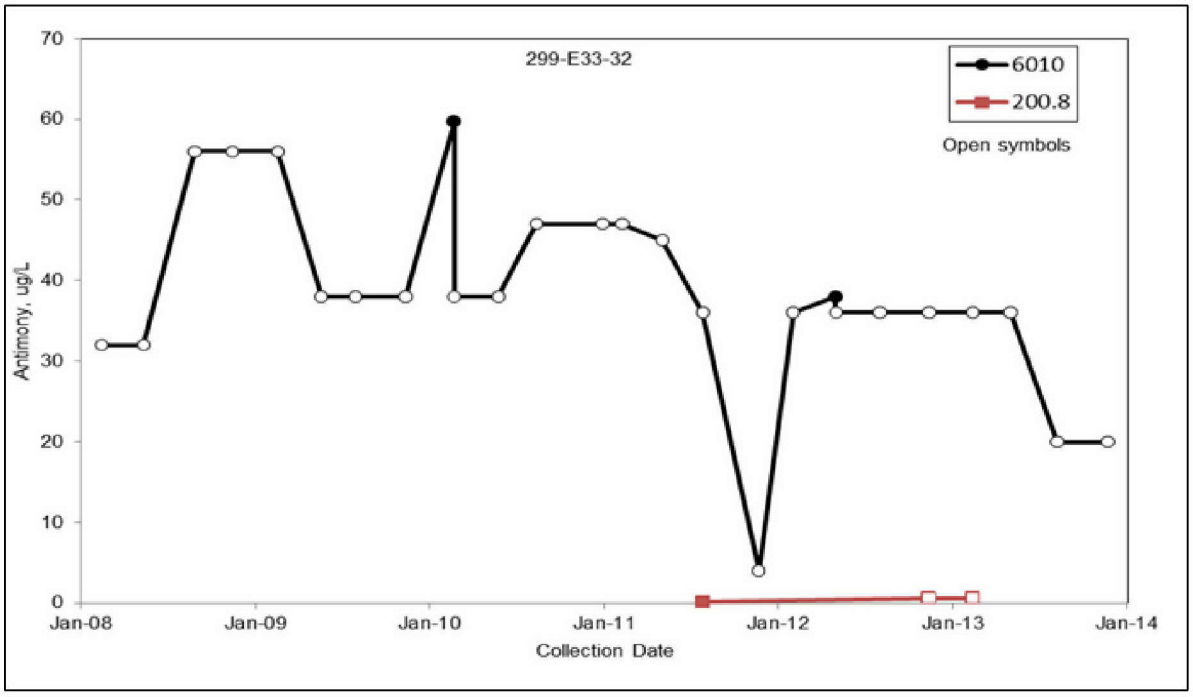

Figure E-21. Antimony Concentrations in Well 299-E33-32 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

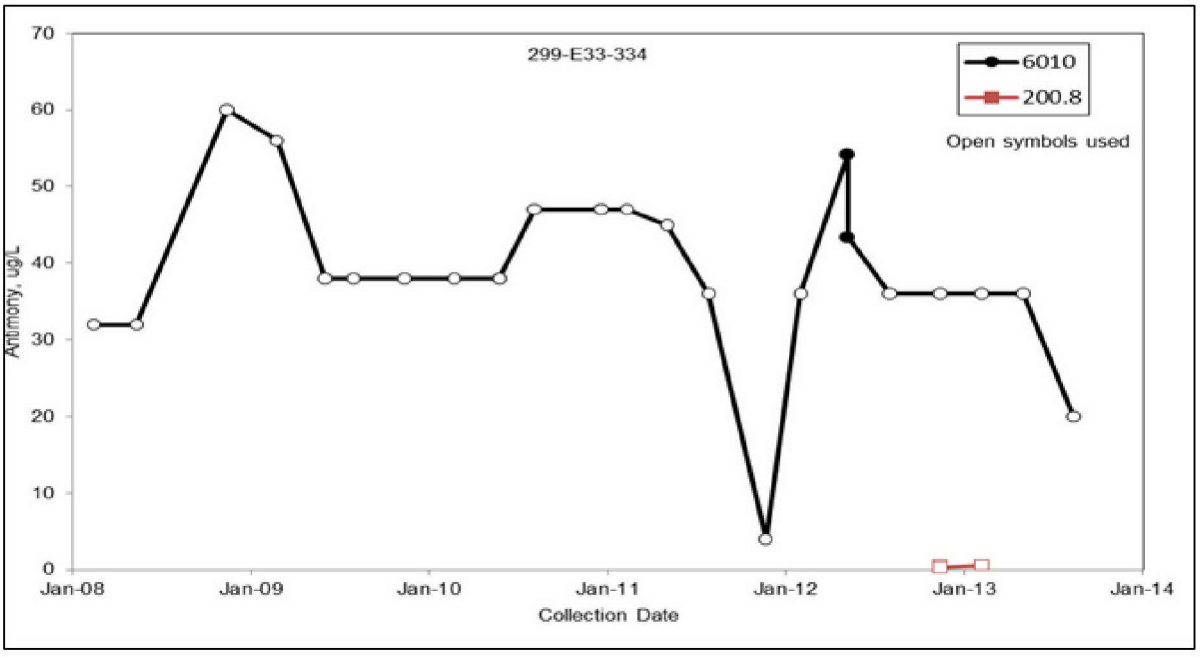

Figure E-22. Antimony Concentrations in Well 299-E33-334 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

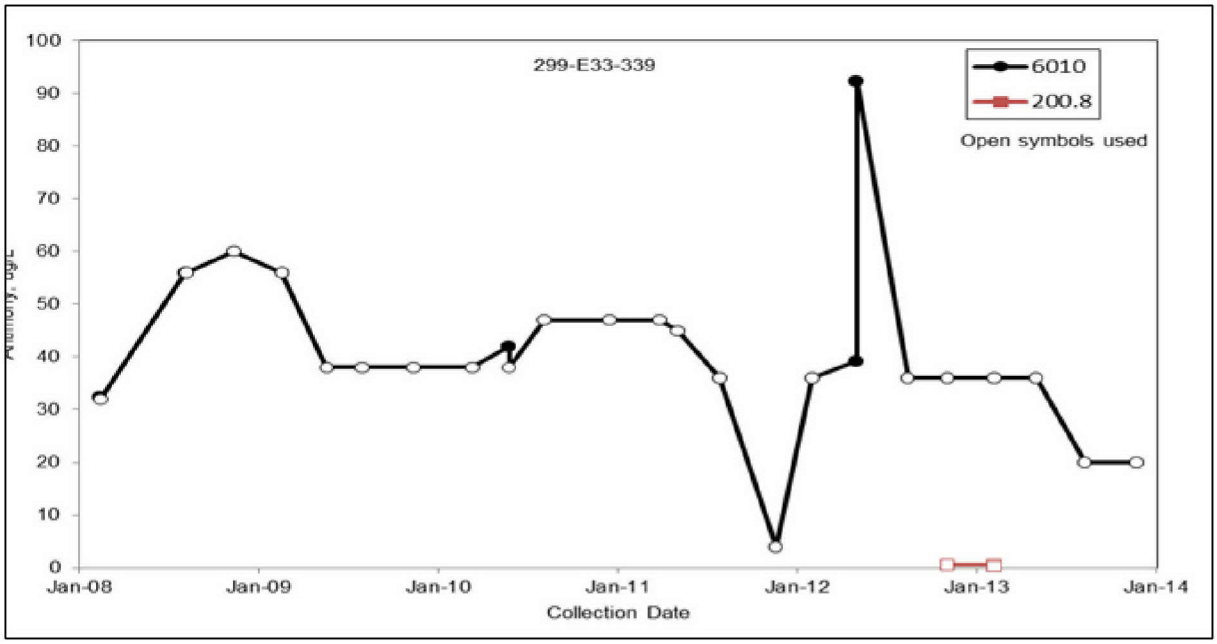

Figure E-23. Antimony Concentrations in Well 299-E33-339 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

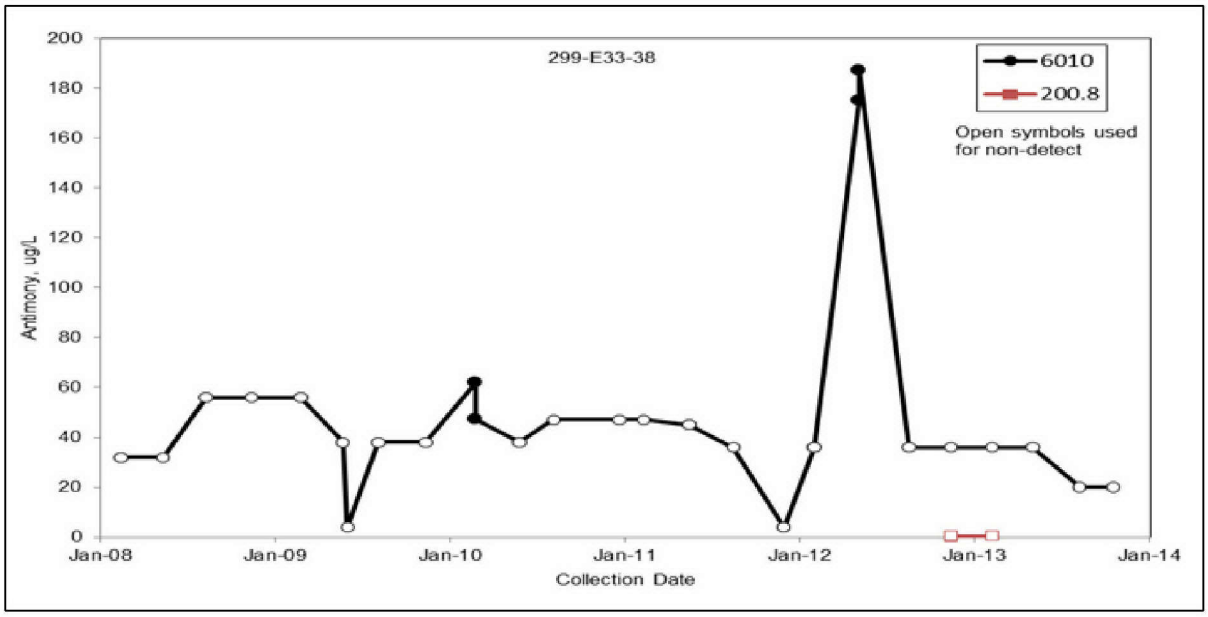

Figure E-24. Antimony Concentrations in Well 299-E33-38 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

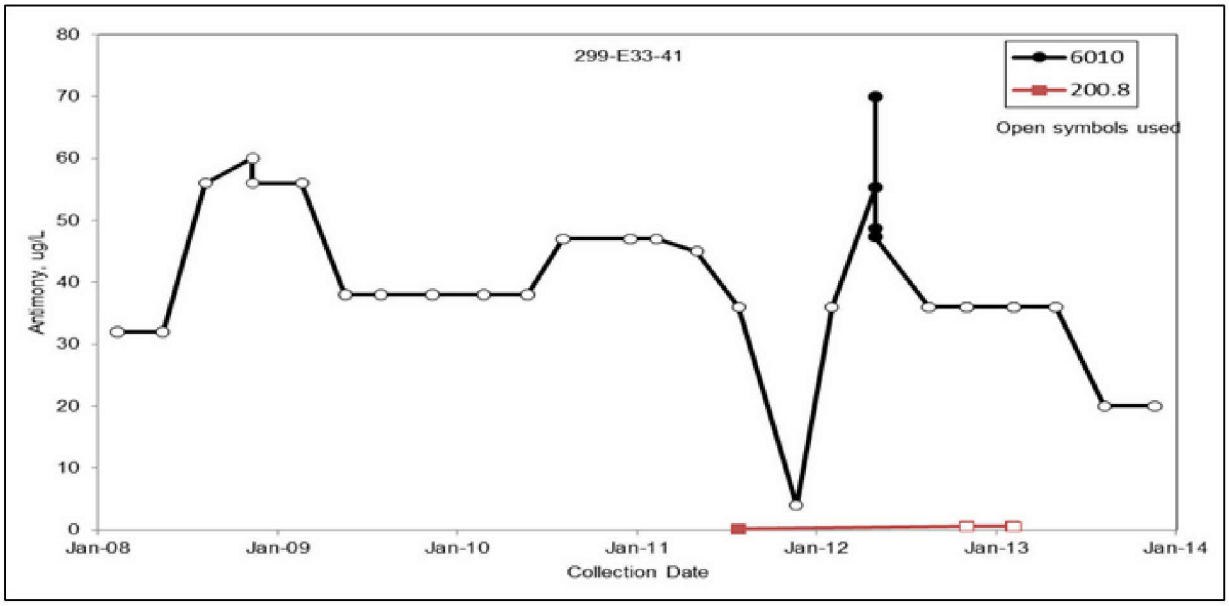

Figure E-25. Antimony Concentrations in Well 299-E33-41 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

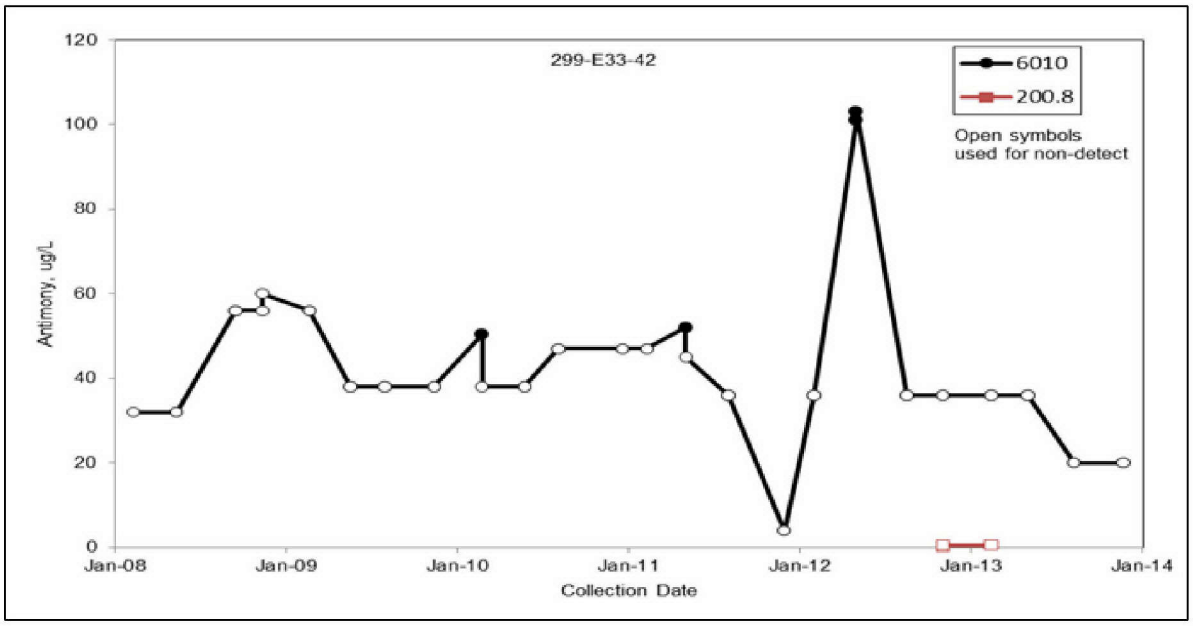

Figure E-26. Antimony Concentrations in Well 299-E33-42 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

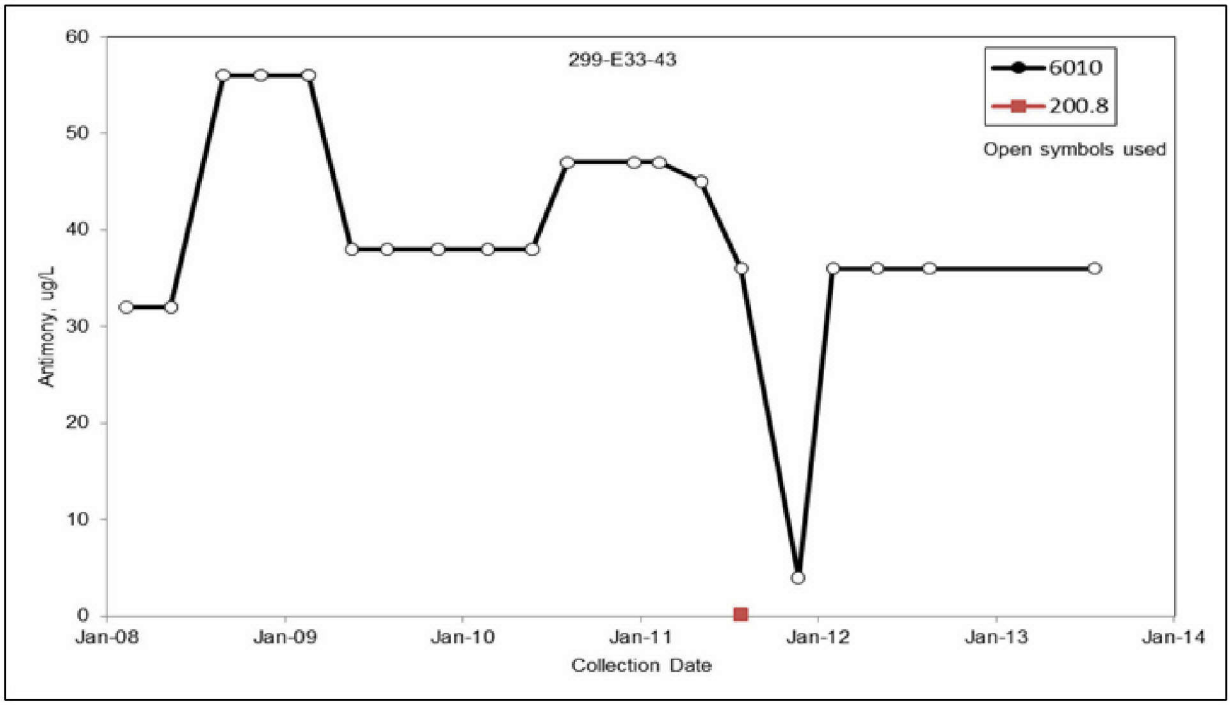

Figure E-27. Antimony Concentrations in Well 299-E33-43 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

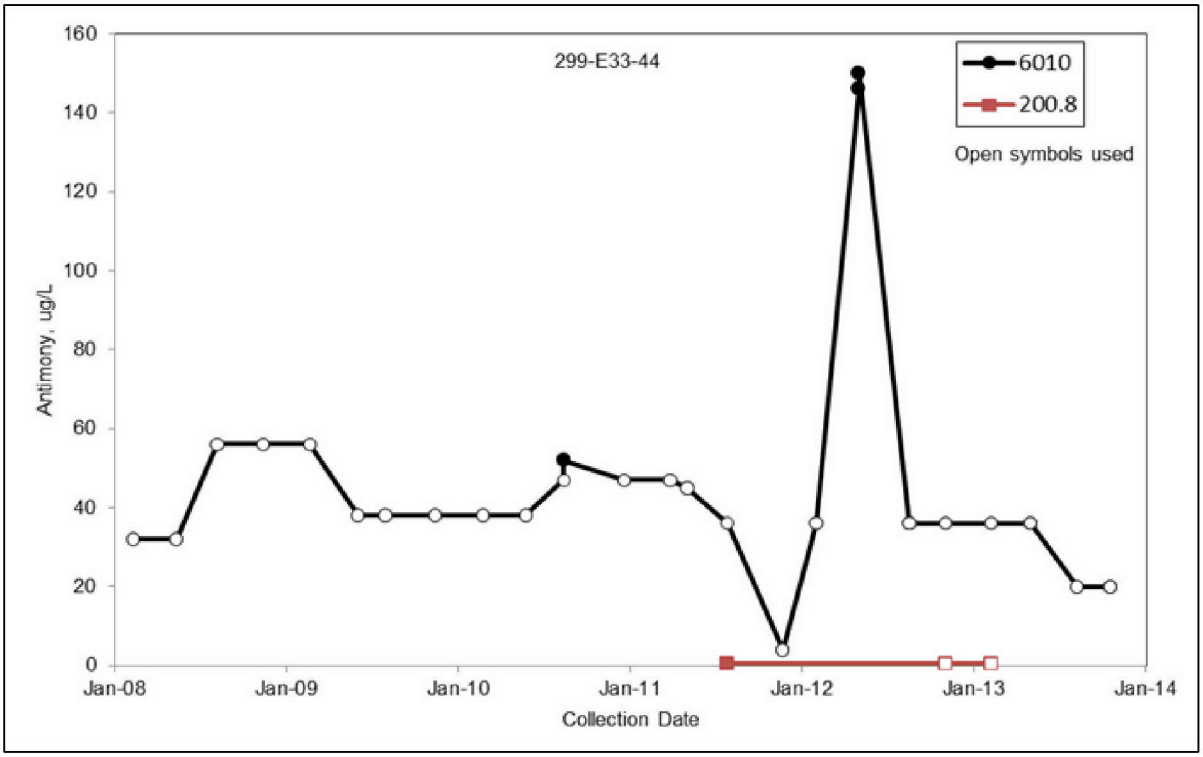

Figure E-28. Antimony Concentrations in Well 299-E33-44 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

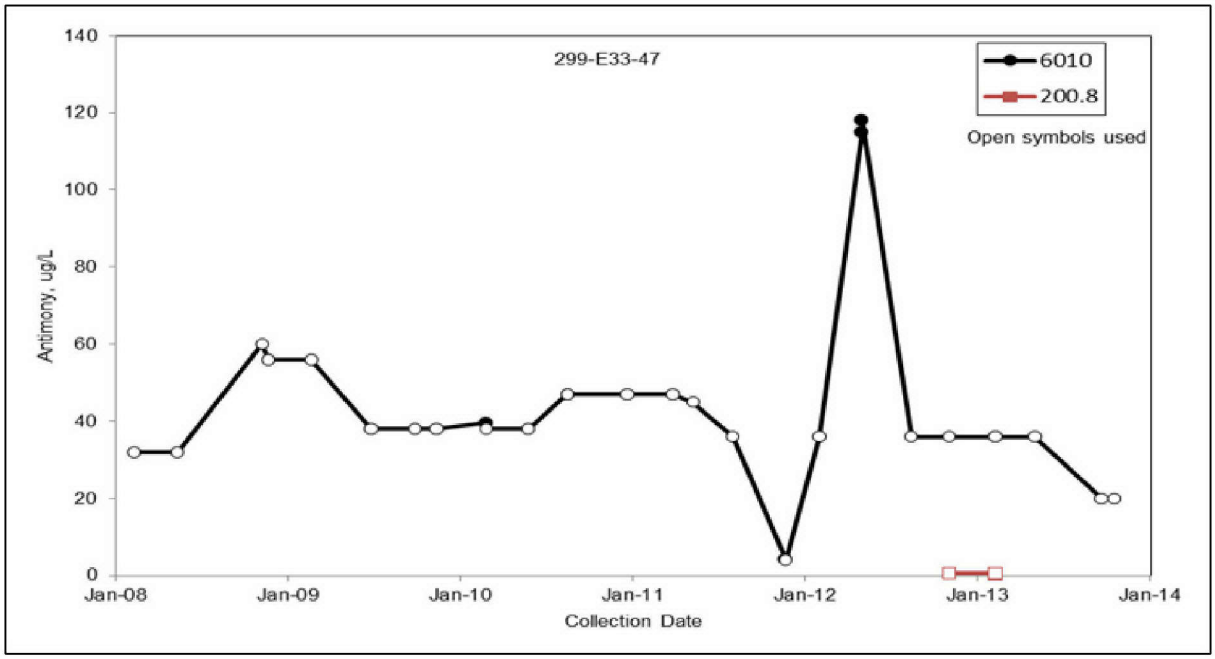

Figure E-29. Antimony Concentrations in Well 299-E33-47 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

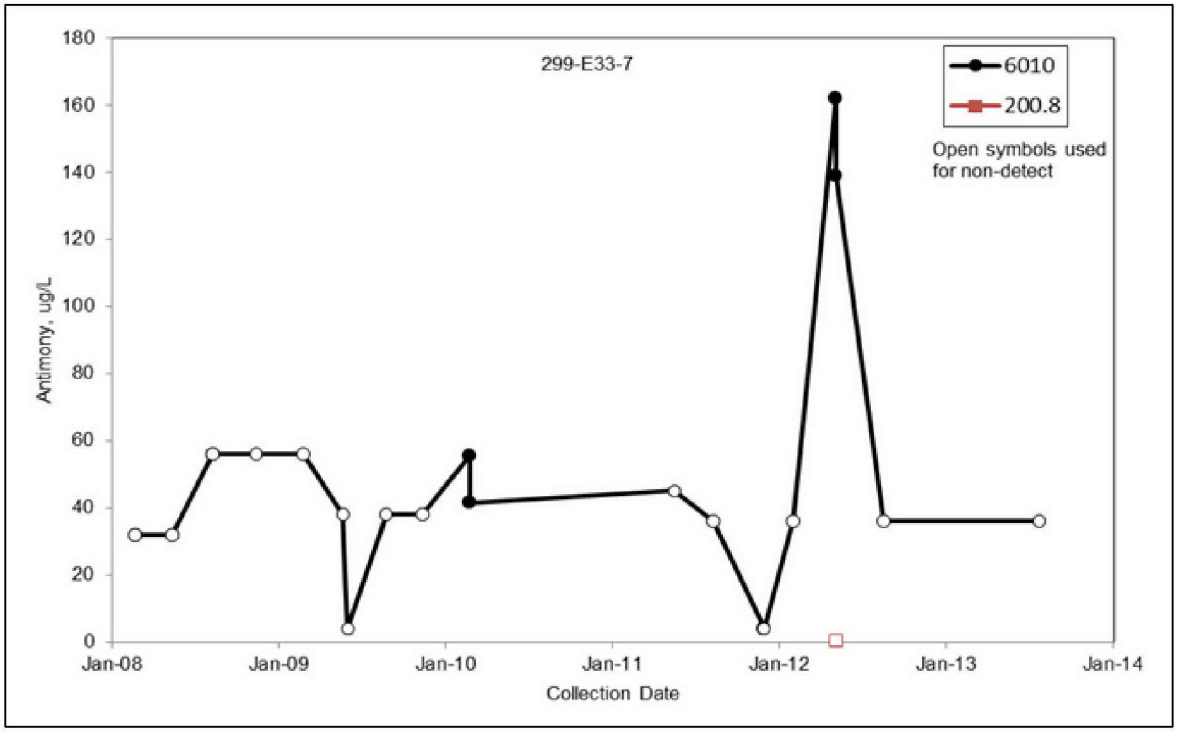

Figure E-30. Antimony Concentrations in Well 299-E33-7 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

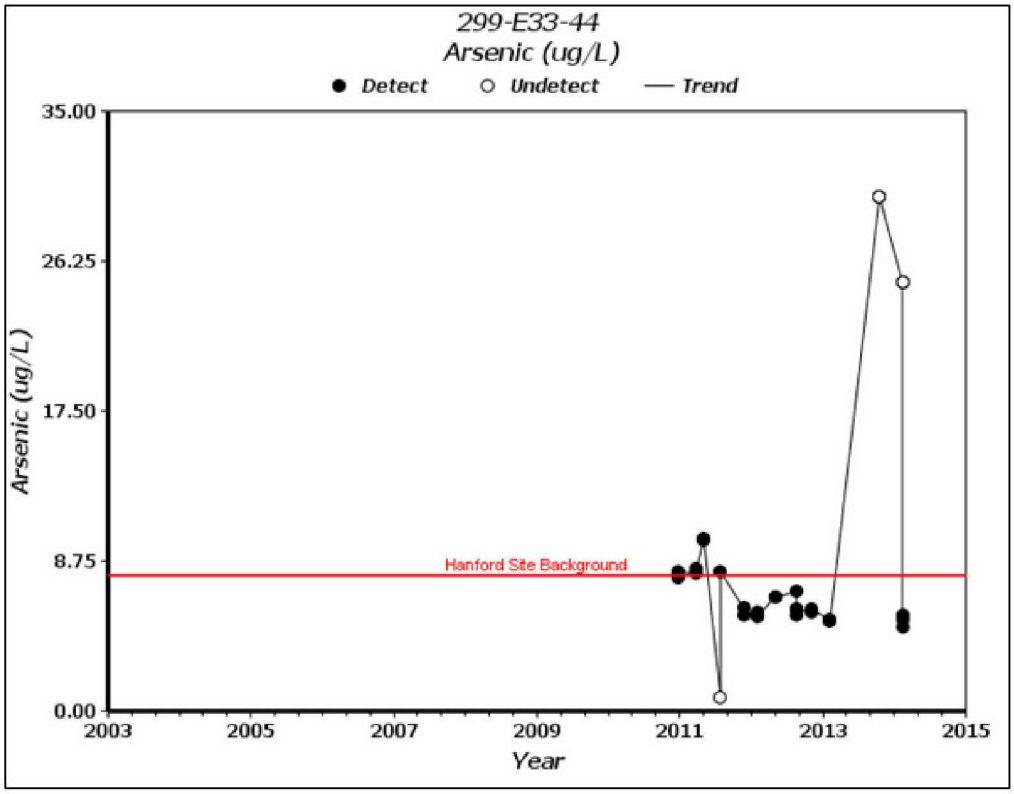

Figure E-31. Arsenic Concentrations in Well 299-E33-44

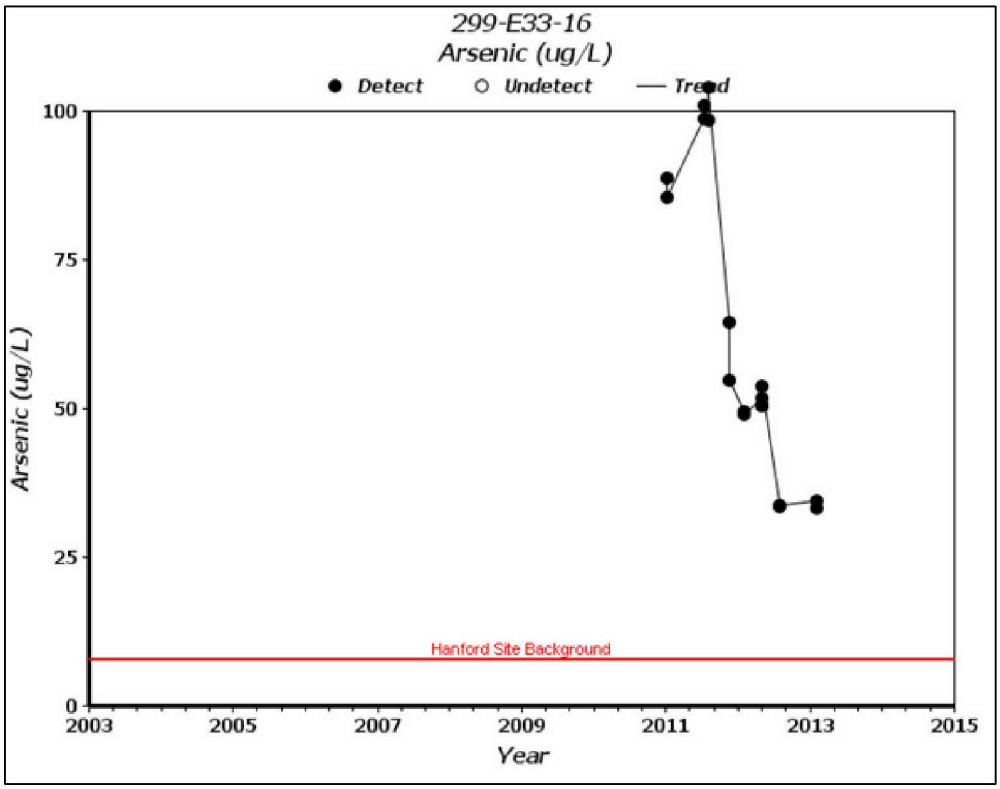

Figure E-32. Arsenic Concentrations in Well 299-E33-16

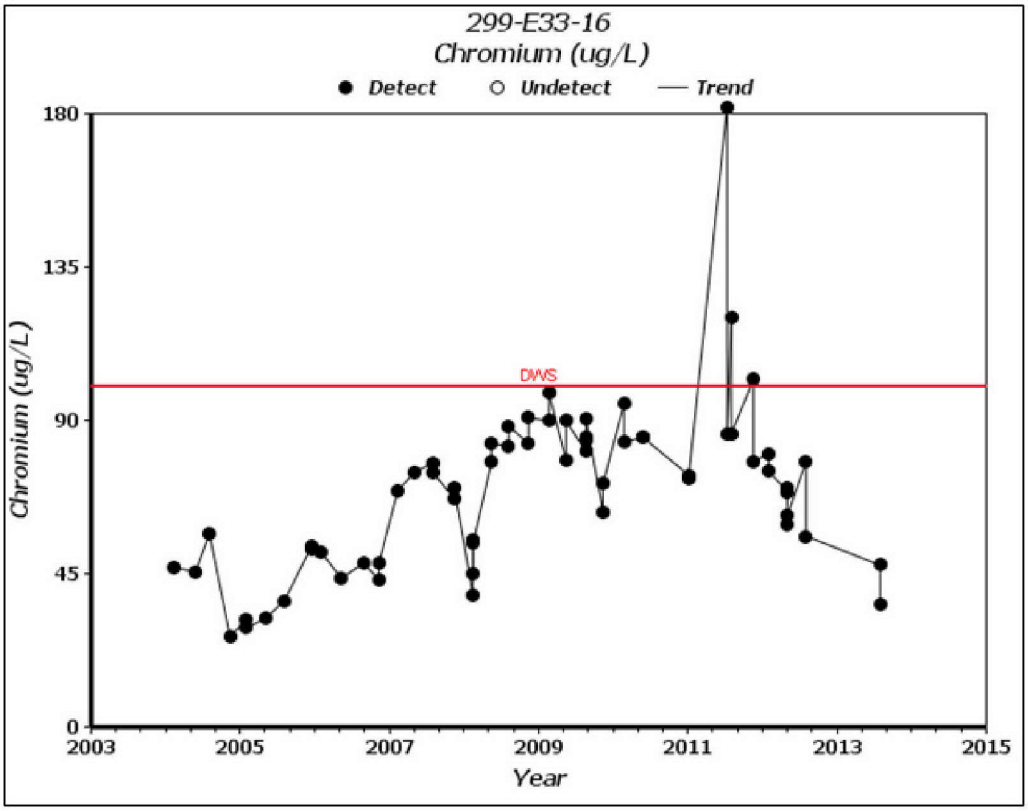

Figure E-33. Total Chromium Concentrations in Well 299-E33-16

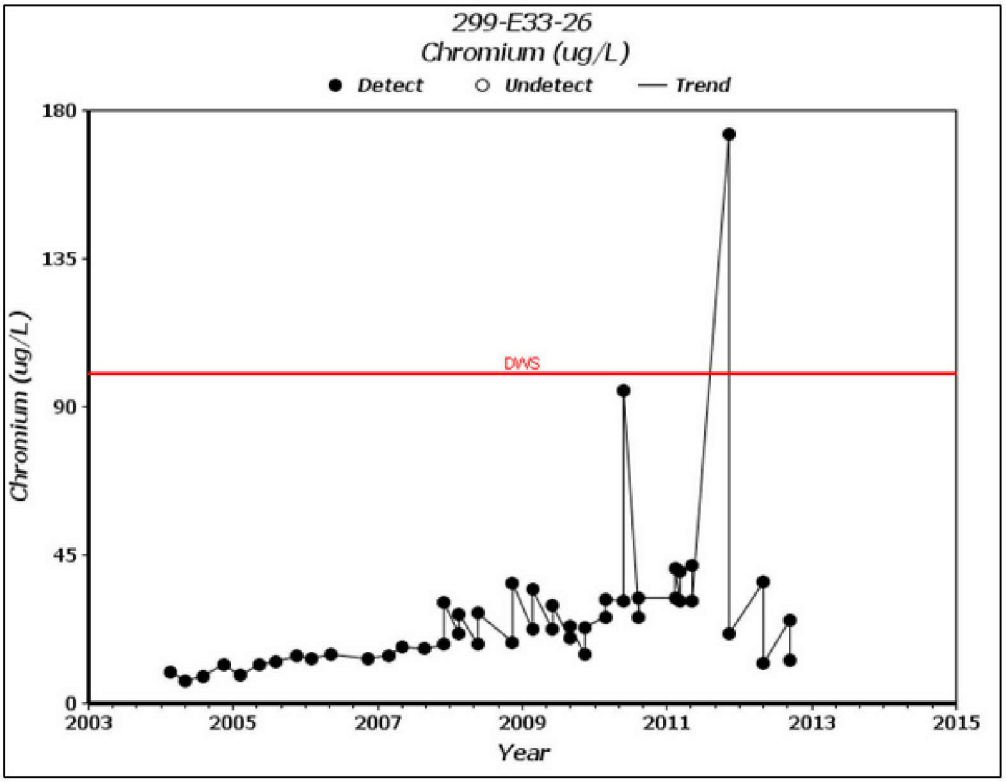

Figure E-34. Total Chromium Concentrations in Well 299-E33-26

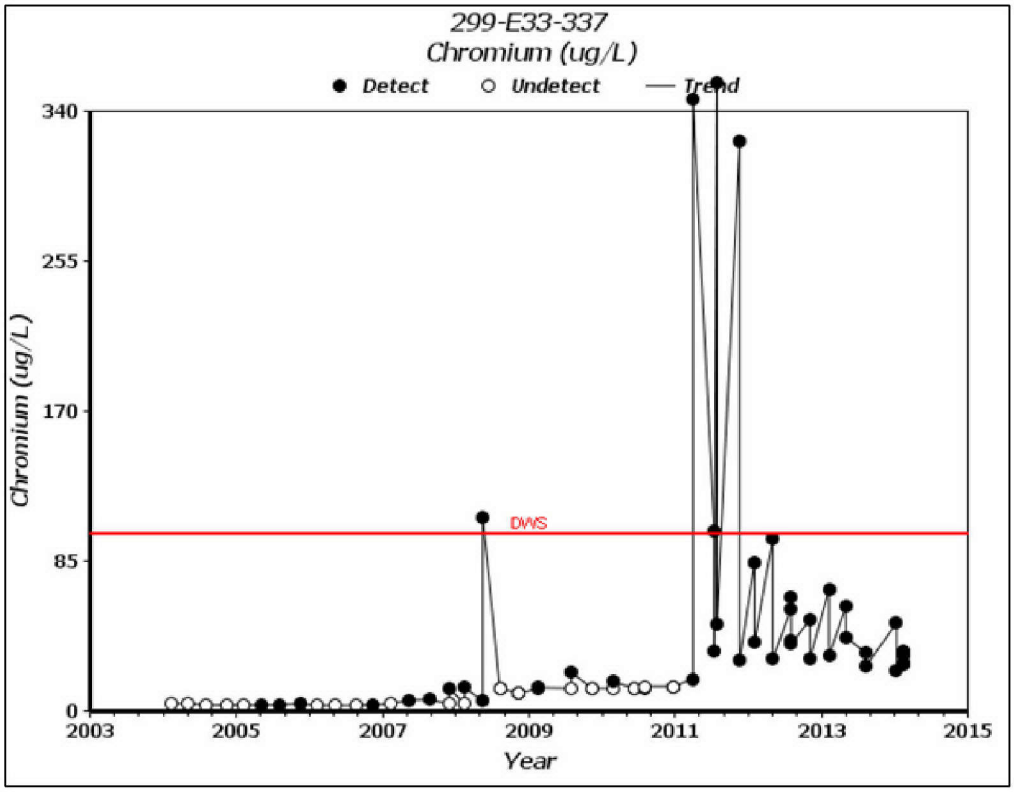

Figure E-35. Total Chromium Concentrations in Well 299-E33-337

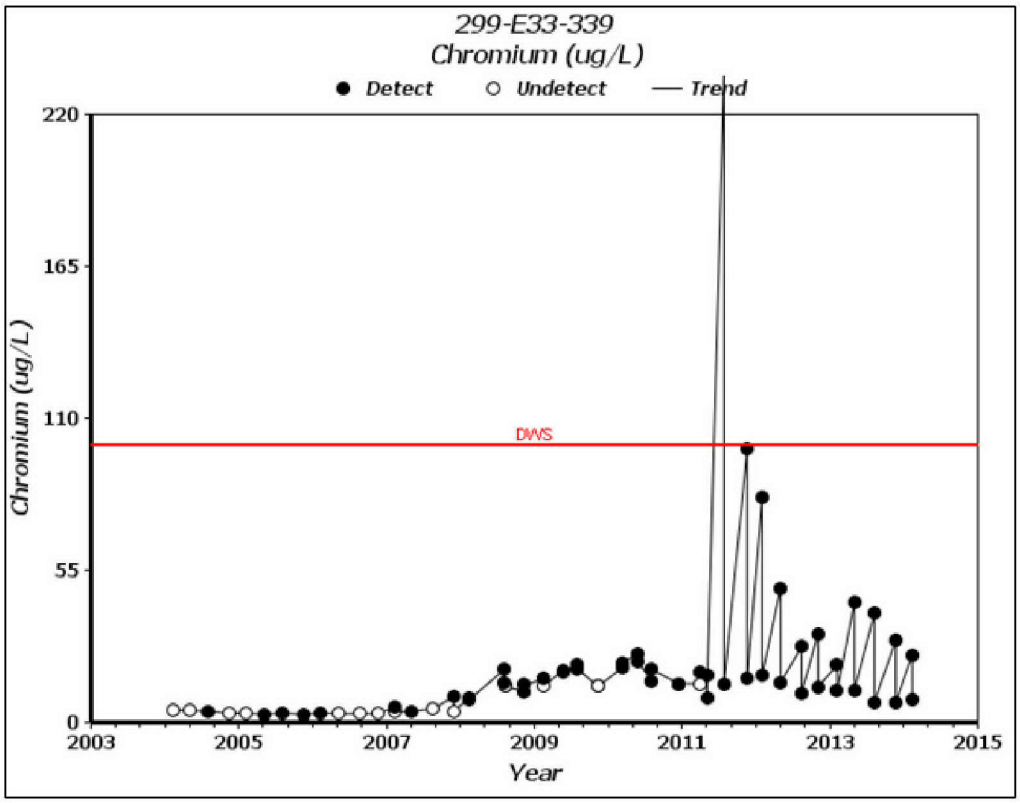

Figure E-36. Total Chromium Concentrations in Well 299-E33-339

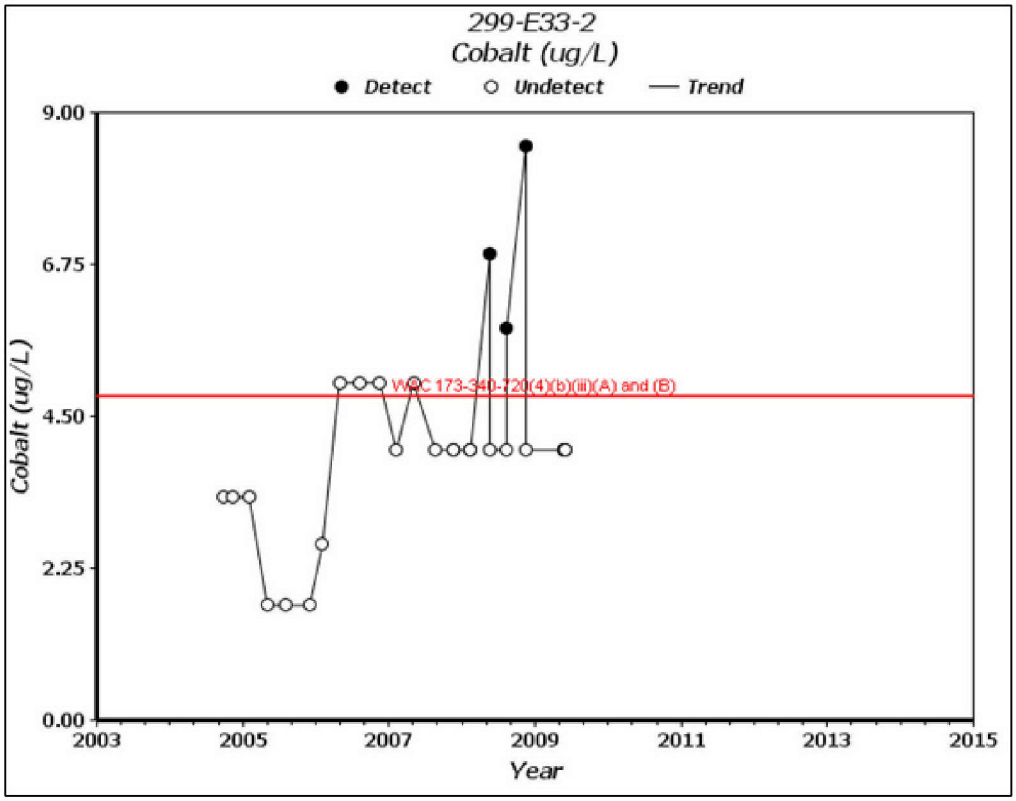

Figure E-37. Cobalt Concentrations in Well 299-E33-2

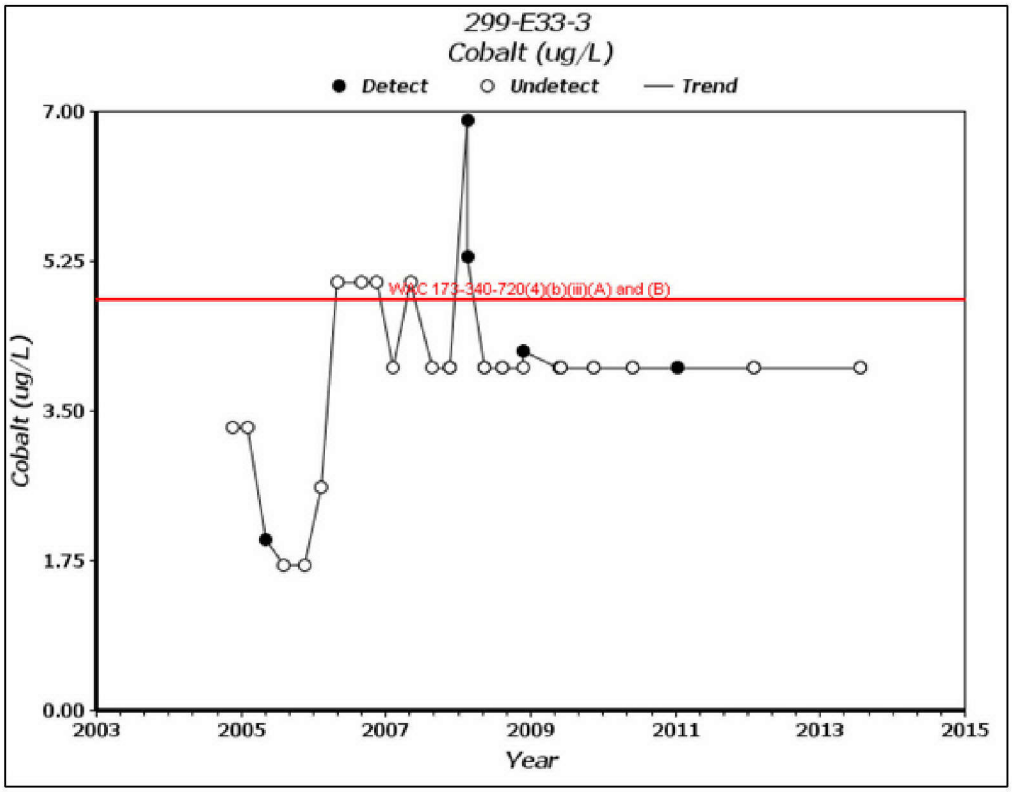

Figure E-38. Cobalt Concentrations in Well 299-E33-3

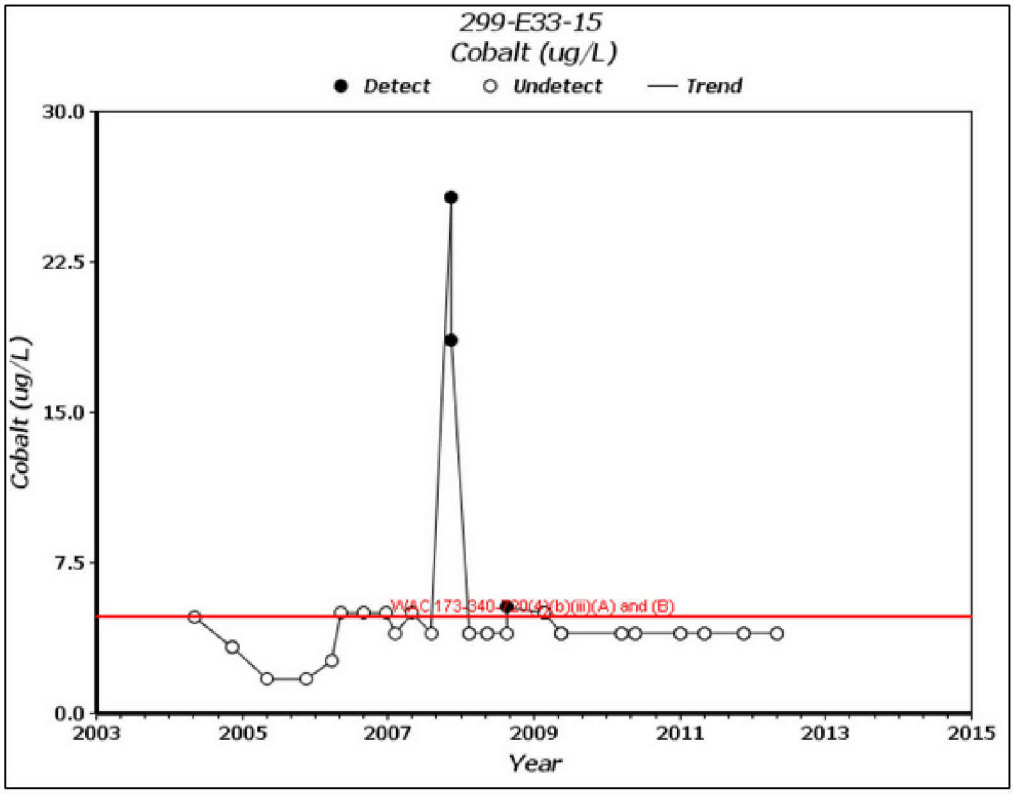

Figure E-39. Cobalt Concentrations in Well 299-E33-15

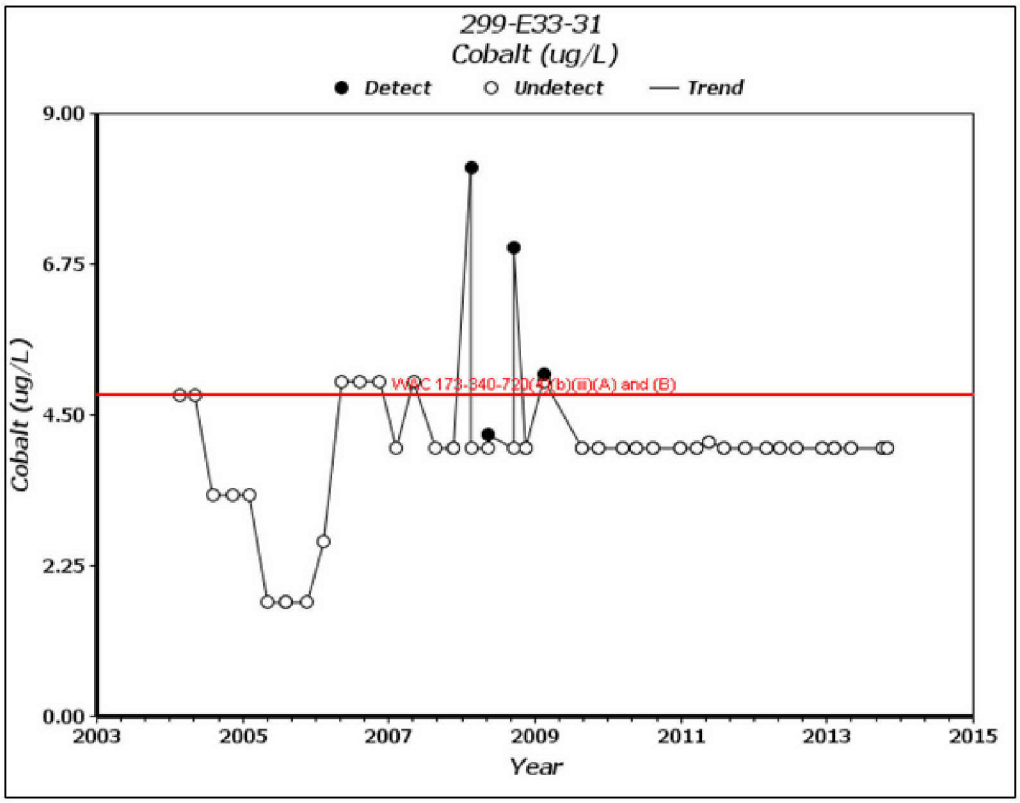

Figure E-40. Cobalt Concentrations in Well 299-E33-31

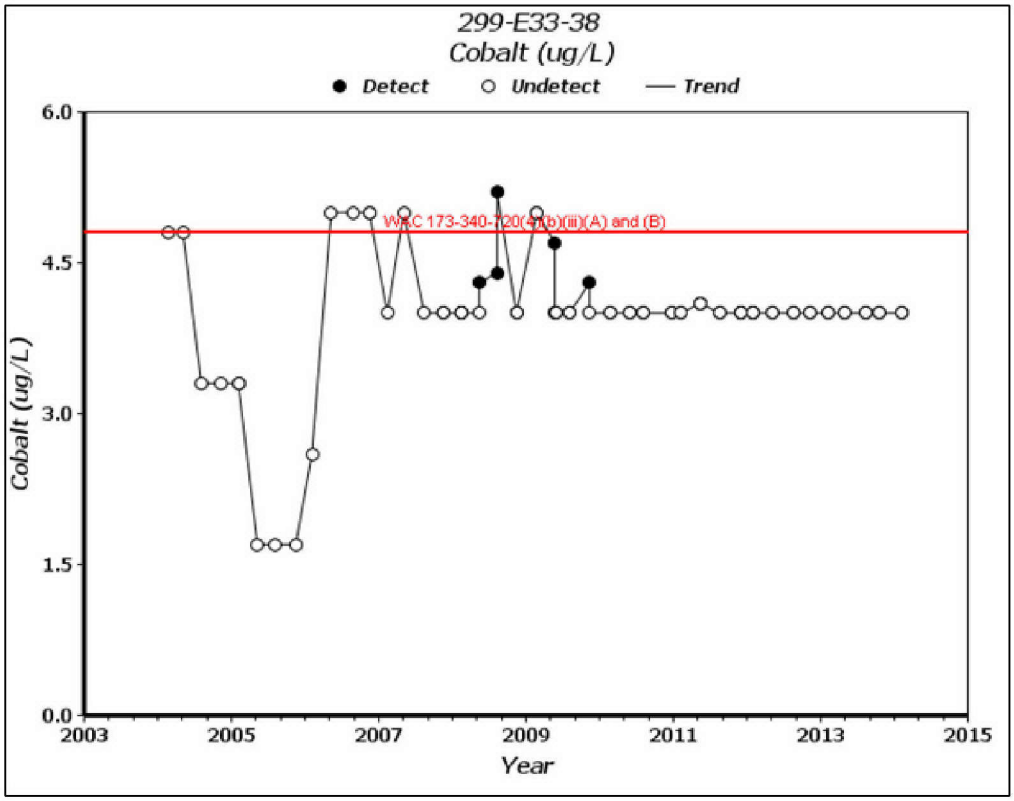

Figure E-41. Cobalt Concentrations in Well 299-E33-38

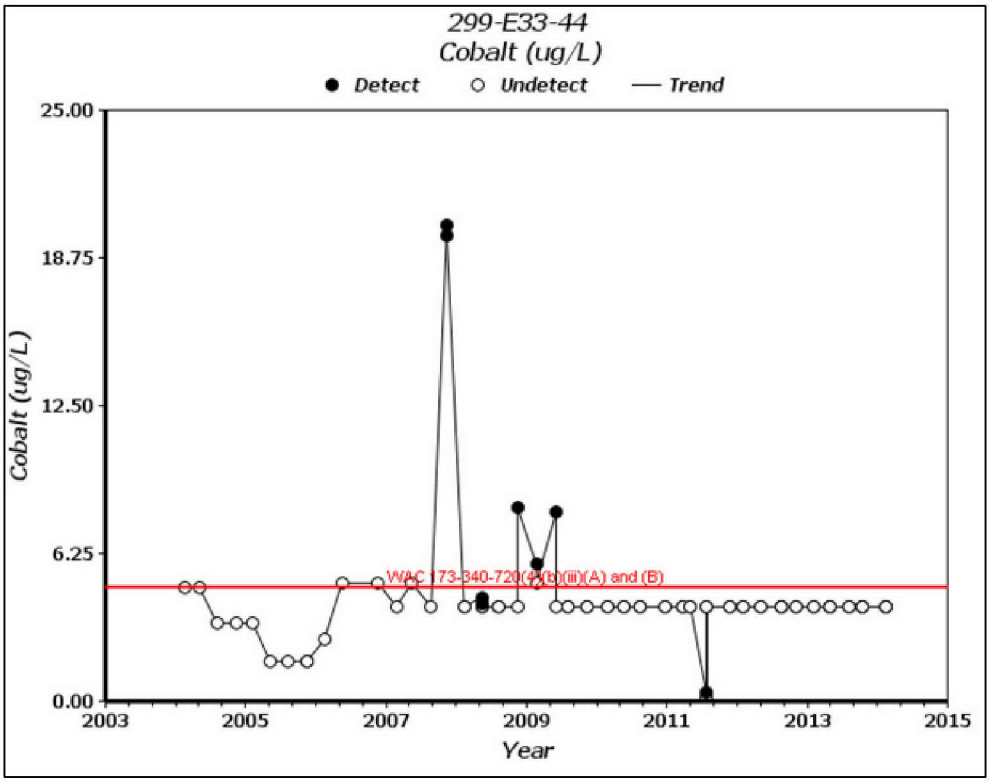

Figure E-42. Cobalt Concentrations in Well 299-E33-44

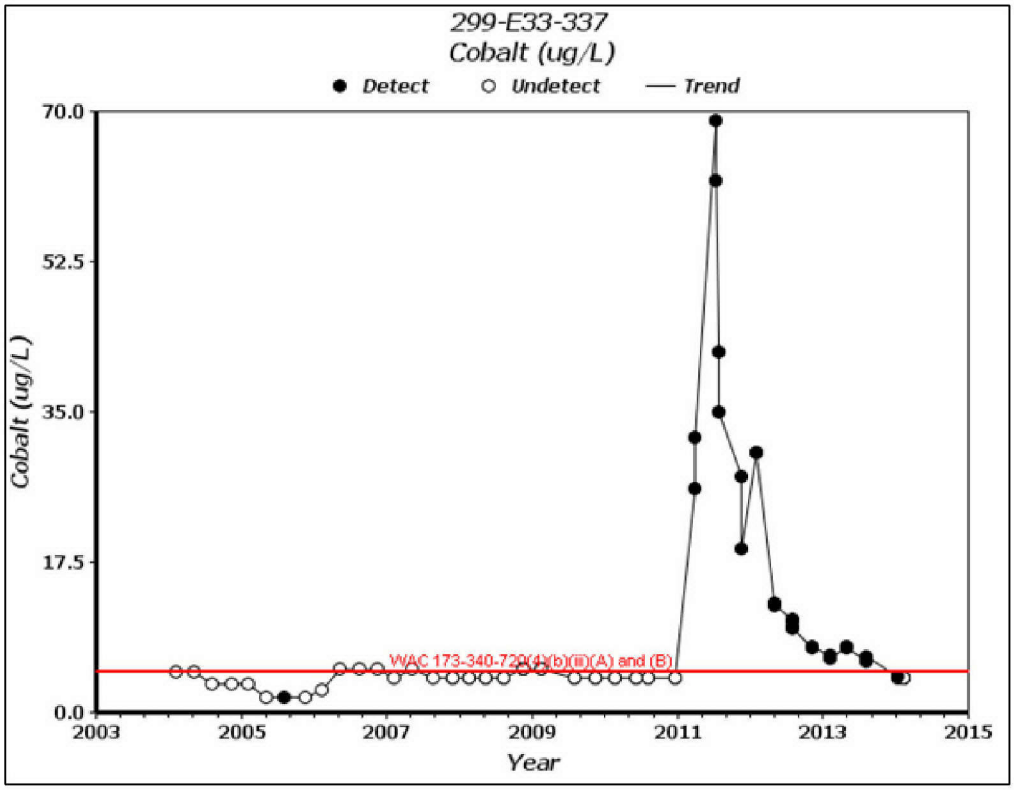

Figure E-43. Cobalt Concentrations in Well 299-E33-337

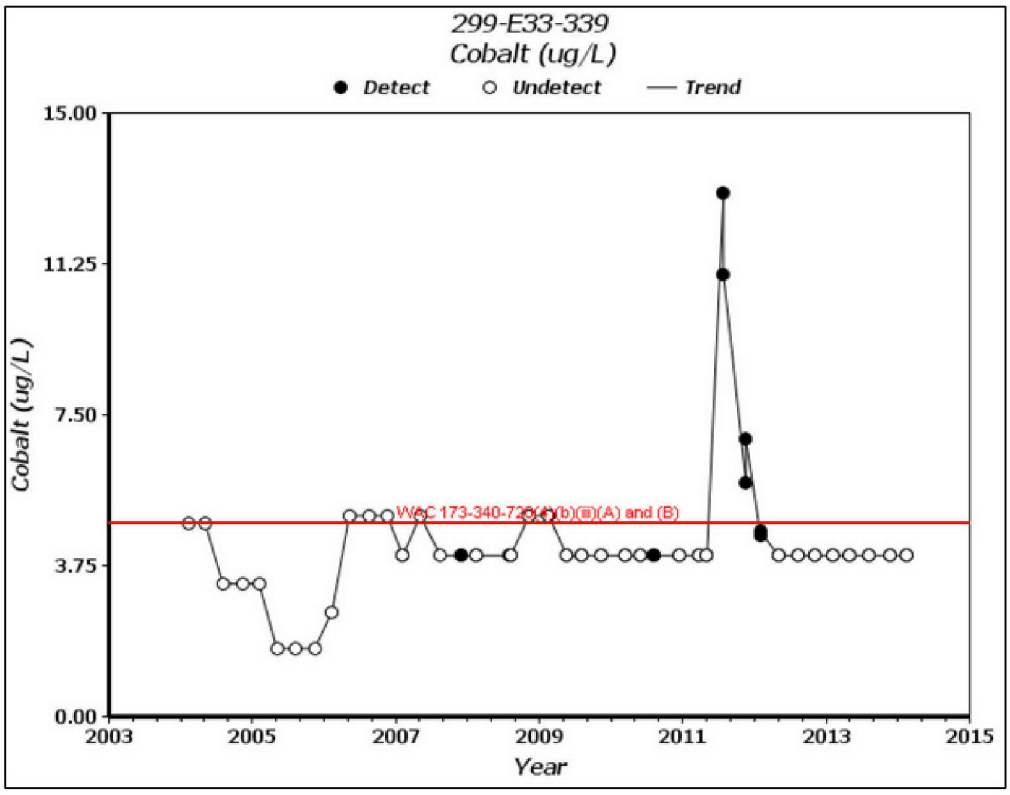

Figure E-44. Cobalt Concentrations in Well 299-E33-339

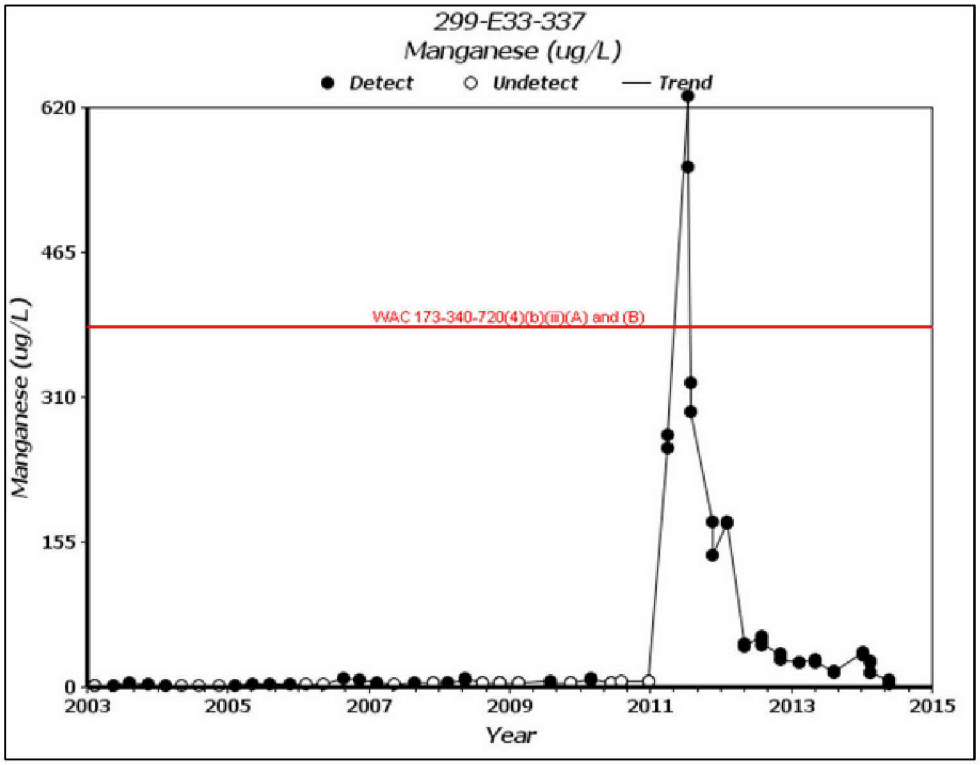

Figure E-45. Manganese Concentrations in Well 299-E33-337

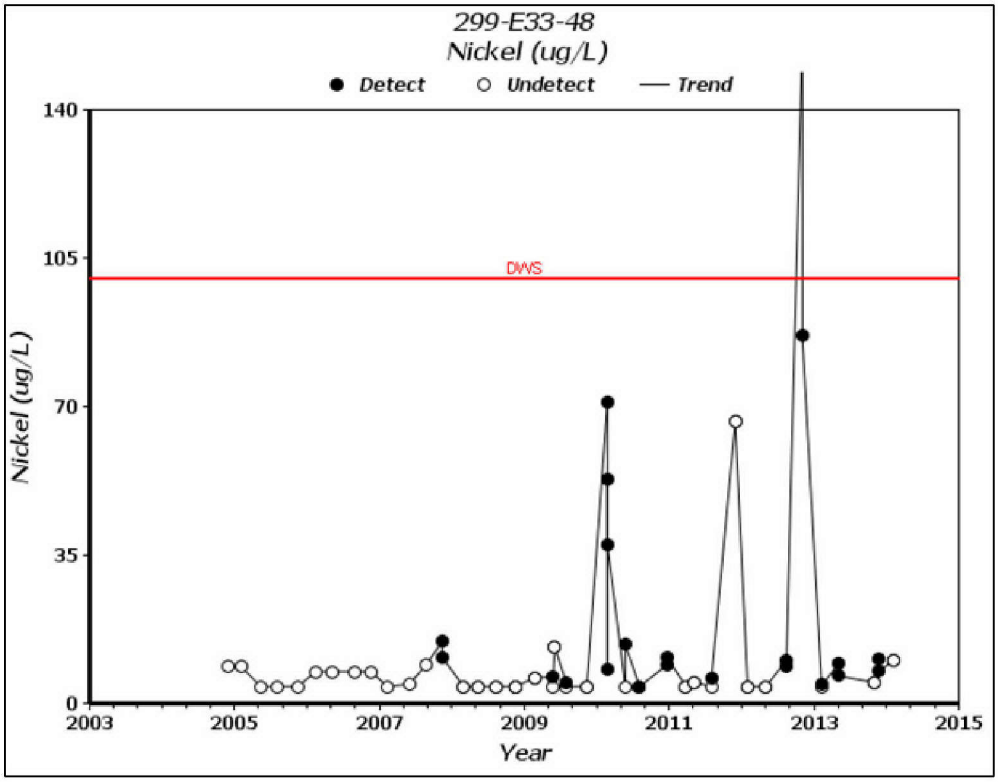

Figure E-46. Nickel Concentrations in Well 299-E33-48

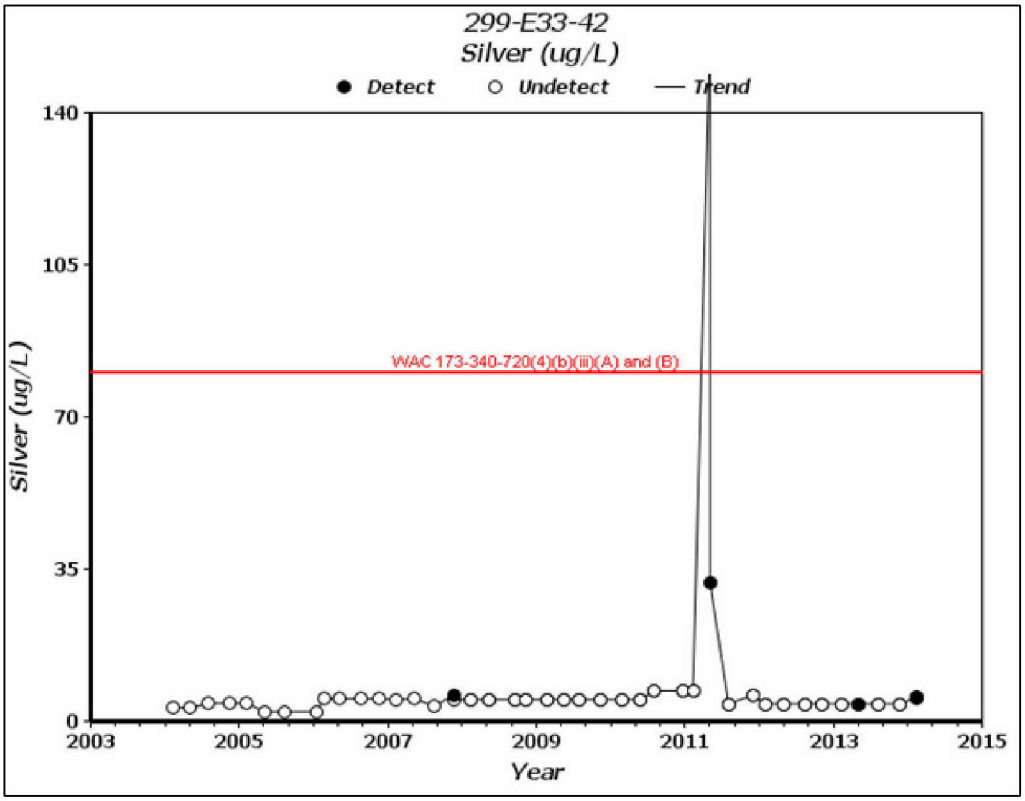

Figure E-47. Silver Concentrations in Well 299-E33-42

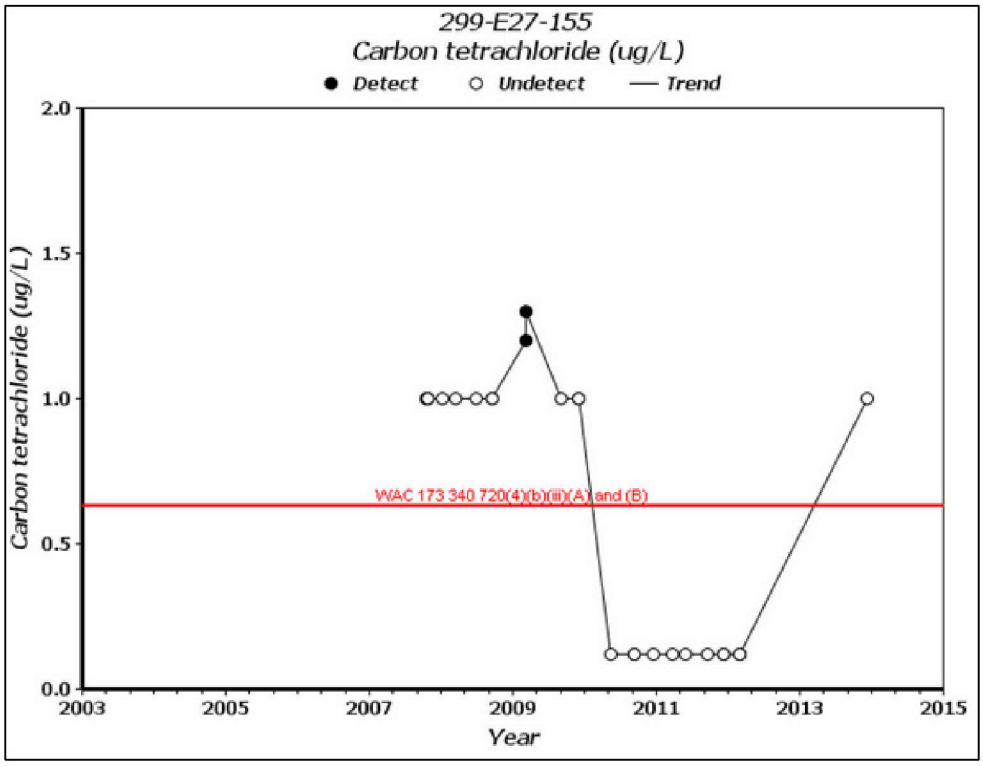

Figure E-48. Carbon Tetrachloride Concentrations in Well 299-E27-155

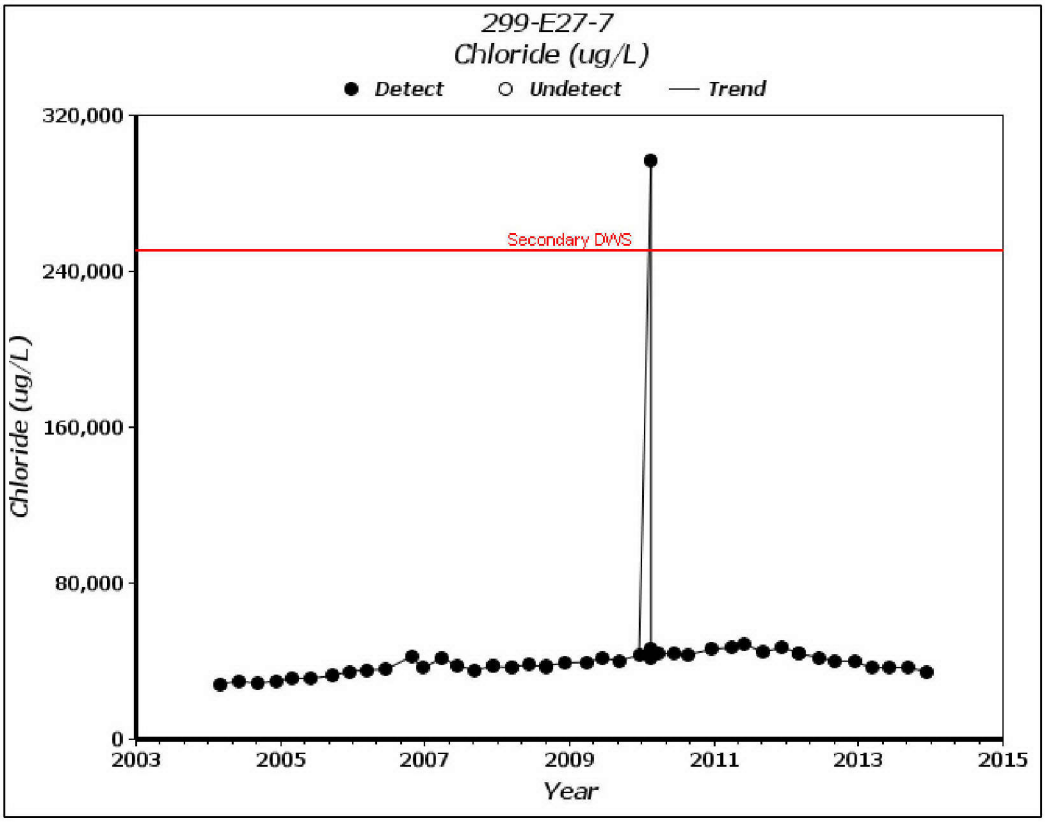

Figure E-49. Chloride Concentrations in Well 299-E27-7

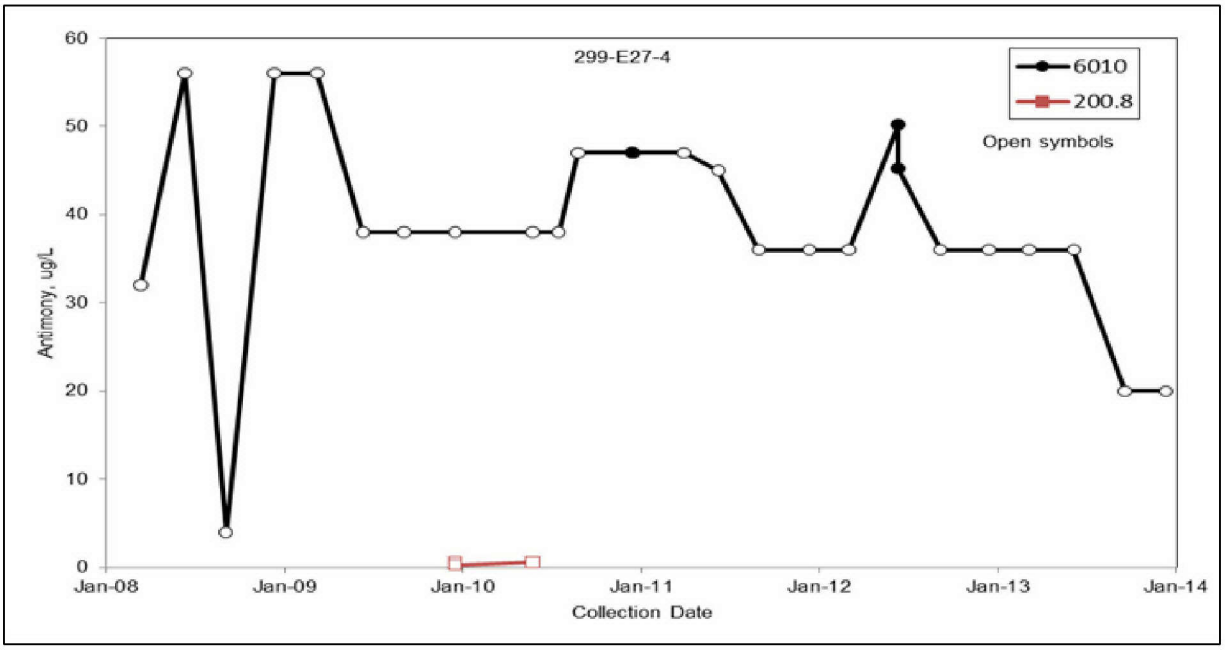

Figure E-50. Antimony Concentrations in Well 299-E27-4 Analyzed by Method 6010 (ICP/AES) and Method 200.8 (ICP/MS)

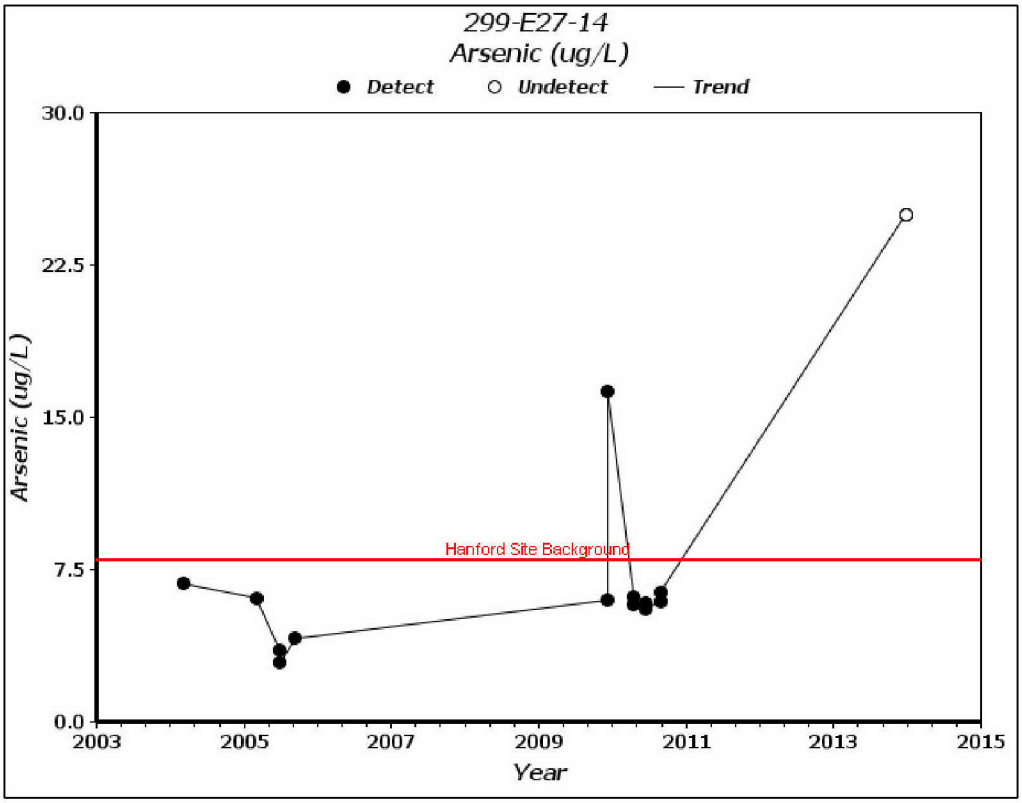

Figure E-51. Arsenic Concentrations in Well 299-E27-14

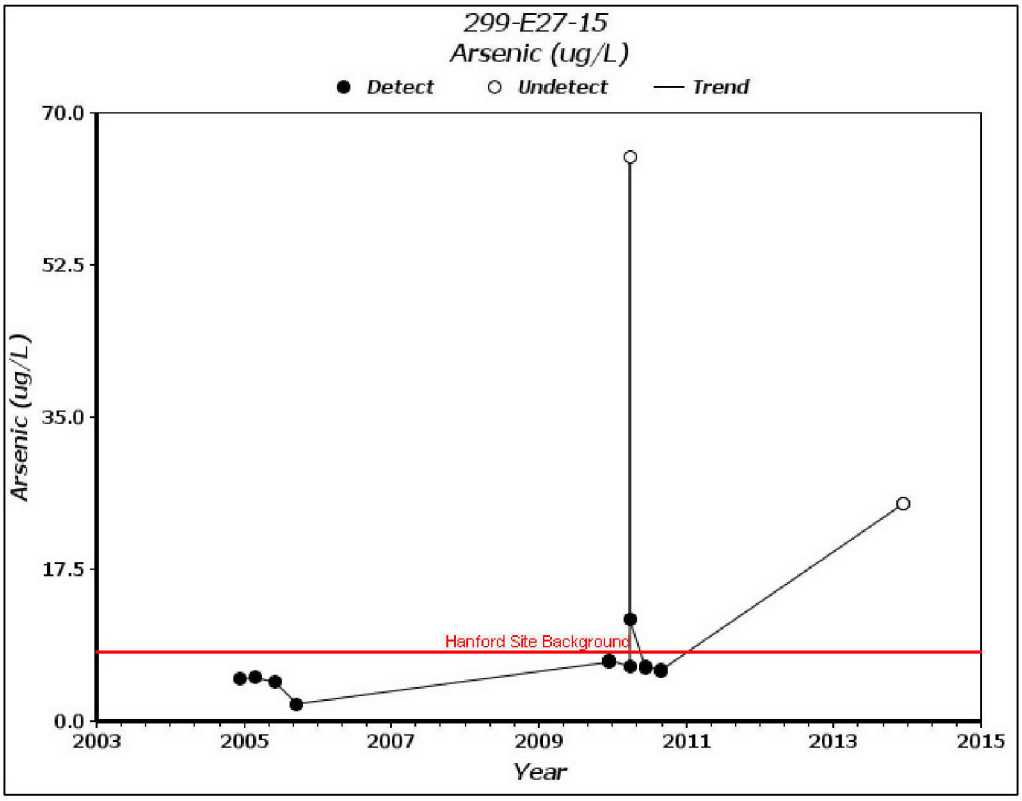

Figure E-52. Arsenic Concentrations in Well 299-E27-15

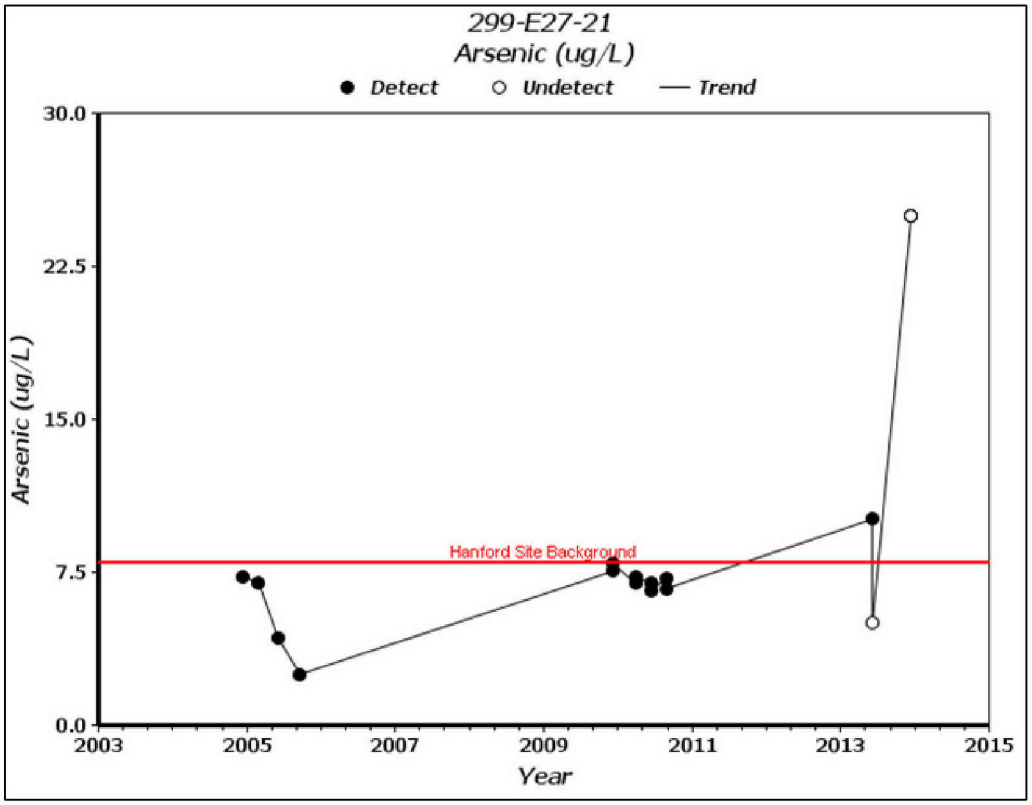

Figure E-53. Arsenic Concentrations in Well 299-E27-21

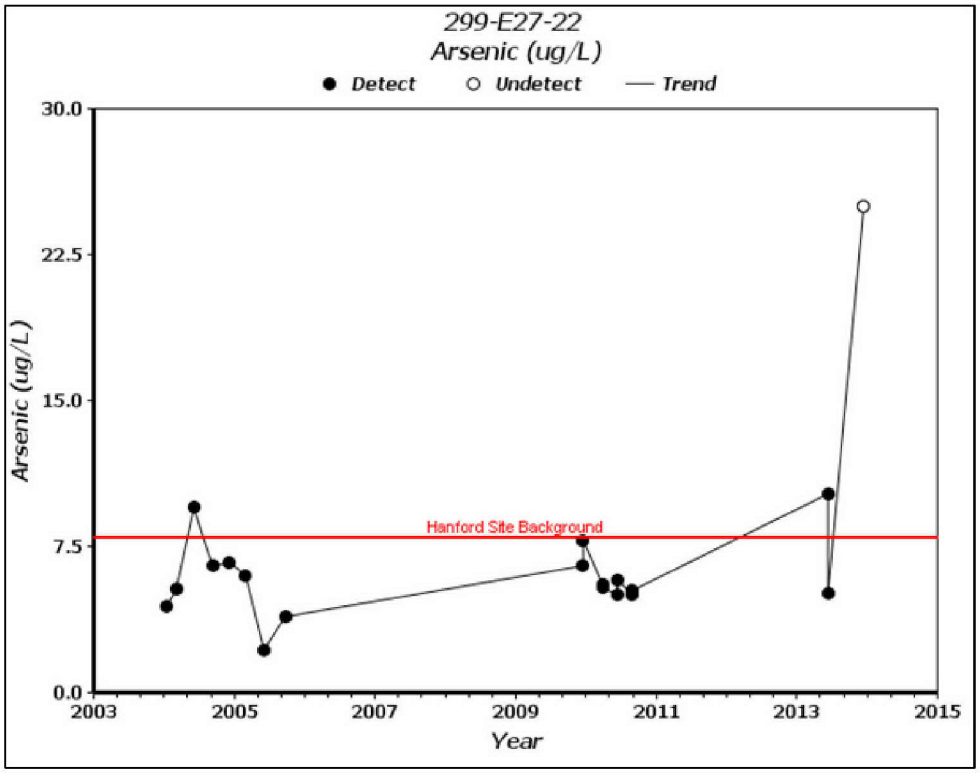

Figure E-54. Arsenic Concentrations in Well 299-E27-22

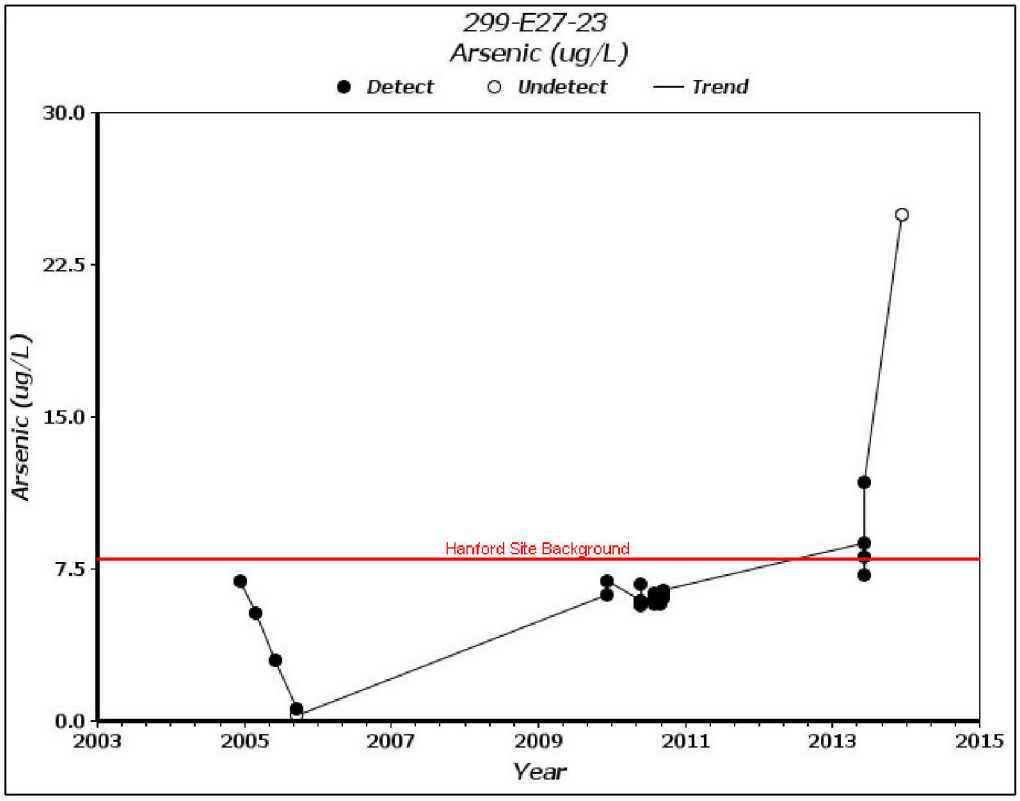

Figure E-55. Arsenic Concentrations in Well 299-E27-23

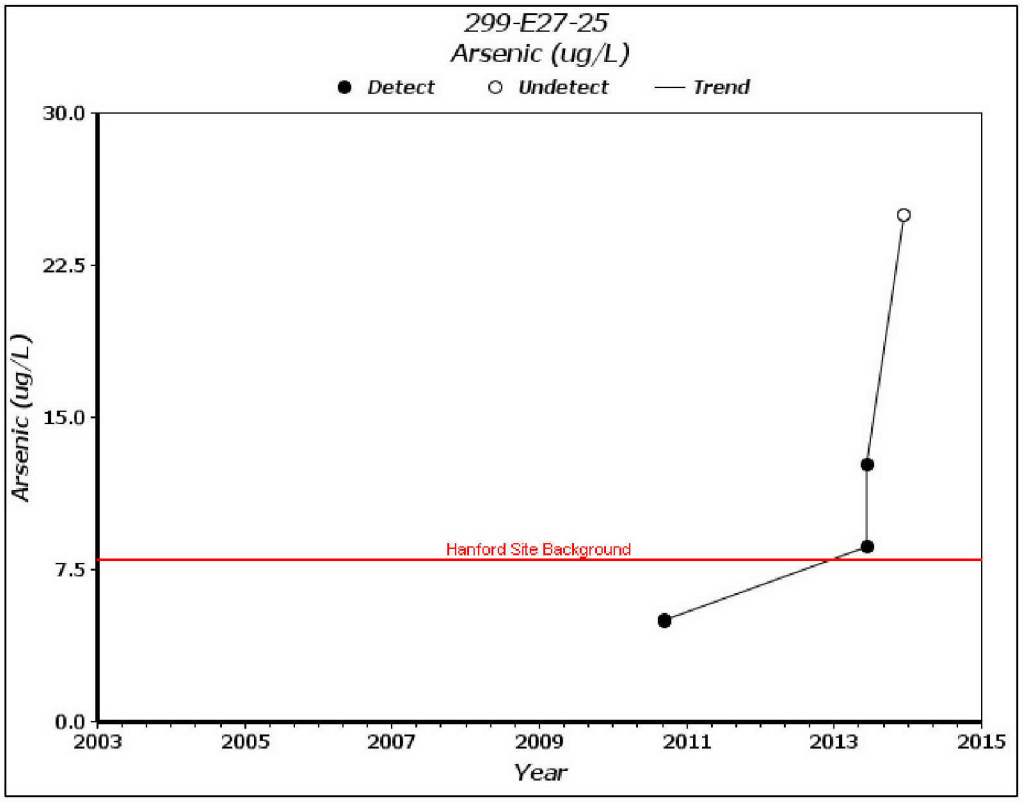

Figure E-56. Arsenic Concentrations in Well 299-E27-25

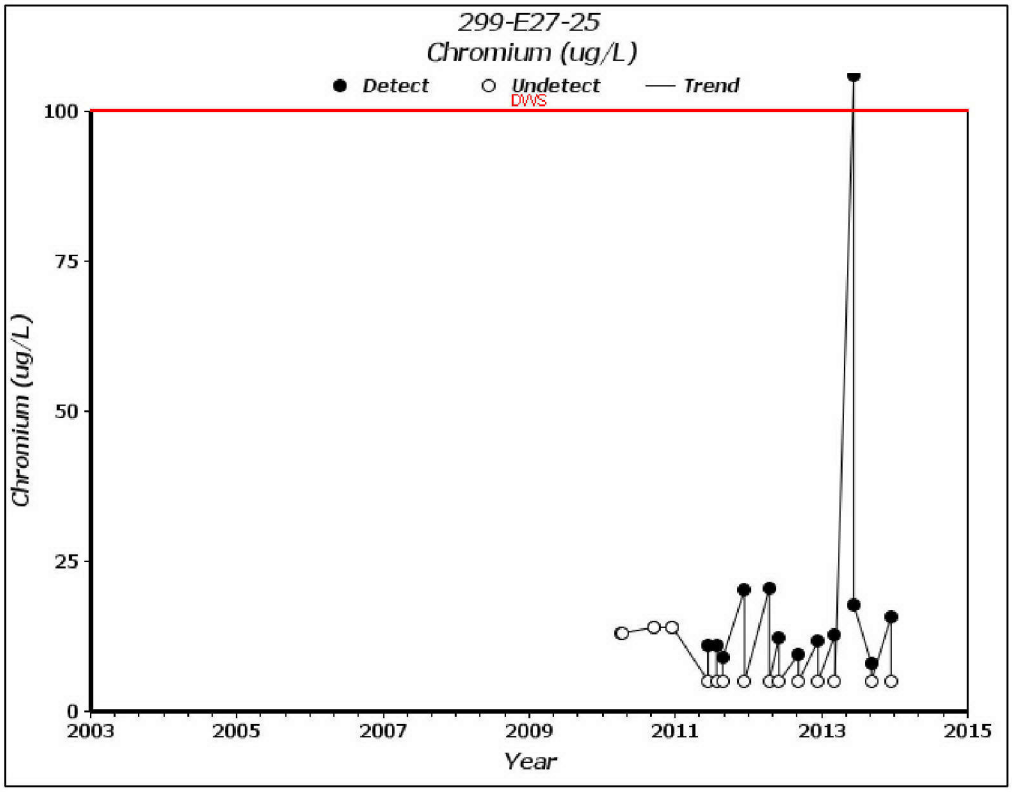

Figure E-57. Total Chromium Concentrations in Well 299-E27-25

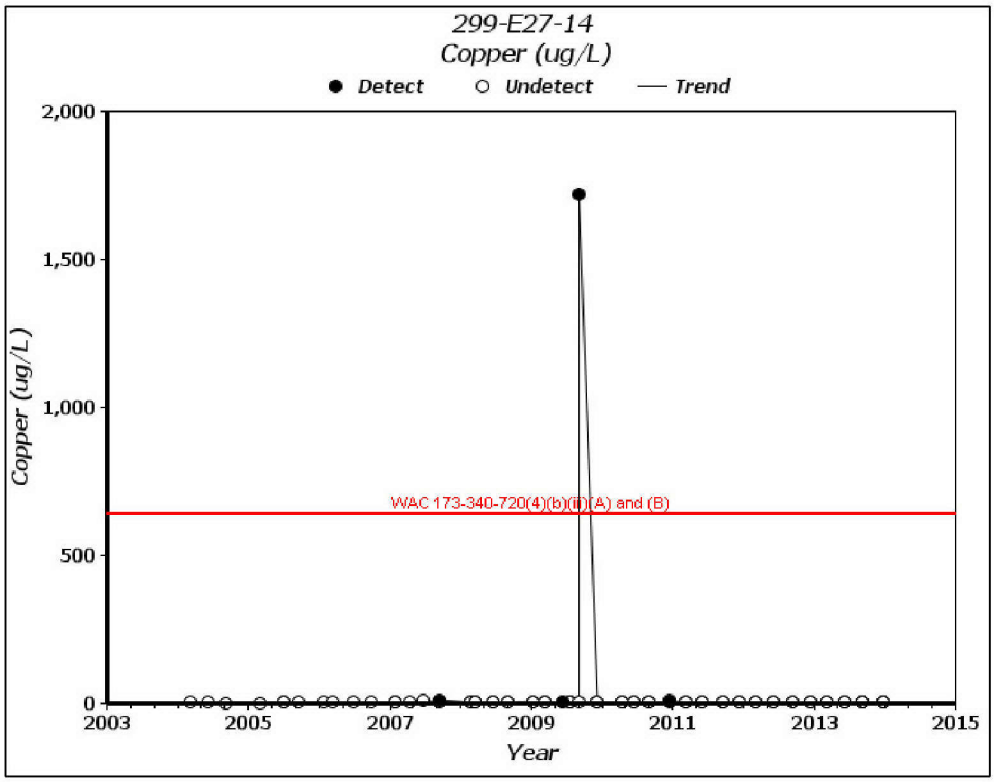

Figure E-58.Copper Concentrations in Well 299-E27-14

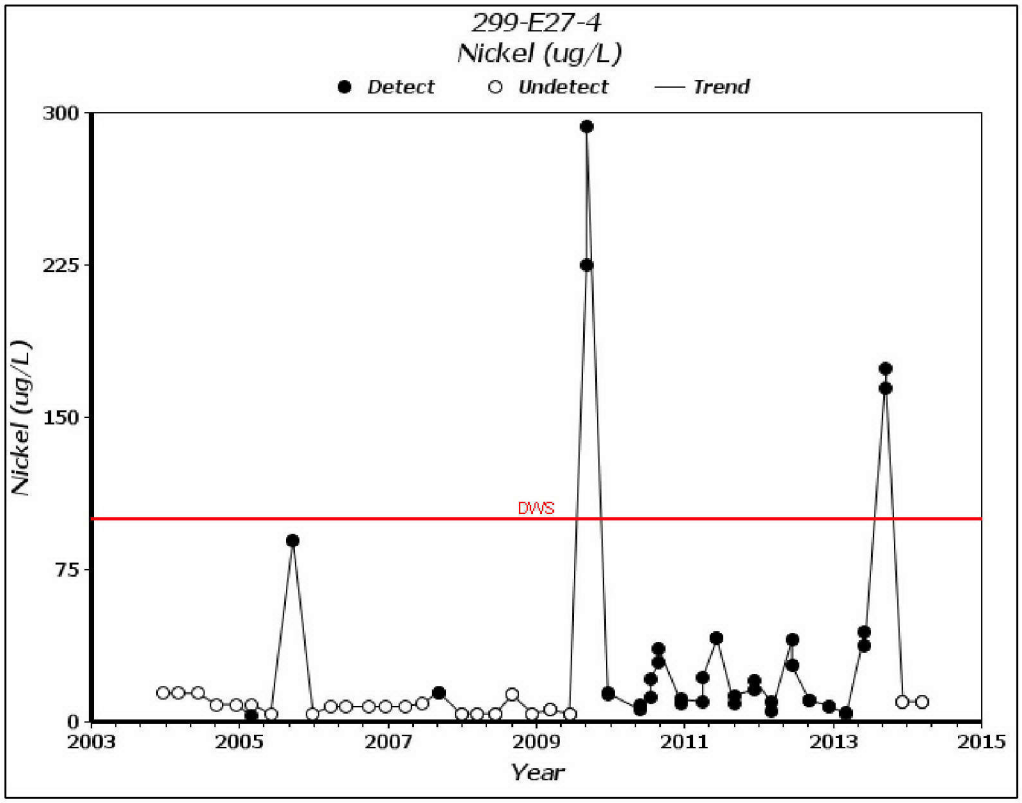

Figure E-59. Nickel Concentrations in Well 299-E27-4

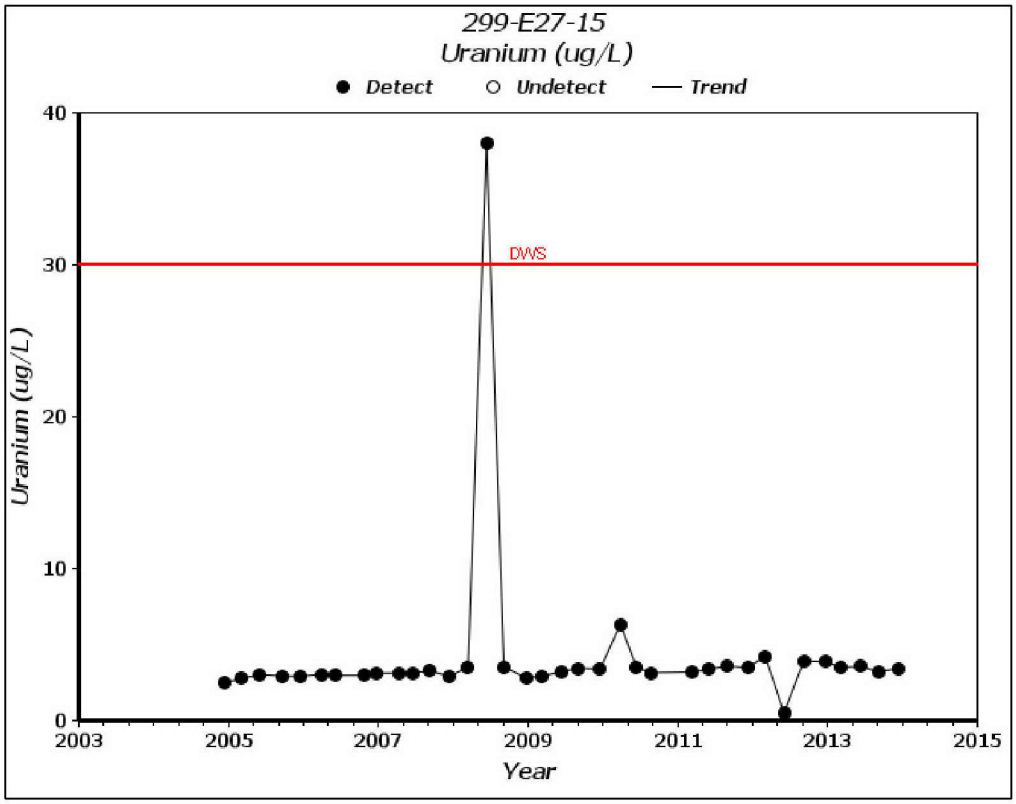

Figure E-60. Uranium Concentrations in Well 299-E27-15

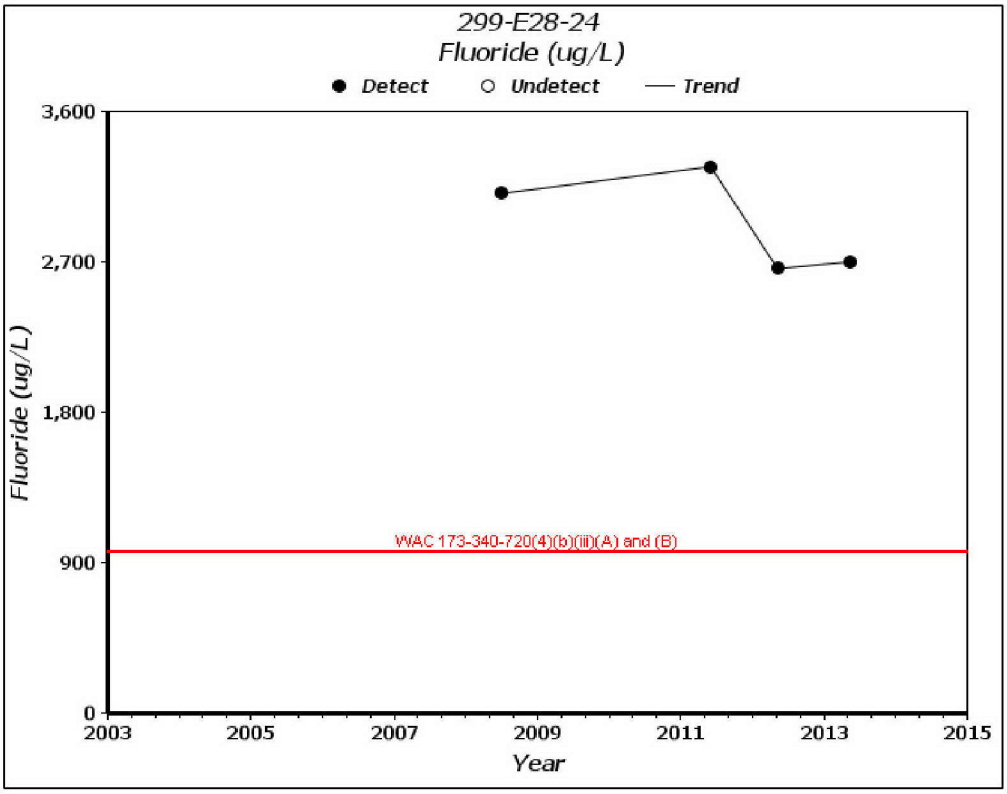

Figure E-61. Fluoride Concentrations in Well 299-E28-24

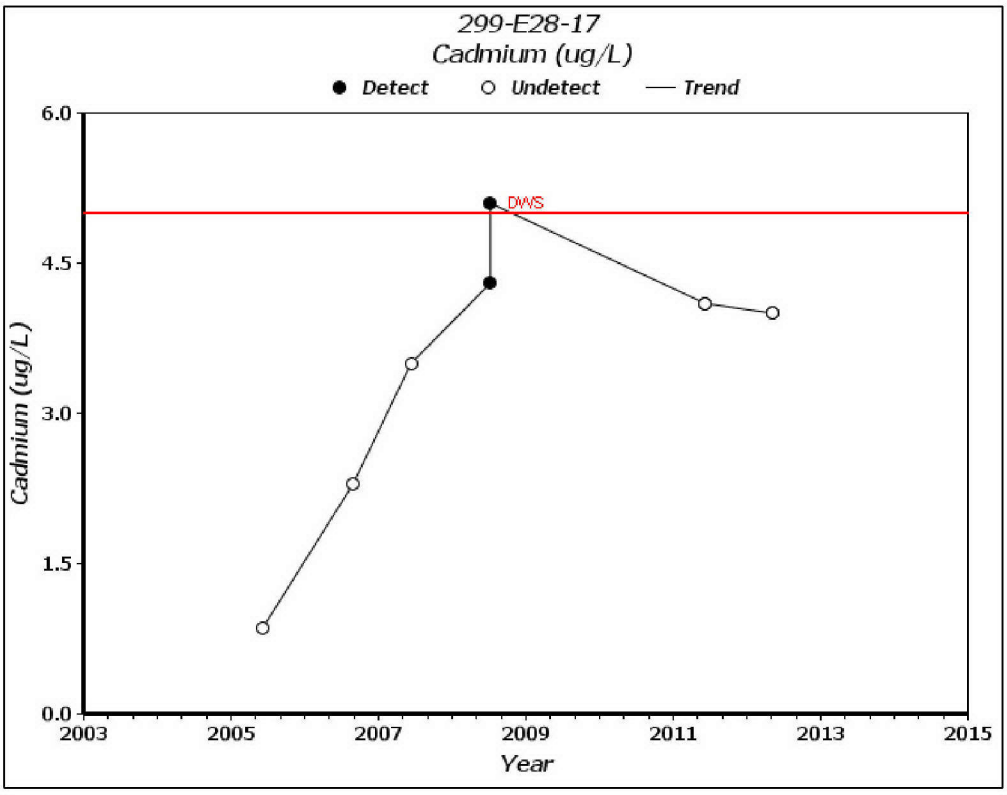

Figure E-62. Cadmium Concentrations in Well 299-E28-17

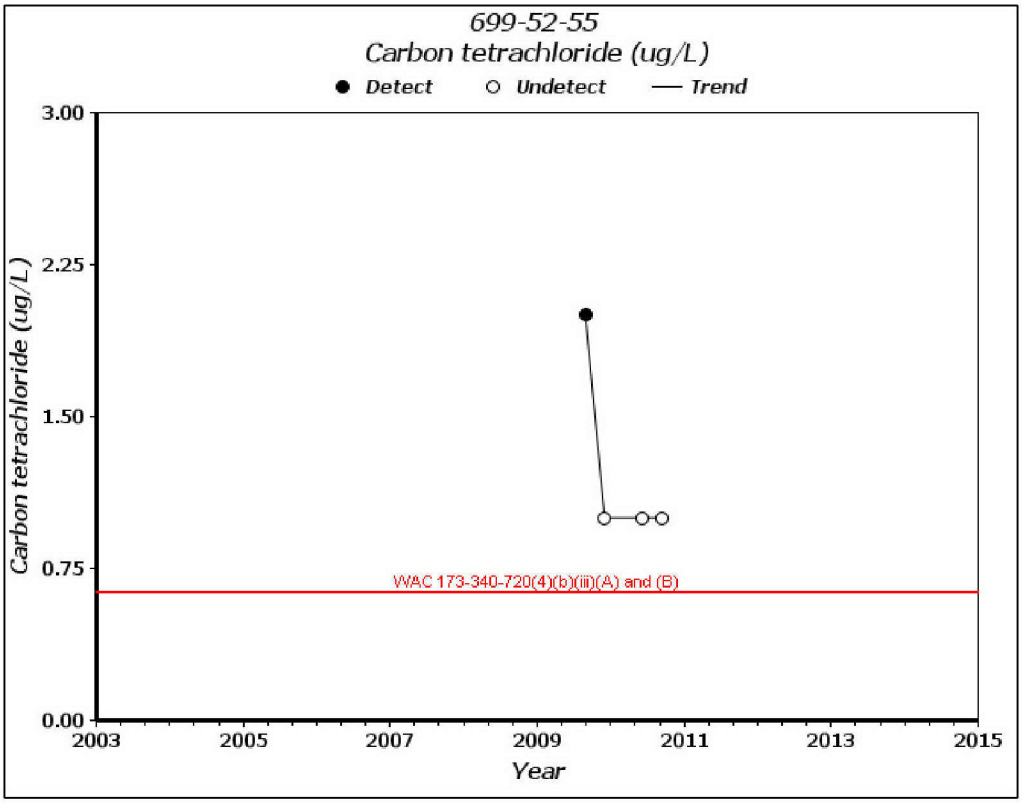

Figure E-63. Carbon Tetrachloride Concentrations in Well 699-52-55

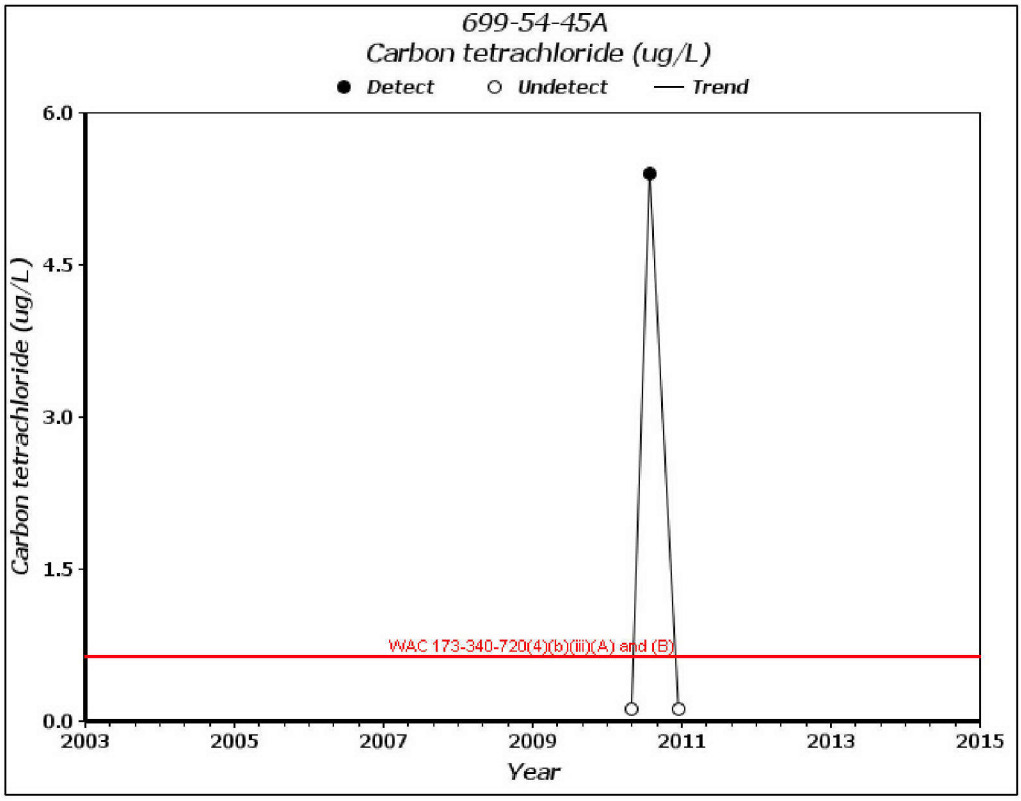

Figure E-64. Carbon Tetrachloride Concentrations in Well 699-54-45A

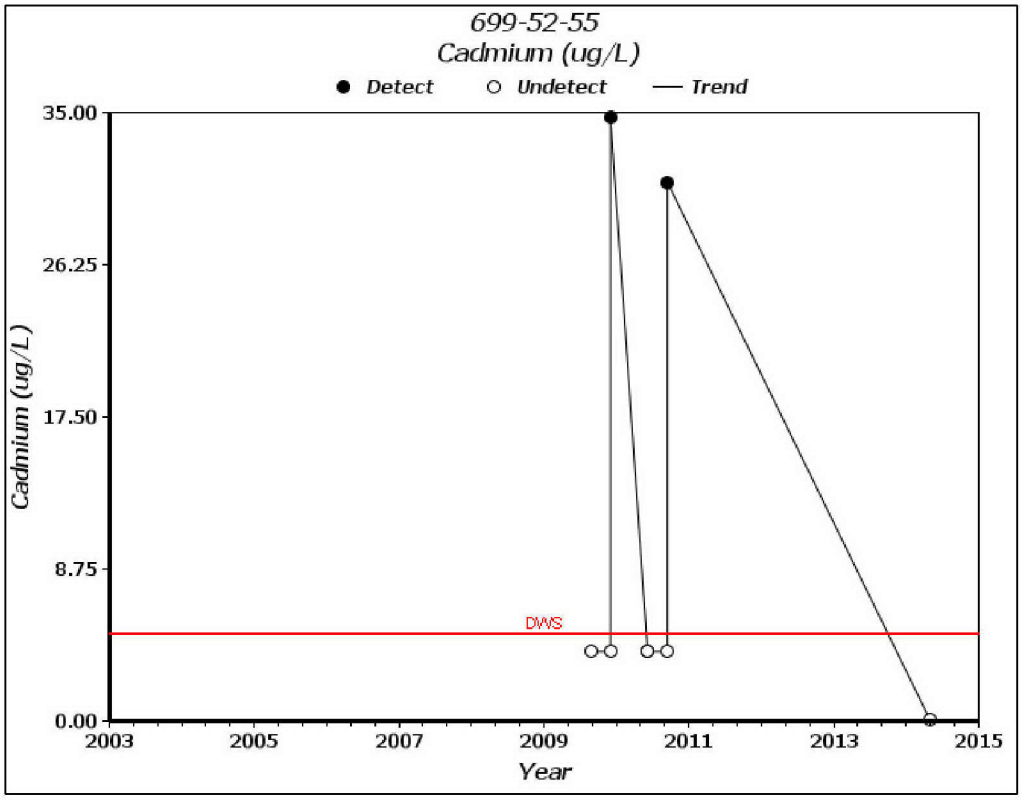

Figure E-65. Cadmium Concentrations in Well 699-52-55

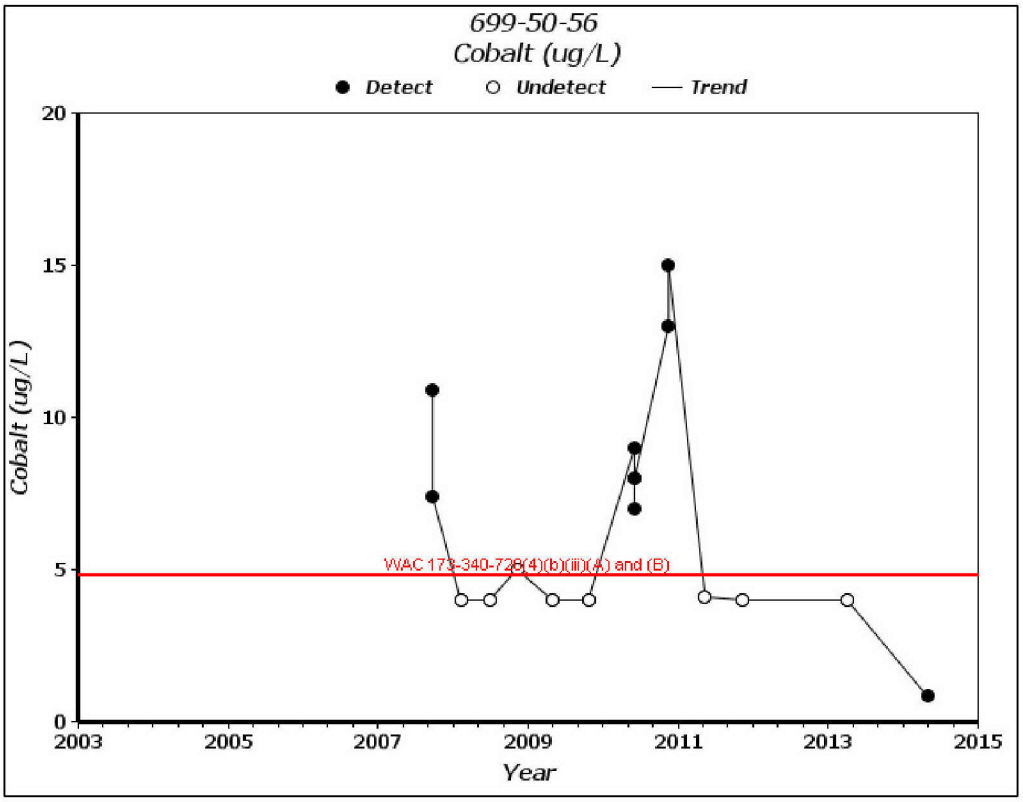

Figure E-66. Cobalt Concentrations in Well 699-50-56

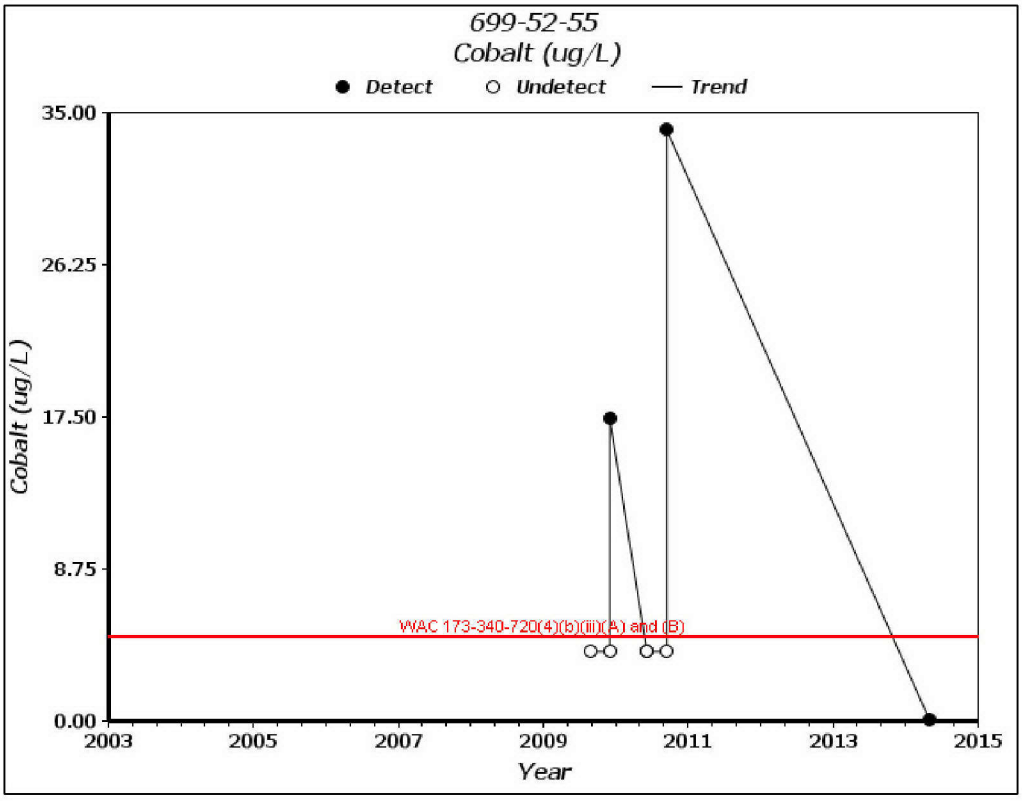

Figure E-67. Cobalt Concentrations in Well 699-52-55

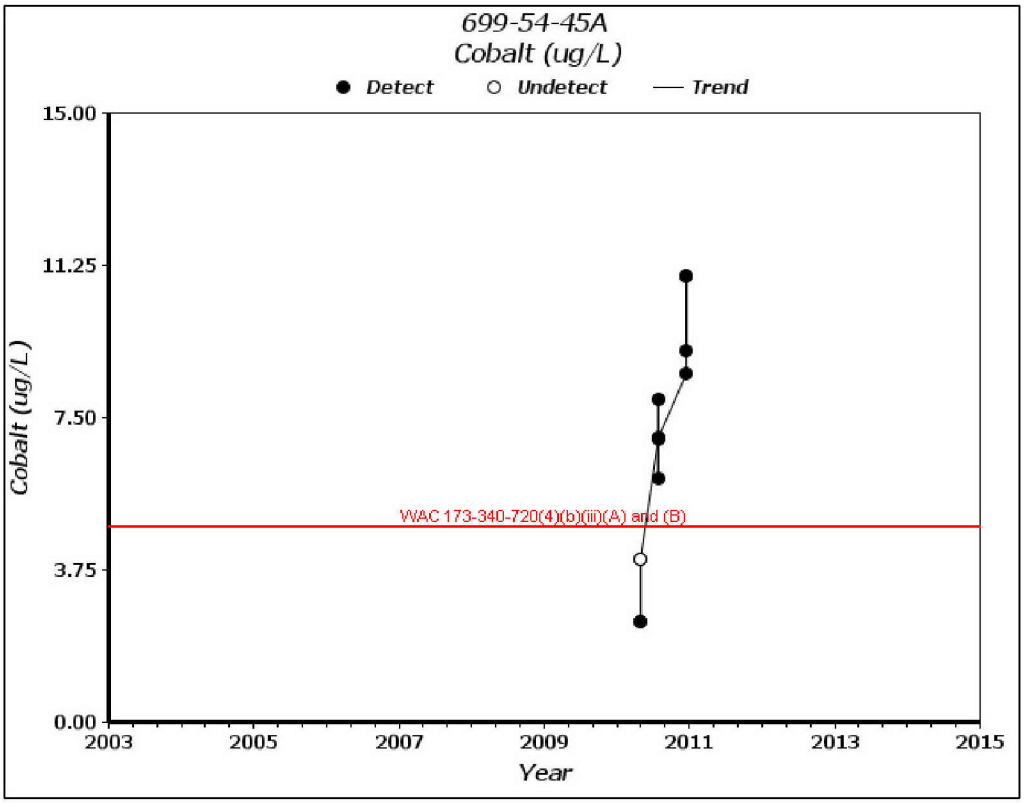

Figure E-68. Cobalt Concentrations in Well 699-54-45A

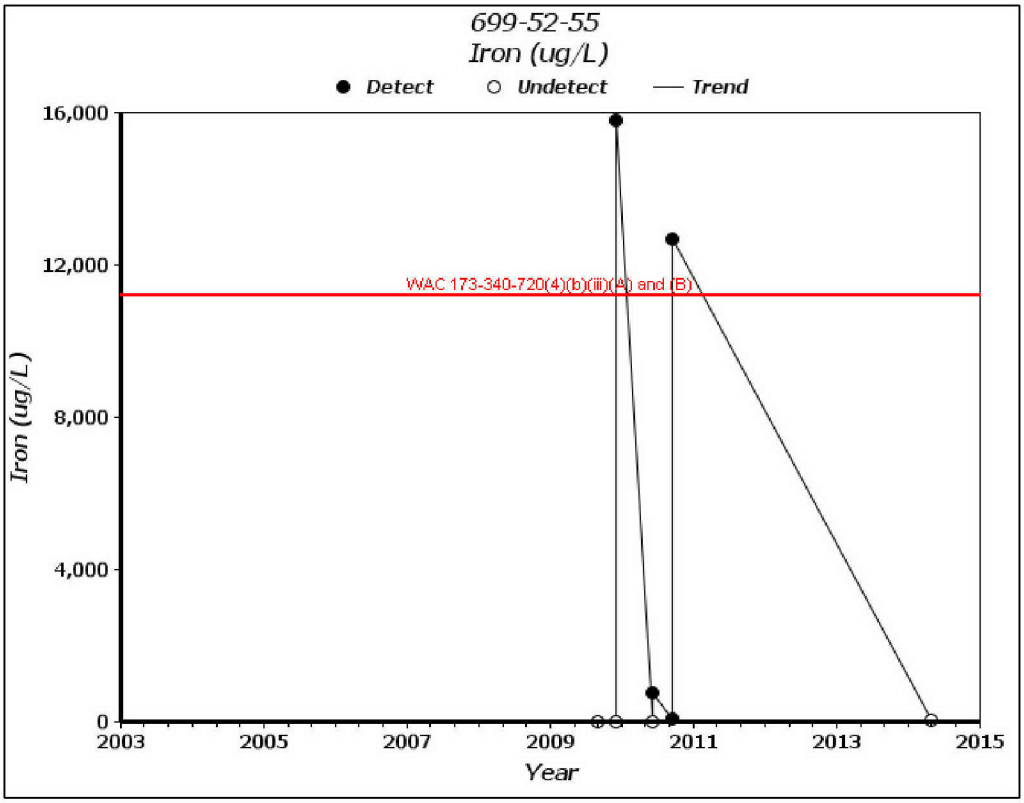

Figure E-69. Iron Concentrations in Well 699-52-55

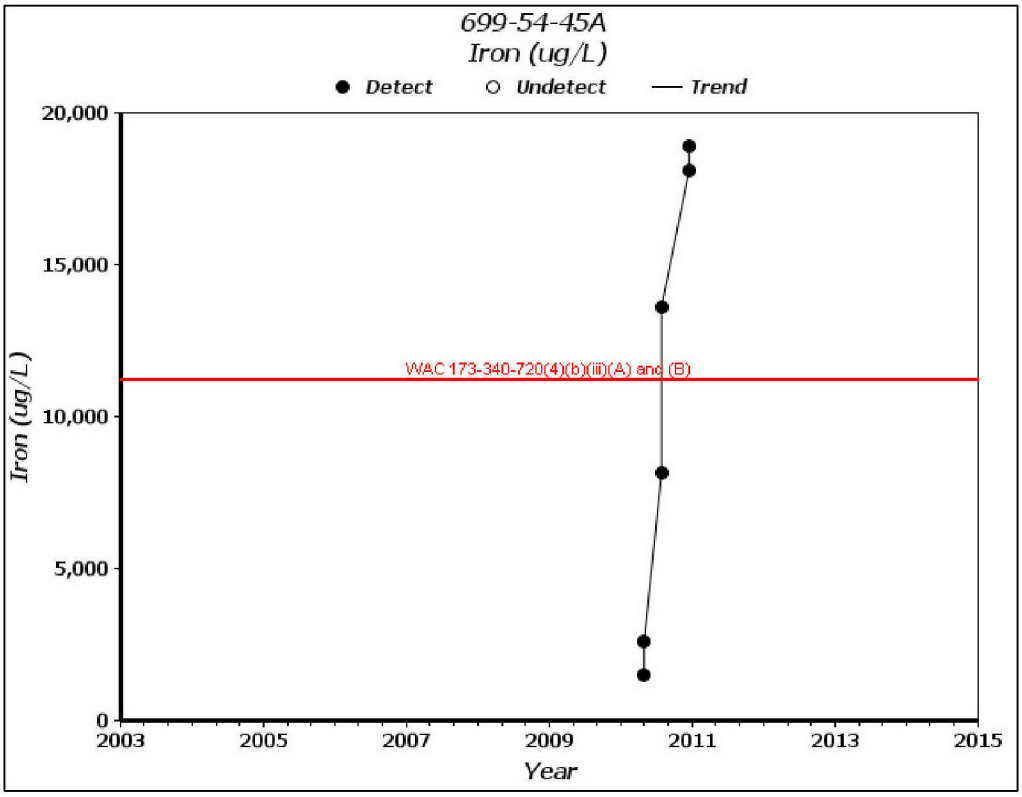

Figure E-70. Iron Concentrations in Well 699-54-45A

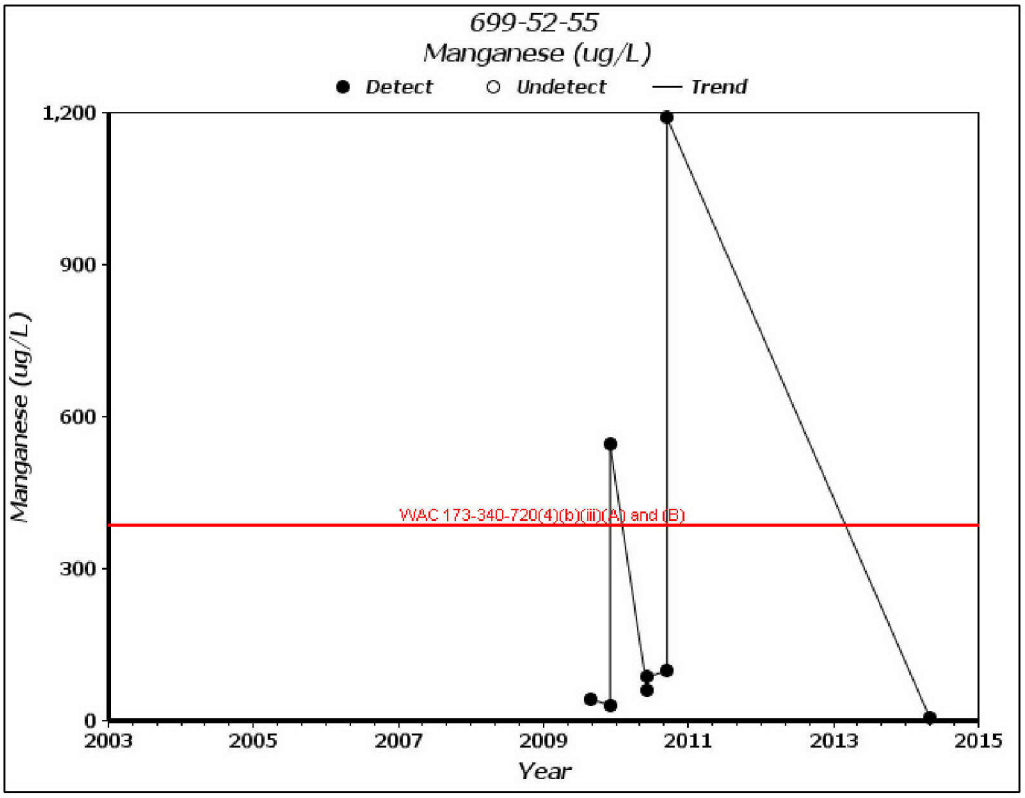

Figure E-71. Manganese Concentrations in Well 699-52-55

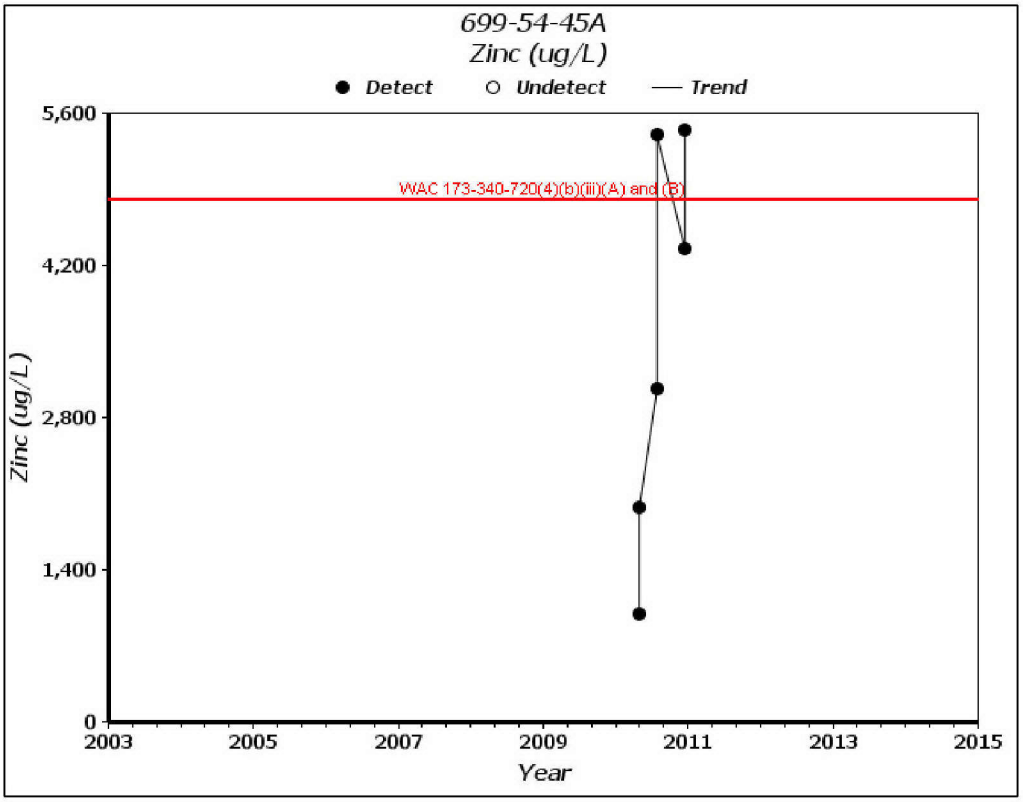

Figure E-72. Zinc Concentrations in Well 699-54-45A

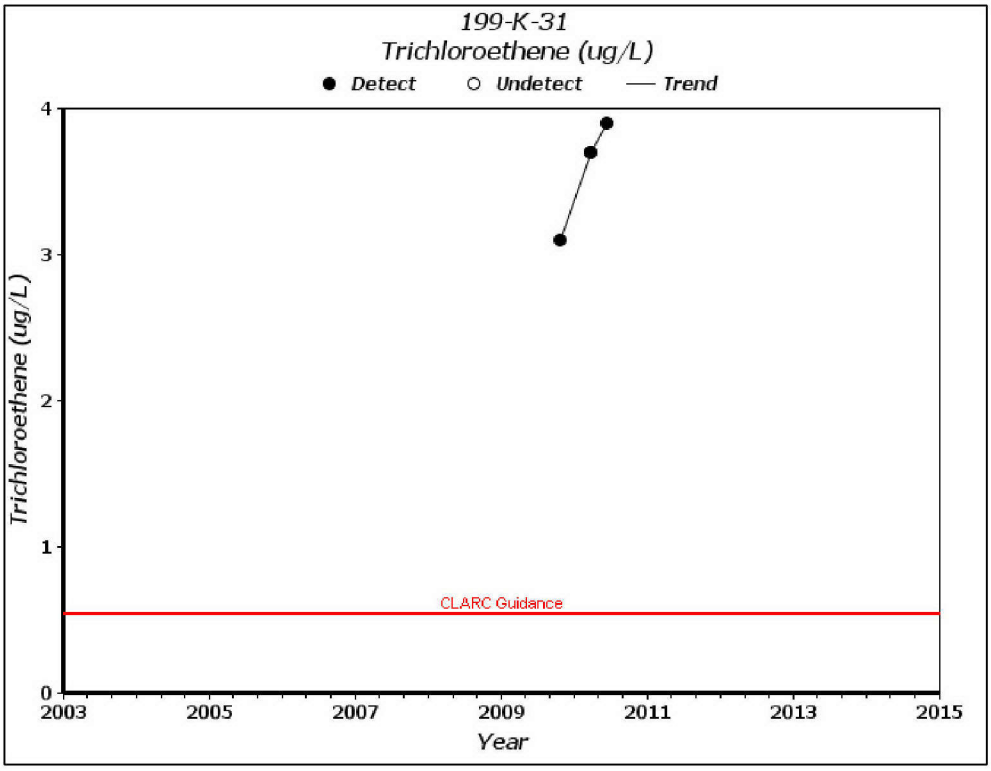

Figure E-73. Trichloroethene Concentrations in Well 199-K-31

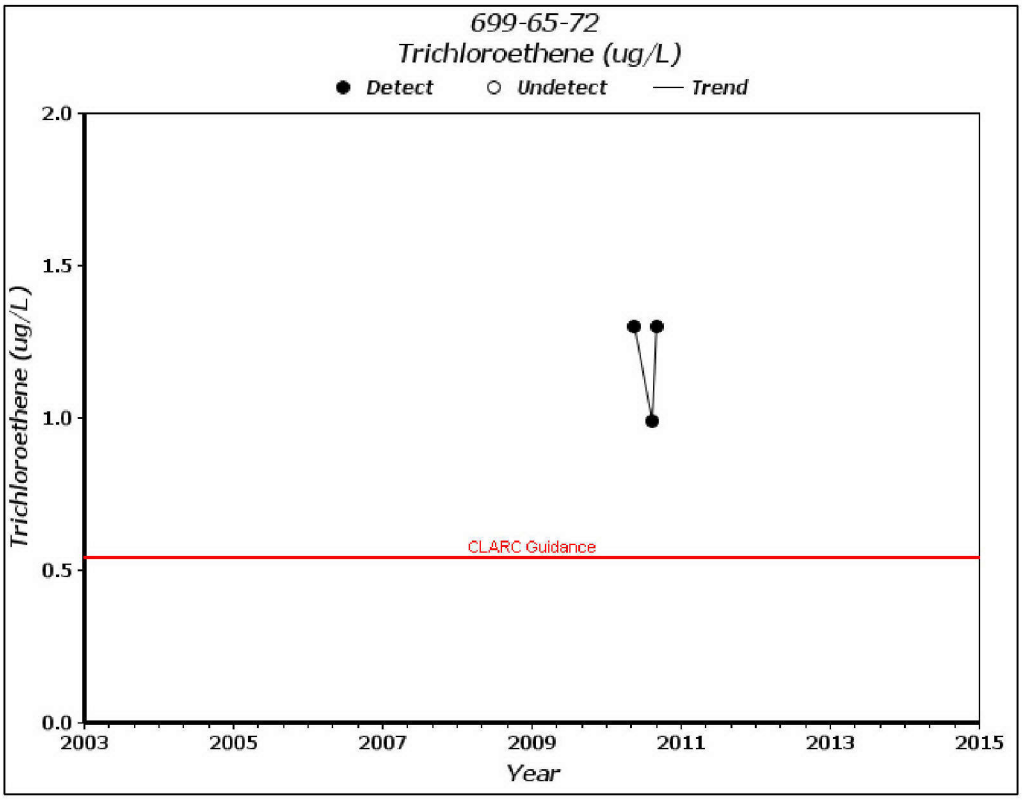

Figure E-74. Trichloroethene Concentrations in Well 699-65-72

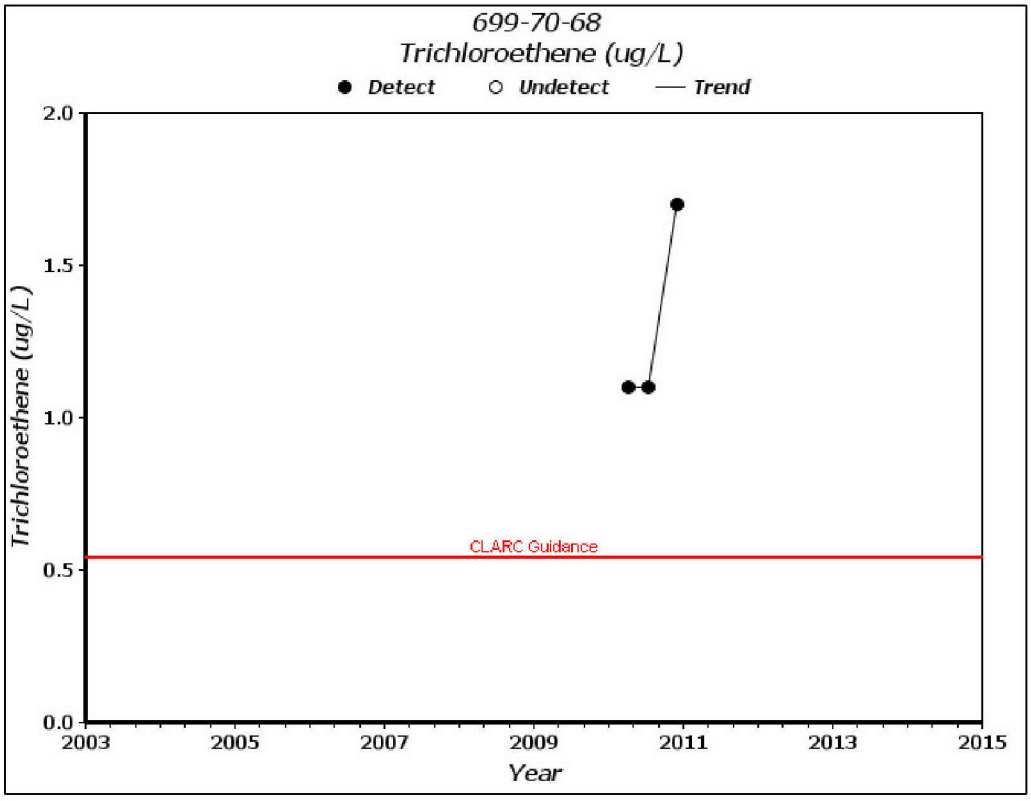

Figure E-75. Trichloroethene Concentrations in Well 699-70-68

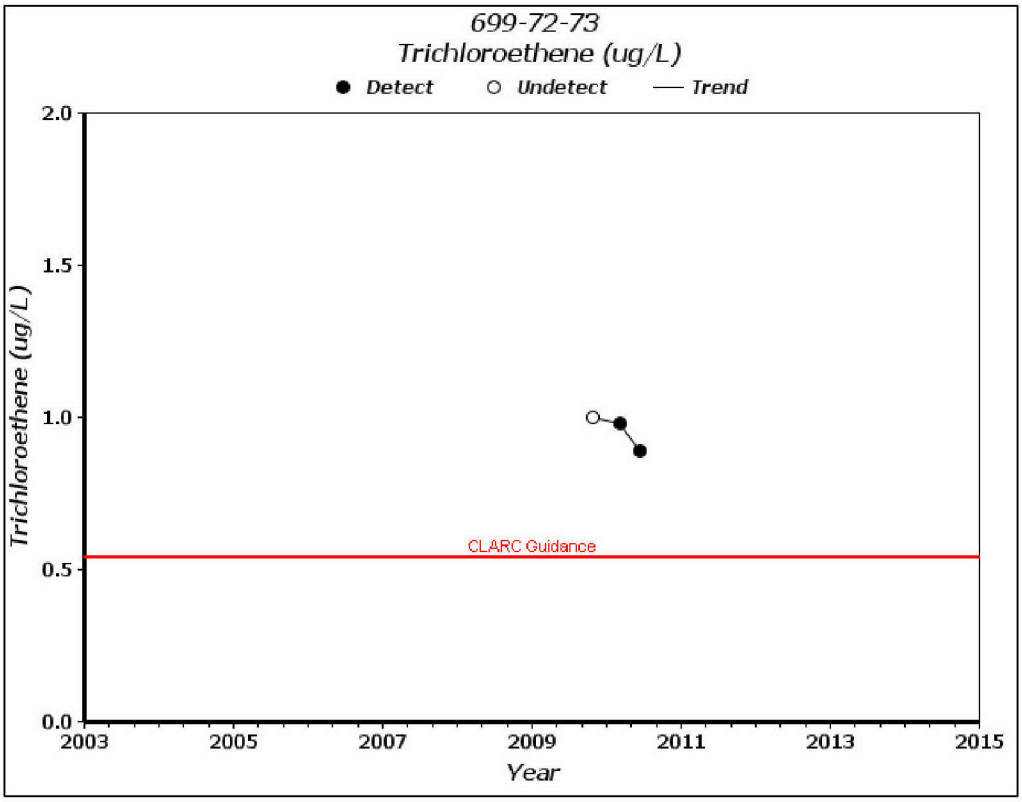

Figure E-76. Trichloroethene Concentrations in Well 699-72-73

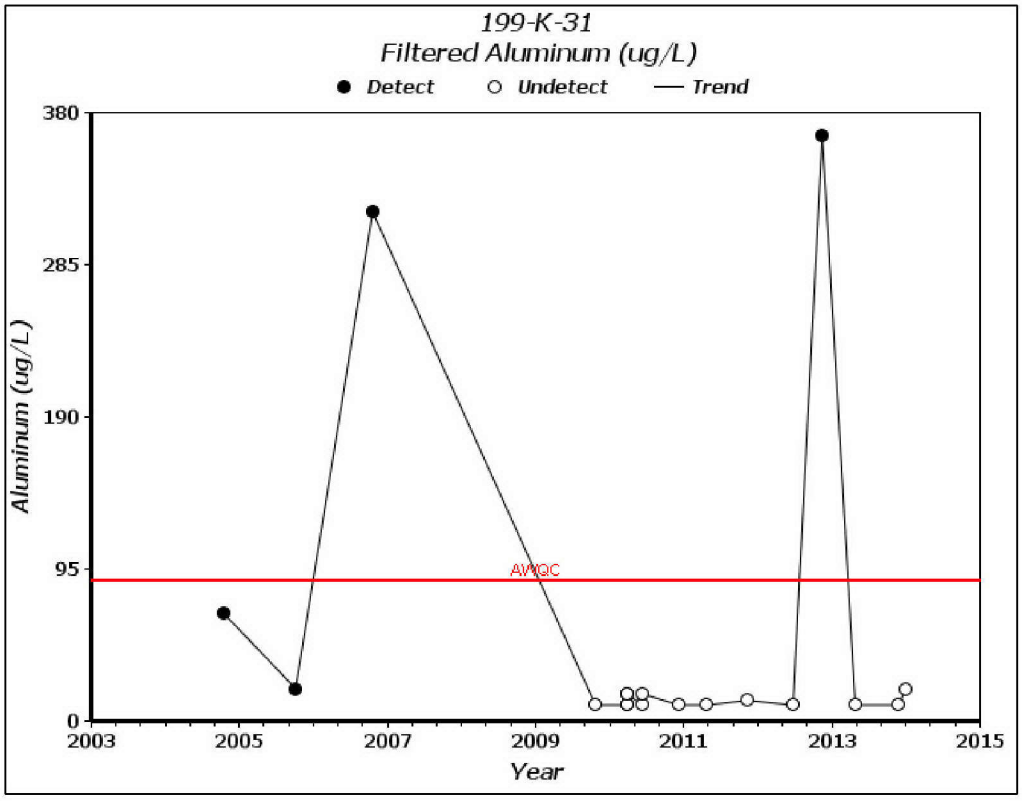

Figure E-77. Aluminum Concentrations in Well 199-K-31

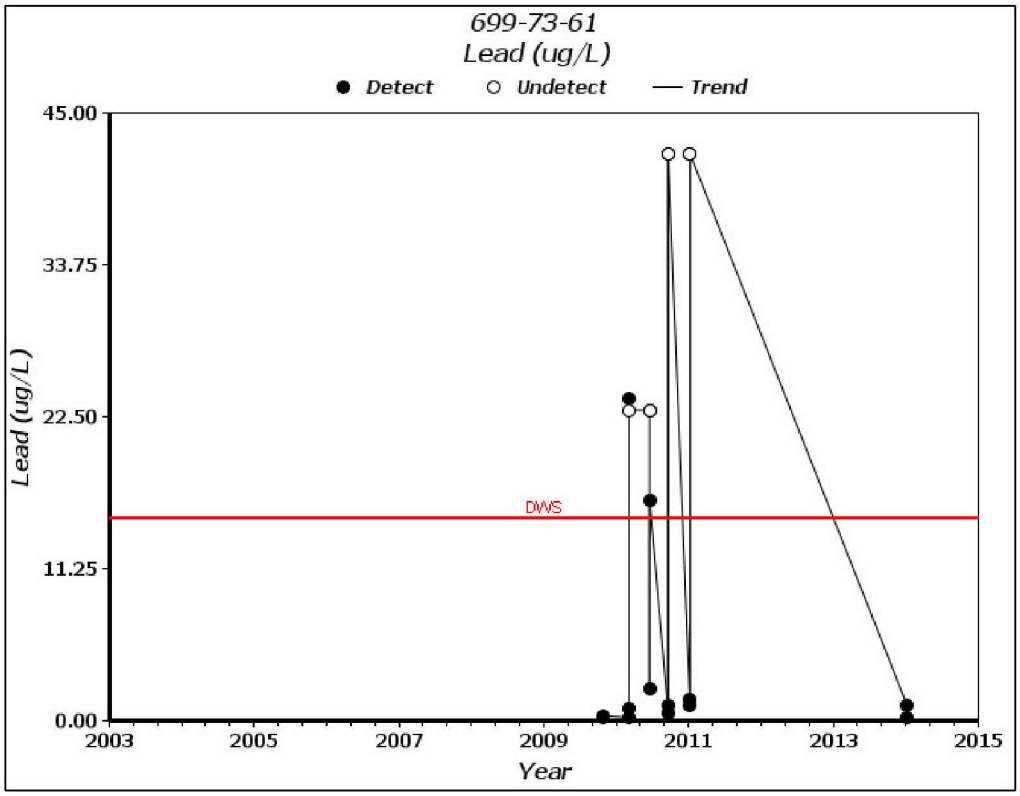

Figure E-78. Total Lead Concentrations in Well 699-73-71

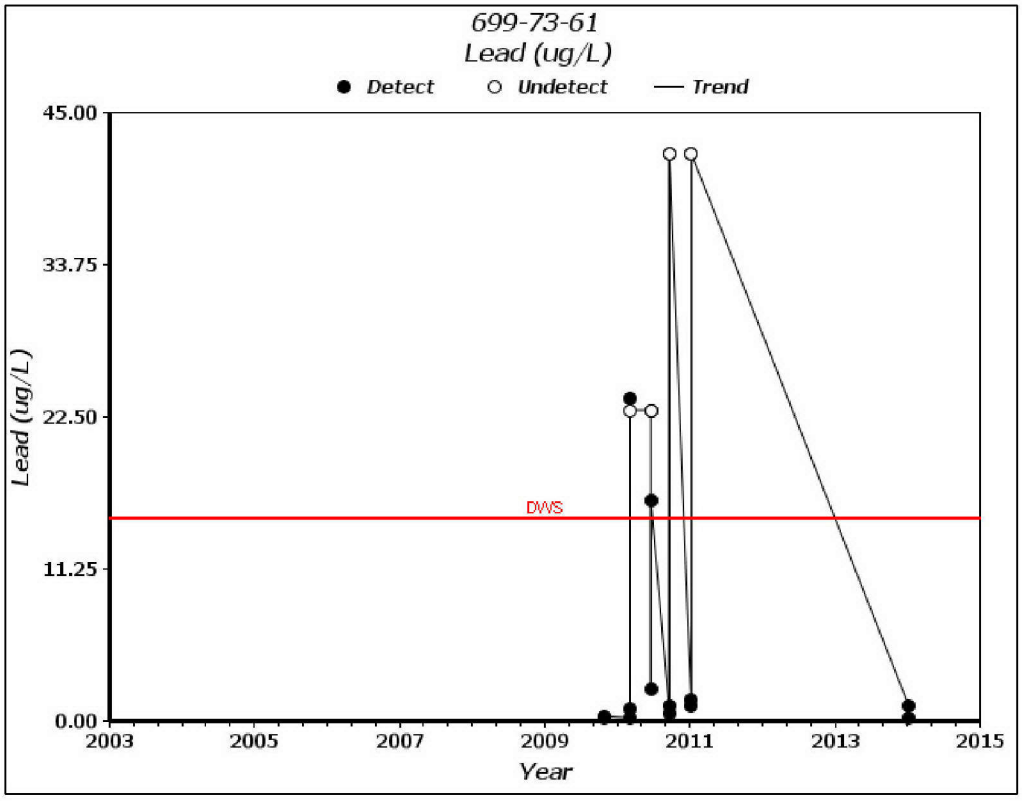

Figure E-79. Dissolved Lead Concentrations in Well 699-73-71

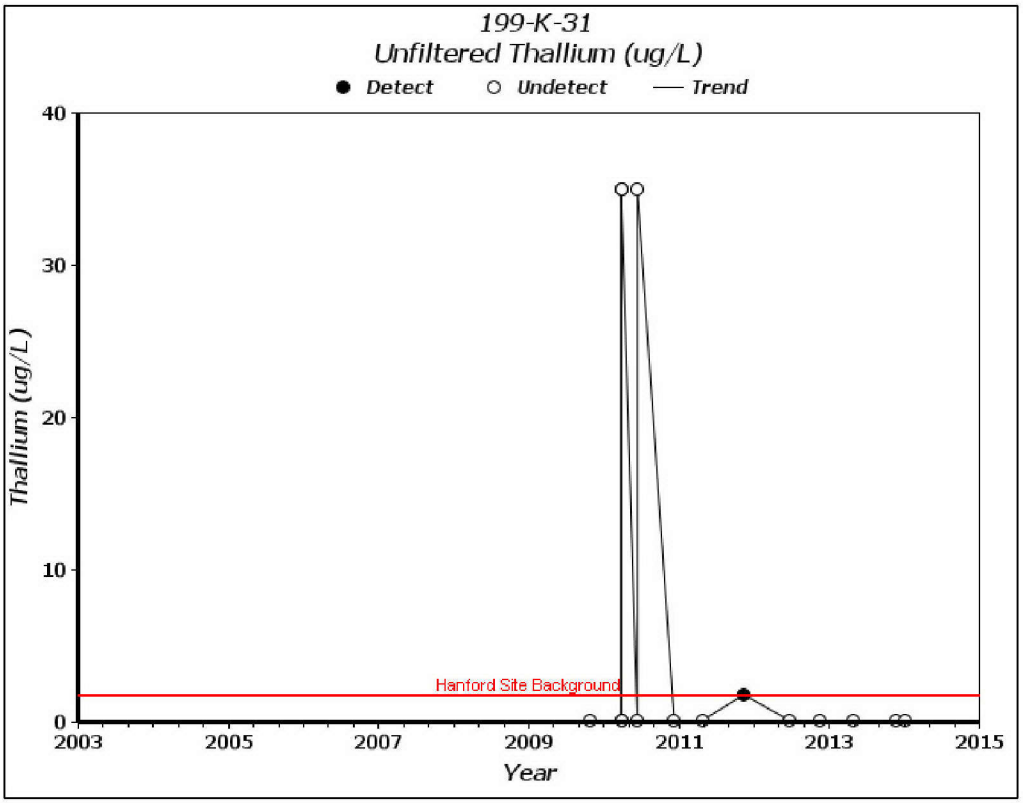

Figure E-80. Thallium Concentrations in Well 699-73-71

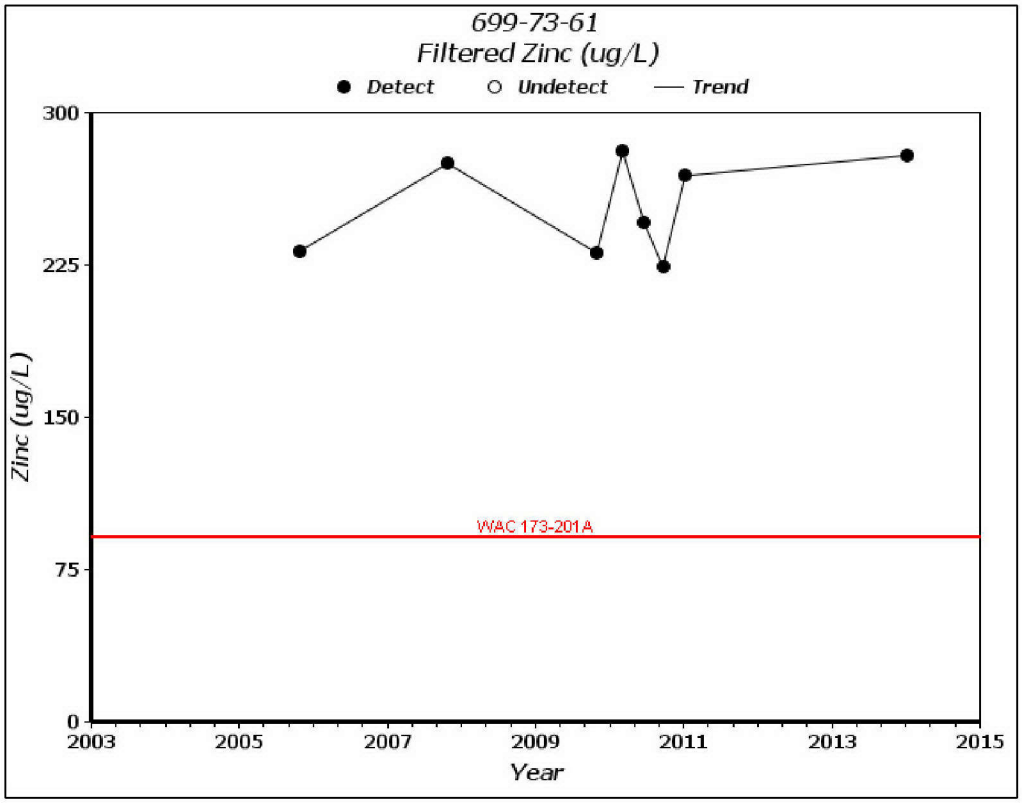

Figure E-81. Dissolved Zinc Concentrations in Well 699-73-61

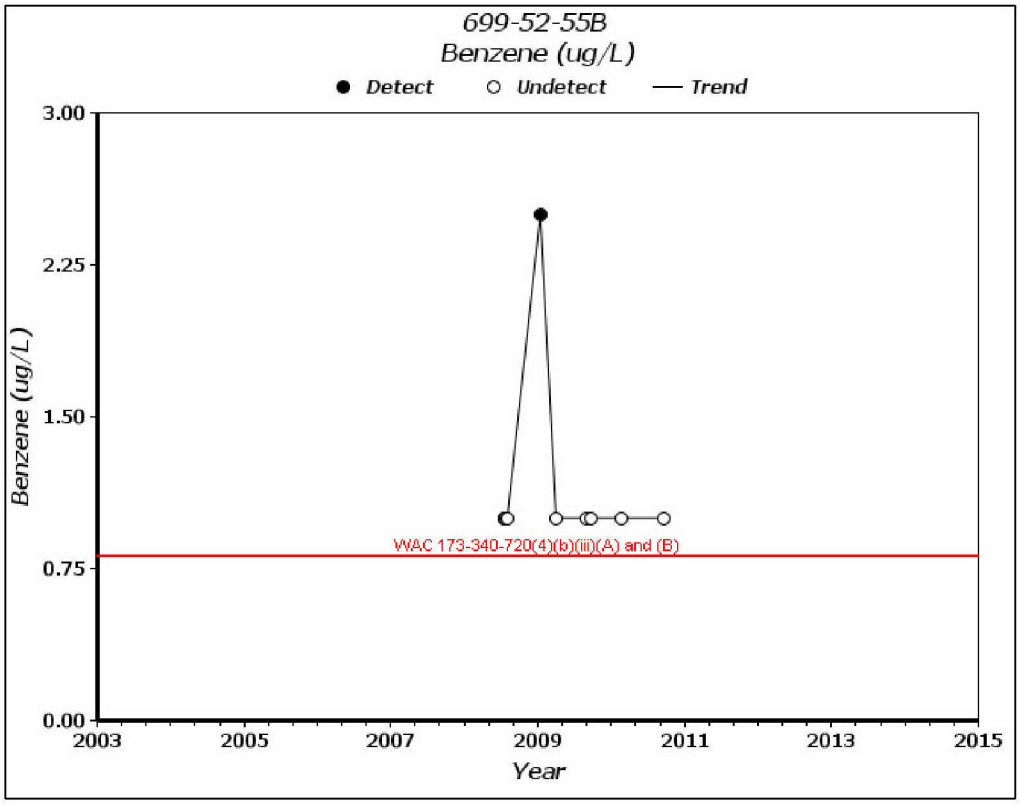

Figure E-82. Benzene Concentrations in Well 699-52-55B

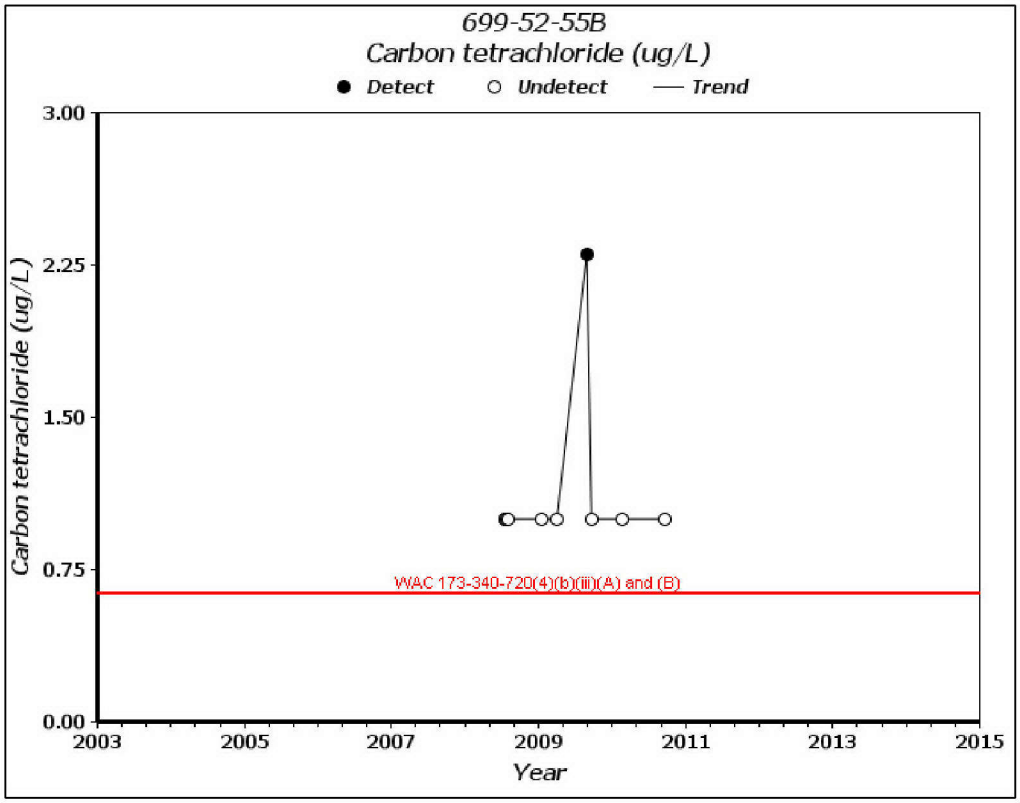

Figure E-83. Carbon Tetrachloride Concentrations in Well 699-52-55B

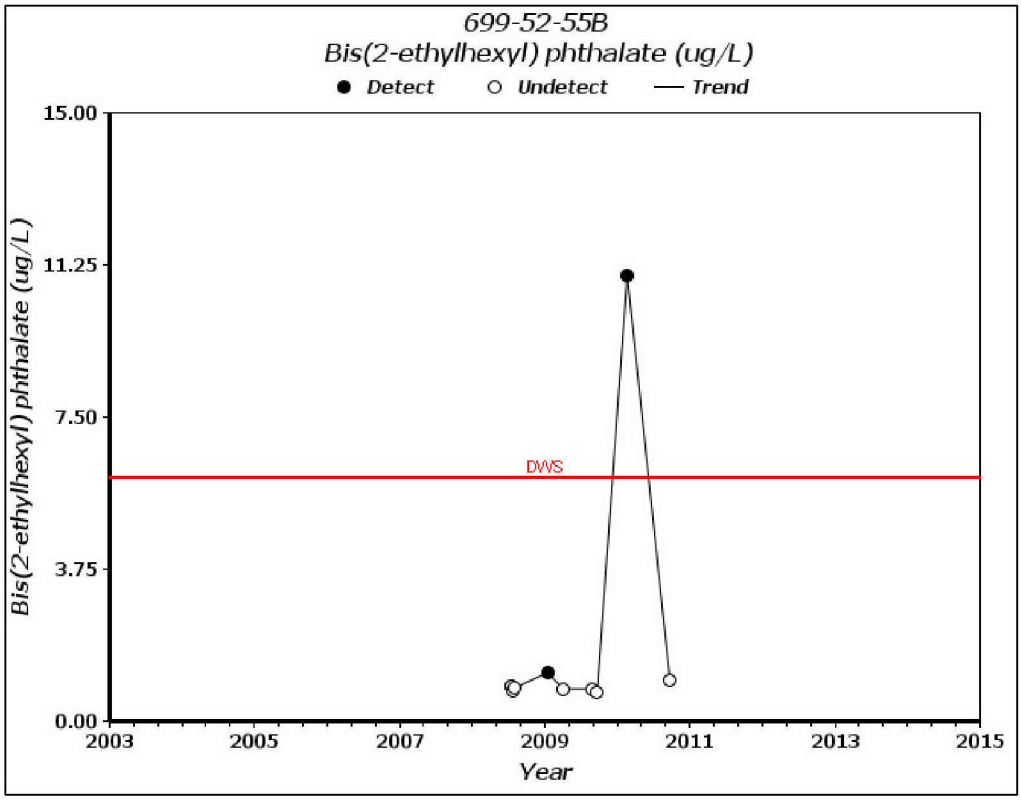

Figure E-84. Bis(2-ethylhexyl) phthalate Concentrations in Well 699-52-55B

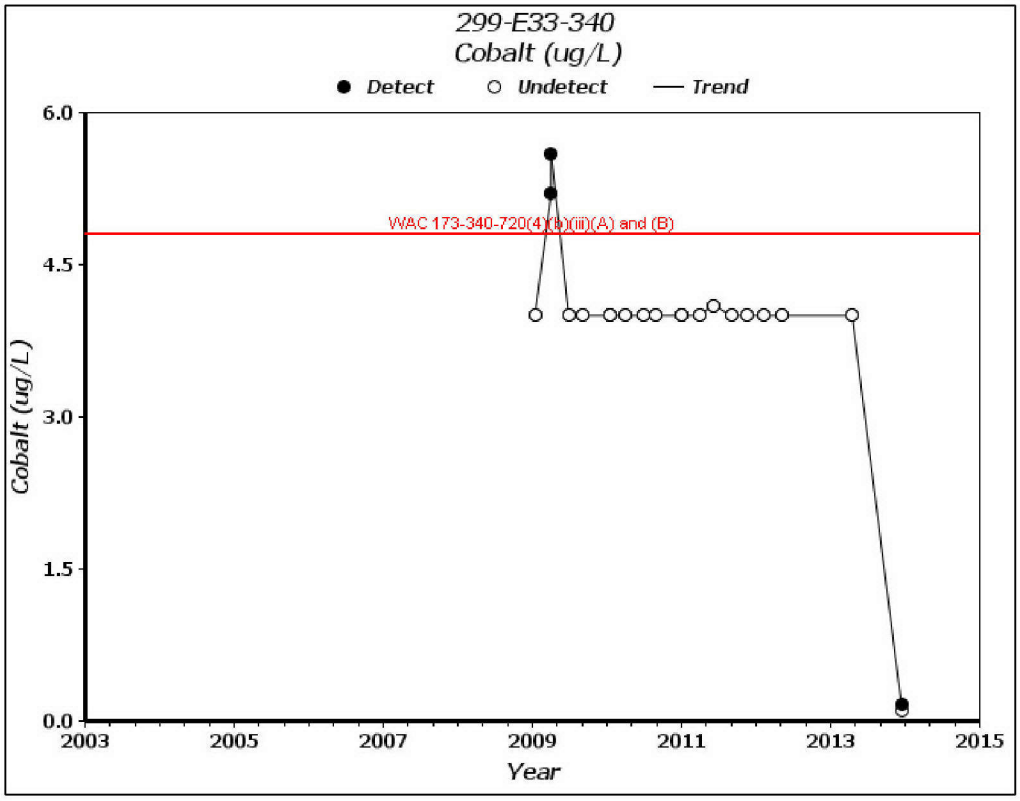

Figure E-85. Cobalt Concentrations in Well 299-E33-340

Table E-1. Groundwater Summary Statistics for LLWMA-1 Exposure Area – Unconfined Aquifer

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																	
Cobalt-60	No	pCi/L	6/12/2008	7/9/2012	36	8	22.22	-4.4	12	10	39	0.023	8	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	1/3/2011	7/18/2013	16	13	81.25	2.4	2.6	3.5	26	--	--	--	15	2	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	6/12/2008	7/18/2013	20	20	100	0	0	17	4,200	3.1	20	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	1/2/2008	7/18/2013	204	140	68.63	-0.098	1.0	0.17	5.2	9.00E-07	140	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	95	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	1/2/2008	7/18/2013	205	204	99.51	-0.20	-0.20	11	21,000	0.83	204	DOE/RL-96-61 Rev. 0, Table ES-1	900	52	40 CFR 141 – federal MCL
Tritium	No	pCi/L	1/2/2008	7/18/2013	206	181	87.86	-110	290	210	26,000	119	181	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	4	40 CFR 141 – federal MCL
Volatile Organic Compounds																	
Acetone	No	µg/L	7/3/2012	1/10/2013	24	1	4.17	0.34	2.0	1.0	1.0	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	µg/L	7/3/2012	1/10/2013	24	1	4.17	0.10	1.0	0.13	0.13	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Dioxins and Furans																	
Octachlorodibenzofuran	No	µg/L	7/3/2012	10/15/2012	22	4	18.18	3.40E-07	1.30E-06	1.00E-06	1.70E-06	--	--	--	0.0022	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons – diesel range	No	µg/L	7/3/2012	10/15/2012	22	2	9.09	70	70	140	140	--	--	--	500	0	WAC 173-340-900, Table 720-1
Metals																	
Aluminum	No	µg/L	10/3/2012	10/15/2012	19	2	10.53	10	21	11	47	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	µg/L	2/10/2008	10/15/2012	23	3	13.04	0.30	0.60	46	50	55.1	0	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	3	40 CFR 141 – federal MCL
Arsenic	No	µg/L	6/22/2008	10/15/2012	33	33	100	--	--	3.3	6.3	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	33	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	1/2/2008	7/18/2013	226	225	99.56	4.1	4.1	39	210	105	19	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL

Table E-1. Groundwater Summary Statistics for LLWMA-1 Exposure Area – Unconfined Aquifer

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	µg/L	1/2/2008	7/18/2013	226	4	1.77	0.10	4.1	0.19	4.6	0.92	3	DOE/RL-96-61 Rev. 0, Table ES-1	5.0	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	1/2/2008	7/18/2013	226	152	67.26	5.0	20	3.0	85	2.4	152	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	1/2/2008	7/18/2013	226	80	35.4	4.0	14	3.1	70	2.4	80	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cobalt	No	µg/L	1/2/2008	7/18/2013	225	19	8.44	0.10	4.1	0.10	5.7	0.92	3	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	1/2/2008	7/18/2013	224	15	6.7	0.20	6.0	0.25	6.6	0.81	5	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	12/9/2008	1/11/2012	24	5	20.83	2.0	2.0	4.6	14	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	1/2/2008	7/18/2013	223	199	89.24	18	69	12	349	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	µg/L	1/2/2008	10/15/2012	48	18	37.5	0.10	0.22	0.11	1.0	0.92	1	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Manganese	No	µg/L	1/2/2008	7/18/2013	226	24	10.62	4.0	6.0	0.21	7.6	38.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	µg/L	1/2/2008	10/15/2012	33	2	6.06	0.050	0.10	0.11	0.18	0.0030	2	DOE/RL-96-61 Rev. 0, Table ES-1	2.0	0	40 CFR 141 – federal MCL
Molybdenum	No	µg/L	10/3/2012	10/15/2012	19	19	100	0	0	3.5	8.4	3.2	19	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	µg/L	1/2/2008	7/18/2013	223	114	51.12	2.7	9.0	0.59	41	1.6	112	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Selenium	No	µg/L	7/3/2012	10/15/2012	22	22	100	--	--	3.1	11	10.5	1	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Silver	No	µg/L	1/2/2008	7/18/2013	221	5	2.26	0.10	8.0	0.14	18	5.3	4	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	µg/L	1/2/2008	7/18/2013	226	225	99.56	4.1	4.1	190	1,290	323	100	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	µg/L	7/3/2012	10/15/2012	22	1	4.55	0.10	0.10	0.24	0.24	1.7	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.50	0	40 CFR 141 – federal MCLG
Tin	No	µg/L	7/3/2012	10/15/2012	22	3	13.64	0.10	0.10	0.10	0.23	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	µg/L	1/2/2008	7/18/2013	206	205	99.51	0.10	0.10	2.3	159	9.9	133	DOE/RL-96-61 Rev. 0, Table ES-1	30	24	40 CFR 141 – federal MCL

Table E-1. Groundwater Summary Statistics for LLWMA-1 Exposure Area – Unconfined Aquifer

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	µg/L	1/3/2008	7/18/2013	225	186	82.67	7.0	17	8.4	29	11.5	176	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	1/2/2008	7/18/2013	223	15	6.73	2.0	24	4.0	17	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)
Anions																	
Chloride	No	µg/L	1/2/2008	7/18/2013	227	227	100	--	--	10,500	46,800	15,630	108	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Cyanide	No	µg/L	1/2/2008	7/18/2013	94	62	65.96	4.0	4.0	4.1	558	8.4	44	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	54	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	µg/L	1/2/2008	7/18/2013	227	225	99.12	60	60	105	536	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	µg/L	1/2/2008	7/18/2013	227	227	100	--	--	31,900	1.05E+06	26,871	227	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	209	40 CFR 141 – federal MCL
Nitrite	No	µg/L	1/2/2008	7/18/2013	227	56	24.67	65	296	125	558	93.7	56	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	1/2/2008	7/18/2013	227	227	100	--	--	36,300	224,000	47,014	204	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141--Secondary 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."

LLWMA = low-level waste management area
MCL = maximum contaminant level
MCLG = maximum contaminant level guideline

Table E-2. Groundwater Summary Statistics for LLWMA-2 and 216-B-63 Trench Exposure Area – Unconfined Aquifer

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																	
Gross alpha	No	pCi/L	4/3/2008	11/11/2013	54	17	31.48	-0.54	4.9	1.6	6.6	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	4/3/2008	11/11/2013	56	55	98.21	3.0	3.0	4.2	1,400	3.1	55	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	4/2/2008	11/11/2013	122	95	77.87	-0.00072	1.5	0.22	4.2	9.00E-07	95	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	59	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	4/2/2008	11/11/2013	133	66	49.62	-15	8.7	7.1	9,800	0.83	66	DOE/RL-96-61 Rev. 0, Table ES-1	900	5	40 CFR 141 – federal MCL
Tritium	No	pCi/L	4/2/2008	11/11/2013	145	77	53.1	-140	341	200	2,200	119	77	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Total Petroleum Hydrocarbons																	
Oil and grease	No	µg/L	4/2/2008	4/2/2008	1	1	100	--	--	1,000	1,000	--	--	--	500	1	WAC 173-340-900 Tables, Table 720-1
Metals																	
Antimony	No	µg/L	4/30/2008	4/18/2012	21	6	28.57	4.0	4.0	5.6	114	55.1	4	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	5	40 CFR 141 – federal MCL
Arsenic	No	µg/L	10/4/2009	4/13/2012	19	19	100	--	--	4.3	9.9	7.9	13	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	19	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	4/2/2008	11/11/2013	154	154	100	--	--	27	199	105	4	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	4/2/2008	11/11/2013	152	113	74.34	4.0	14	3.4	51	2.4	113	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	4/2/2008	11/11/2013	153	63	41.18	3.1	14	3.2	54	2.4	63	DOE/RL-96-61 Rev. 0, Table ES-1	48	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	4/2/2008	11/11/2013	154	7	4.55	4.0	6.0	4.1	6.1	0.81	7	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	10/8/2008	10/4/2011	30	9	30	2.0	2.0	2.3	8.5	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	4/2/2008	11/11/2013	157	144	91.72	16	62	20	436	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	µg/L	10/8/2008	10/13/2009	18	4	22.22	0.10	0.20	0.16	0.28	0.92	0	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Manganese	No	µg/L	4/2/2008	11/11/2013	154	13	8.44	0.96	6.0	1.1	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)

Table E-2. Groundwater Summary Statistics for LLWMA-2 and 216-B-63 Trench Exposure Area – Unconfined Aquifer

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
Mercury	No	µg/L	10/8/2008	10/13/2009	18	3	16.67	0.050	0.10	0.052	0.11	0.0030	3	DOE/RL-96-61 Rev. 0, Table ES-1	2.0	0	40 CFR 141 – federal MCL
Nickel	No	µg/L	4/2/2008	11/11/2013	154	104	67.53	4.0	67	4.0	198	1.6	104	DOE/RL-96-61 Rev. 0, Table ES-1	100	5	40 CFR 141 – federal MCL
Silver	No	µg/L	4/2/2008	11/11/2013	154	3	1.95	4.0	7.0	4.4	15	5.3	2	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	µg/L	4/2/2008	11/11/2013	153	153	100	--	--	166	963	323	34	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	µg/L	4/2/2008	11/11/2013	139	137	98.56	0.10	4.6	2.3	7.7	9.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL
Vanadium	No	µg/L	4/2/2008	11/11/2013	154	148	96.1	7.0	50	11	31	11.5	147	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	4/2/2008	11/11/2013	154	19	12.34	4.0	9.0	4.0	60	21.8	2	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Chloride	No	µg/L	4/2/2008	11/11/2013	172	172	100	--	--	9,100	101,000	15,630	104	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	Chloride
Cyanide	No	µg/L	5/12/2008	11/11/2013	25	5	20	4.0	5.0	6.2	411	8.4	4	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	5	Cyanide
Fluoride	No	µg/L	4/2/2008	11/11/2013	172	162	94.19	60	300	53	402	1,047	0	DOE/RL-96-61 Rev. 0, Table ES-1	960	0	Fluoride
Nitrate	No	µg/L	4/2/2008	11/11/2013	172	172	100	--	--	6,770	452,000	26,871	71	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	46	Nitrate
Nitrite	No	µg/L	4/2/2008	11/11/2013	171	31	18.13	9.9	2,500	141	368	93.7	31	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	Nitrite
Sulfate	No	µg/L	4/2/2008	11/11/2013	172	172	100	--	--	53,000	361,000	47,014	172	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	15	Sulfate

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."
LLWMA = low-level waste management area
MCL = maximum contaminant level

Table E-3. Groundwater Summary Statistics for WMA B-BX-BY Exposure Area – Unconfined Aquifer

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																	
Americium-241	No	pCi/L	7/15/2008	9/23/2010	32	8	25	-0.11	0.24	0.071	0.19	7.70E-05	8	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Carbon-14	No	pCi/L	7/15/2008	9/23/2010	32	32	100	--	--	9.3	146	--	--	--	2,000	0	40 CFR 141 – federal MCL
Cobalt-60	No	pCi/L	2/10/2008	10/29/2013	357	144	40.34	-6.8	31	3.9	1,040	0.023	144	DOE/RL-96-61 Rev. 0, Table ES-1	100	3	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	2/10/2008	9/19/2013	435	331	76.09	-18	19	1.5	2,300	--	--	--	15.0	254	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	2/10/2008	9/19/2013	462	462	100	--	--	16	26,000	3.1	462	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	5/12/2008	7/22/2013	139	131	94.24	0.011	4.5	0.73	6.7	9.00E-07	131	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	124	40 CFR 141 – federal MCL
Neptunium-237	No	pCi/L	7/15/2008	9/23/2010	32	3	9.38	-0.060	0.91	0.48	1.3	--	--	--	15	0	40 CFR 141 – federal MCL
Plutonium-239/240	No	pCi/L	7/15/2008	11/29/2011	42	3	7.14	-0.028	0.11	0.073	0.098	--	--	--	15	0	40 CFR 141 – federal MCL
Strontium-90	No	pCi/L	5/12/2008	5/7/2012	72	8	11.11	-8.0	2.2	1.2	4.6	0.0010	8	DOE/RL-96-61 Rev. 0, Table ES-1	8.0	0	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	2/10/2008	10/29/2013	596	596	100	--	--	23	39,000	0.83	596	DOE/RL-96-61 Rev. 0, Table ES-1	900	441	40 CFR 141 – federal MCL
Tritium	No	pCi/L	2/10/2008	10/29/2013	577	576	99.83	-37	-37	190	91,000	119	576	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	39	40 CFR 141 – federal MCL
Uranium-234	No	pCi/L	11/29/2011	11/29/2011	1	1	100	--	--	598	598	--	--	--	--	--	--
Uranium-235	No	pCi/L	11/29/2011	11/29/2011	1	1	100	--	--	27	27	--	--	--	--	--	--
Uranium-238	No	pCi/L	11/29/2011	11/29/2011	1	1	100	--	--	585	585	--	--	--	--	--	--
Volatile Organic Compounds																	
Carbon tetrachloride	No	µg/L	7/15/2008	2/12/2013	64	4	6.25	1.0	1.0	1.2	5.9	--	--	--	0.63	4	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	µg/L	7/15/2008	2/12/2013	64	2	3.13	1.0	1.0	1.4	1.5	--	--	--	1.4	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methylene chloride	No	µg/L	7/15/2008	2/12/2013	64	1	1.56	1.0	1.0	1.8	1.8	--	--	--	5.0	0	40 CFR 141 – federal MCL

Table E-3. Groundwater Summary Statistics for WMA B-BX-BY Exposure Area – Unconfined Aquifer

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																	
Acetophenone	No	µg/L	11/2/2012	11/21/2013	74	1	1.35	0.90	1.0	1.7	1.7	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Bis(2-ethylhexyl) phthalate	No	µg/L	7/15/2008	11/21/2013	106	9	8.49	0.70	3.0	1.4	9.6	--	--	--	6.0	1	40 CFR 141 – federal MCL
Butylbenzylphthalate	No	µg/L	11/2/2012	11/21/2013	74	1	1.35	0.90	1.0	2.8	2.8	--	--	--	46	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Methyl methanesulfonate	No	µg/L	11/2/2012	11/21/2013	74	1	1.35	0.90	1.0	340	340	--	--	--	0.88	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
n-Nitrosodi-n-dipropylamine	No	µg/L	7/15/2008	11/21/2013	98	2	2.04	0.50	1.0	2.6	3.5	--	--	--	0.013	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Phenol	No	µg/L	7/15/2008	11/21/2013	106	2	1.89	0.48	2.0	1.1	1.1	--	--	--	2,400	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tributyl phosphate	No	µg/L	7/15/2008	11/21/2013	106	1	0.94	0.48	1.0	1.1	1.1	--	--	--	9.7	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Aluminum	No	µg/L	7/15/2008	7/27/2011	36	8	22.22	5.0	100	6.2	30	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	µg/L	2/14/2008	2/12/2013	106	40	37.74	0.10	4.0	0.11	213	55.1	17	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	34	40 CFR 141 – federal MCL
Arsenic	No	µg/L	5/12/2008	2/12/2013	233	231	99.14	0.80	6.4	3.0	99	7.9	13	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	231	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	2/10/2008	11/21/2013	631	630	99.84	4.0	4.0	3.6	324	105	289	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Cadmium	No	µg/L	2/10/2008	11/21/2013	631	2	0.32	0.10	4.1	1.7	4.7	0.92	2	DOE/RL-96-61 Rev. 0, Table ES-1	5.0	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	2/10/2008	11/21/2013	621	512	82.45	4.0	14	2.9	356	2.4	512	DOE/RL-96-61 Rev. 0, Table ES-1	100	10	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	2/10/2008	11/21/2013	616	468	75.97	3.1	14	3.6	114	2.4	468	DOE/RL-96-61 Rev. 0, Table ES-1	48	102	40 CFR 141 – federal MCL
Cobalt	No	µg/L	2/10/2008	11/21/2013	594	31	5.22	0.20	4.1	0.20	69	0.92	30	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	19	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	2/10/2008	11/21/2013	630	38	6.03	0.20	30	2.1	166	0.81	38	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-3. Groundwater Summary Statistics for WMA B-BX-BY Exposure Area – Unconfined Aquifer

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	µg/L	7/15/2008	6/6/2012	114	100	87.72	2.0	3.7	2.0	80	--	--	--	48	26	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	2/10/2008	11/21/2013	622	507	81.51	9.0	70	11	7,070	570	72	DOE/RL-96-61 Rev. 0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	µg/L	7/15/2008	2/12/2013	37	27	72.97	0.10	0.51	0.11	2.4	0.92	2	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Manganese	No	µg/L	2/10/2008	11/21/2013	630	243	38.57	0.20	6.0	0.91	632	38.5	56	DOE/RL-96-61 Rev. 0, Table ES-1	384	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	µg/L	7/15/2008	11/21/2013	95	29	30.53	0.050	0.10	0.099	1.7	0.0030	29	DOE/RL-96-61 Rev. 0, Table ES-1	2.0	0	40 CFR 141 – federal MCL
Molybdenum	No	µg/L	7/27/2011	7/27/2011	4	4	100	--	--	0.58	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	µg/L	2/10/2008	11/21/2013	630	189	30	0.40	67	3.8	4,070	1.6	189	DOE/RL-96-61 Rev. 0, Table ES-1	100	16	40 CFR 141 – federal MCL
Selenium	No	µg/L	7/27/2011	2/12/2013	36	35	97.22	0.60	0.60	5.5	18	10.5	15	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Silver	No	µg/L	2/10/2008	11/21/2013	622	21	3.38	0.10	24	4.0	158	5.3	15	DOE/RL-96-61 Rev. 0, Table ES-1	80	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	µg/L	2/10/2008	10/29/2013	619	619	100	0	0	46	2,310	323	509	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	µg/L	7/15/2008	2/12/2013	68	2	2.94	0.050	0.10	0.11	0.13	1.7	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.50	0	40 CFR 141 – federal MCLG
Tin	No	µg/L	7/27/2011	2/12/2013	36	18	50	0.10	0.49	0.12	1.5	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	µg/L	2/10/2008	10/29/2013	573	573	100	--	--	2.9	5,550	9.9	397	DOE/RL-96-61 Rev. 0, Table ES-1	30	337	40 CFR 141 – federal MCL
Vanadium	No	µg/L	2/10/2008	11/21/2013	624	419	67.15	0.40	50	5.0	35	11.5	336	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	2/10/2008	11/21/2013	622	142	22.83	1.6	15	3.4	986	21.8	37	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-3. Groundwater Summary Statistics for WMA B-BX-BY Exposure Area – Unconfined Aquifer

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																	
Chloride	No	µg/L	2/10/2008	11/21/2013	642	642	100	--	--	11,500	284,000	15,630	613	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	1	40 CFR 141 – federal MCL
Cyanide	No	µg/L	2/10/2008	11/21/2013	620	370	59.68	3.6	4.0	2.2	1,730	8.4	328	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	356	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	µg/L	2/10/2008	11/21/2013	641	573	89.39	30	500	35	1,100	1,047	1	DOE/RL-96-61 Rev. 0, Table ES-1	960	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	µg/L	2/10/2008	11/21/2013	642	642	100	--	--	22,800	1.70E+06	26,871	637	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	588	40 CFR 141 – federal MCL
Nitrite	No	µg/L	2/10/2008	11/21/2013	629	105	16.69	9.9	591	21	14,400	93.7	97	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	4	40 CFR 141 – federal MCL
Sulfate	No	µg/L	2/10/2008	11/21/2013	642	642	100	--	--	52,800	374,000	47,014	642	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	131	40 CFR 141 – secondary 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 guideline
WMA = waste management area

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Table E-4. Groundwater Summary Statistics for WMA C Exposure Area – Unconfined Aquifer

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																	
Americium-241	No	pCi/L	1/9/2008	12/10/2013	8	1	12.5	0.0096	0.058	0.14	0.14	7.70E-05	1	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	1/9/2008	9/18/2013	75	17	22.67	-2.6	2.9	1.5	5.4	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	1/9/2008	12/23/2013	243	242	99.59	8.2	8.2	8.4	16,000	3.1	242	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	1/9/2008	12/23/2013	92	92	100	--	--	1.3	7.5	9.00E-07	92	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	92	40 CFR 141 – federal MCL
Plutonium-239/240	No	pCi/L	1/9/2008	12/10/2013	8	2	25	0.0091	0.045	0.055	0.11	--	--	--	15	0	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	1/9/2008	12/23/2013	259	245	94.59	-4.4	4.9	7.0	26,000	0.83	245	DOE/RL-96-61 Rev. 0, Table ES-1	900	152	40 CFR 141 – federal MCL
Tritium	No	pCi/L	1/9/2008	12/23/2013	80	78	97.5	210	250	370	2,900	119	78	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Volatile Organic Compounds																	
2-Hexanone	No	µg/L	12/17/2009	9/6/2012	99	1	1.01	0.22	1.0	2.0	2.0	--	--	--	40	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Acetone	No	µg/L	1/9/2008	12/10/2013	112	3	2.68	0.34	5.0	0.94	5.6	--	--	--	7,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon disulfide	No	µg/L	1/9/2008	12/10/2013	112	3	2.68	0.050	1.0	0.065	0.12	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	µg/L	1/9/2008	12/10/2013	112	3	2.68	0.063	1.0	0.22	1.3	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	µg/L	1/9/2008	12/10/2013	112	20	17.86	0.10	1.0	0.11	0.27	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Semivolatile Organic Compounds																	
Methyl methacrylate	No	µg/L	3/26/2010	9/6/2012	95	1	1.05	0.26	0.26	1.4	1.4	--	--	--	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tributyl phosphate	No	µg/L	1/9/2008	12/17/2010	28	1	3.57	0.47	1.0	1.0	1.0	--	--	--	9.7	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Aluminum	No	µg/L	1/9/2008	12/10/2013	9	3	33.33	5.0	20	12	26	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	µg/L	3/13/2008	12/10/2013	48	8	16.67	0.60	4.0	3.6	74	55.1	3	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	7	40 CFR 141 – federal MCL

Table E-4. Groundwater Summary Statistics for WMA C Exposure Area – Unconfined Aquifer

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	µg/L	1/9/2008	12/13/2013	62	61	98.39	5.0	5.0	4.1	16	7.9	7	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	61	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	1/9/2008	12/23/2013	274	274	100	--	--	25	98	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Boron	No	µg/L	12/10/2013	12/10/2013	1	1	100	--	--	23	23	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	µg/L	1/9/2008	12/23/2013	274	1	0.36	0.10	4.1	4.0	4.0	0.92	1	DOE/RL-96-61 Rev. 0, Table ES-1	5.0	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	1/9/2008	12/23/2013	271	143	52.77	3.1	14	2.4	106	2.4	143	DOE/RL-96-61 Rev. 0, Table ES-1	100	1	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	1/9/2008	12/23/2013	271	62	22.88	3.1	14	2.4	18	2.4	61	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cobalt	No	µg/L	1/9/2008	12/23/2013	268	2	0.75	0.10	4.1	1.8	4.0	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	µg/L	1/9/2008	12/23/2013	274	14	5.11	0.20	8.0	0.62	1,720	0.81	13	DOE/RL-96-61 Rev. 0, Table ES-1	640	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	1/9/2008	12/10/2013	10	10	100	--	--	2.4	6.9	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	1/9/2008	12/23/2013	272	178	65.44	9.0	80	18	603	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	µg/L	6/26/2008	12/10/2013	24	2	8.33	0.10	0.20	0.29	0.37	0.92	0	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Manganese	No	µg/L	1/9/2008	12/23/2013	274	30	10.95	0.20	6.0	0.80	70	38.5	3	DOE/RL-96-61 Rev. 0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	µg/L	1/9/2008	12/10/2013	29	3	10.34	0.050	0.10	0.054	0.20	0.0030	3	DOE/RL-96-61 Rev. 0, Table ES-1	2.0	0	40 CFR 141 – federal MCL
Molybdenum	No	µg/L	12/17/2010	12/10/2013	2	2	100	--	--	1.2	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)
Nickel	No	µg/L	1/9/2008	12/23/2013	274	121	44.16	1.5	13	0.23	293	1.6	119	DOE/RL-96-61 Rev. 0, Table ES-1	100	2	40 CFR 141 – federal MCL
Selenium	No	µg/L	12/3/2009	12/10/2013	45	45	100	--	--	3.4	17	10.5	18	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Silver	No	µg/L	1/9/2008	12/23/2013	272	6	2.21	0.10	11	4.0	6.8	5.3	4	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-4. Groundwater Summary Statistics for WMA C Exposure Area – Unconfined Aquifer

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	µg/L	1/9/2008	12/23/2013	274	274	100	0	0	113	739	323	186	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	µg/L	1/9/2008	12/10/2013	29	2	6.9	0.050	0.10	0.30	0.32	1.7	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.50	0	40 CFR 141 – federal MCLG
Tin	No	µg/L	12/3/2009	12/10/2013	23	4	17.39	0.10	0.10	0.14	0.42	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	µg/L	1/9/2008	12/23/2013	239	237	99.16	0.10	0.10	0.51	38	9.9	3	DOE/RL-96-61 Rev. 0, Table ES-1	30	1	40 CFR 141 – federal MCL
Vanadium	No	µg/L	1/9/2008	12/23/2013	273	240	87.91	7.0	24	7.6	35	11.5	227	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	1/9/2008	12/23/2013	272	52	19.12	3.3	25	4.0	53	21.8	2	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Chloride	No	µg/L	1/9/2008	12/23/2013	280	280	100	--	--	11,300	297,000	15,630	241	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	1	40 CFR 141 – federal MCL
Cyanide	No	µg/L	1/9/2008	12/23/2013	269	89	33.09	1.7	4.0	3.3	41	8.4	46	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	78	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	µg/L	1/9/2008	12/23/2013	280	212	75.71	46	300	56	329	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	µg/L	1/9/2008	12/23/2013	280	280	100	--	--	8,280	118,000	26,871	201	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	77	40 CFR 141 – federal MCL
Nitrite	No	µg/L	1/9/2008	12/23/2013	272	46	16.91	65	591	125	532	93.7	46	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	1/9/2008	12/23/2013	280	280	100	--	--	51,800	333,000	47,014	280	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	52	40 CFR 141 – secondary 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 guideline

Table E-5. Groundwater Summary Statistics for B Plant Exposure Area – Unconfined Aquifer

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																	
Americium-241	No	pCi/L	7/2/2008	10/22/2013	16	4	25	-0.033	0.11	0.091	0.25	7.70E-05	4	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Carbon-14	No	pCi/L	7/26/2011	10/22/2013	4	1	25	2.7	18	12	12	--	--	--	2,000	0	40 CFR 141 – federal MCL
Cesium-137	No	pCi/L	6/22/2008	10/22/2013	36	16	44.44	-6.0	5.3	35	2,430	8.6	16	DOE/RL-96-61 Rev. 0, Table ES-1	200	4	40 CFR 141 – federal MCL
Europium-154	No	pCi/L	6/22/2008	10/22/2013	36	1	2.78	-32	18	45	45	69.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	60	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	6/4/2008	7/29/2013	43	37	86.05	0.12	4.2	2.0	45	--	--	--	15	7	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	6/4/2008	7/29/2013	44	44	100	--	--	6.1	34,000	3.1	44	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	6/4/2008	10/22/2013	41	29	70.73	-0.028	1.9	0.23	3.3	9.00E-07	29	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	20	40 CFR 141 – federal MCL
Neptunium-237	No	pCi/L	7/2/2008	10/22/2013	14	1	7.14	-0.06.4	0.12	0.71	0.71	--	--	--	15	0	40 CFR 141 – federal MCL
Plutonium-238	No	pCi/L	7/2/2008	10/22/2013	32	1	3.13	-0.17	0.49	0.19	0.19	0.00050	1	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Plutonium-239/240	No	pCi/L	7/2/2008	10/22/2013	32	19	59.38	-0.018	0.052	0.028	52	--	--	--	15	4	40 CFR 141 – federal MCL
Strontium-90	No	pCi/L	6/22/2008	10/22/2013	41	26	63.41	-10	1.5	2.8	4,900	0.0010	26	DOE/RL-96-61 Rev. 0, Table ES-1	8.0	24	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	6/11/2008	10/22/2013	23	23	100	--	--	24	5,700	0.83	23	DOE/RL-96-61 Rev. 0, Table ES-1	900	1	40 CFR 141 – federal MCL
Tritium	No	pCi/L	6/4/2008	10/22/2013	53	53	100	--	--	690	12,000	119	53	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Uranium-233/234	No	pCi/L	5/8/2012	5/13/2013	3	3	100	--	--	4.6	11	--	--	--	--	--	--
Uranium-234	No	pCi/L	7/2/2008	6/25/2009	7	7	100	--	--	3.1	10	--	--	--	--	--	--
Uranium-235	No	pCi/L	7/2/2008	5/13/2013	10	9	90	0.088	0.088	0.18	0.72	--	--	--	--	--	--
Uranium-238	No	pCi/L	7/2/2008	5/13/2013	10	10	100	--	--	2.2	10	--	--	--	--	--	--
Metals																	
Antimony	No	µg/L	5/8/2012	10/22/2013	8	5	62.5	0.60	0.60	44	85	55.1	4	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	5	40 CFR 141 – federal MCL
Arsenic	No	µg/L	6/4/2008	10/22/2013	18	18	100	--	--	1.2	6.7	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	18	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-5. Groundwater Summary Statistics for B Plant Exposure Area – Unconfined Aquifer

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	µg/L	6/4/2008	10/22/2013	28	28	100	--	--	47	100	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Boron	No	µg/L	10/10/2013	10/22/2013	3	3	100	--	--	20	53	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	µg/L	6/4/2008	10/22/2013	28	1	3.57	0.10	4.1	5.1	5.1	0.92	1	DOE/RL-96-61 Rev. 0, Table ES-1	5.0	1	40 CFR 141 – federal MCL
Chromium	No	µg/L	6/4/2008	10/22/2013	28	9	32.14	5.0	14	0.83	36	2.4	7	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	6/4/2008	5/8/2012	23	2	8.7	5.0	14	5.1	5.4	2.4	2	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	6/4/2008	10/22/2013	28	5	17.86	4.0	6.0	0.28	8.3	0.81	4	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	1/17/2011	10/22/2013	6	3	50	2.0	2.0	2.6	3.1	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	6/4/2008	10/22/2013	28	21	75	19	38	38	400	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	µg/L	6/4/2008	10/22/2013	28	7	25	0.20	6.0	0.24	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	µg/L	10/10/2013	10/22/2013	3	3	100	--	--	3.6	7.1	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	µg/L	6/4/2008	10/22/2013	28	6	21.43	0.20	5.1	0.94	20	1.6	4	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Selenium	No	µg/L	10/10/2013	10/22/2013	3	3	100	--	--	4.4	8.2	10.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Silver	No	µg/L	6/4/2008	10/22/2013	28	1	3.57	0.10	7.0	8.0	8.0	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	µg/L	6/4/2008	10/22/2013	28	28	100	--	--	217	458	323	12	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tin	No	µg/L	10/10/2013	10/22/2013	3	1	33.33	0.10	0.10	0.28	0.28	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	µg/L	6/4/2008	10/22/2013	64	64	100	--	--	2.6	47	9.9	45	DOE/RL-96-61 Rev. 0, Table ES-1	30	17	40 CFR 141 – federal MCL
Vanadium	No	µg/L	6/4/2008	10/22/2013	28	25	89.29	12	17	9.0	26	11.5	19	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-5. Groundwater Summary Statistics for B Plant Exposure Area – Unconfined Aquifer

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	µg/L	6/4/2008	10/22/2013	28	9	32.14	4.0	9.0	4.0	793	21.8	3	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Chloride	No	µg/L	6/4/2008	10/22/2013	57	57	100	--	--	11,700	30,700	15,630	36	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Cyanide	No	µg/L	6/4/2008	10/22/2013	7	4	57.14	4.0	4.0	4.2	9.0	8.4	1	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	3	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	µg/L	6/4/2008	10/22/2013	57	57	100	--	--	99	3,270	1,047	4	DOE/RL-96-61 Rev. 0, Table ES-1	960	4	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	µg/L	6/4/2008	10/22/2013	57	57	100	--	--	30,100	420,000	26,871	57	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	50	40 CFR 141 – federal MCL
Nitrite	No	µg/L	6/4/2008	10/22/2013	57	11	19.3	65	177	155	279	93.7	11	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	6/4/2008	10/22/2013	57	57	100	--	--	42,900	166,000	47,014	56	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141--Secondary 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

Table E-6. Groundwater Summary Statistics for Semiworks Exposure Area – Unconfined Aquifer

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																	
Gross beta	No	pCi/L	9/1/2010	9/1/2010	1	1	100	--	--	26	26	3.1	1	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	9/1/2010	10/10/2013	3	3	100	--	--	0.69	1.8	9.00E-07	3	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	2	40 CFR 141 – federal MCL
Plutonium-239/240	No	pCi/L	10/10/2013	10/10/2013	1	1	100	--	--	0.11	0.11	--	--	--	15	0	40 CFR 141 – federal MCL
Strontium-90	No	pCi/L	10/10/2013	10/10/2013	1	1	100	--	--	2.8	2.8	0.0010	1	DOE/RL-96-61 Rev. 0, Table ES-1	8.0	0	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	2/24/2012	10/10/2013	2	2	100	--	--	24	62	0.83	2	DOE/RL-96-61 Rev. 0, Table ES-1	900	0	40 CFR 141 – federal MCL
Tritium	No	pCi/L	9/1/2010	10/10/2013	2	2	100	--	--	5,000	7,500	119	2	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Metals																	
Arsenic	No	µg/L	9/1/2010	10/10/2013	2	2	100	--	--	1.0	4.0	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	2/24/2012	10/10/2013	2	2	100	--	--	65	83	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Boron	No	µg/L	10/10/2013	10/10/2013	1	1	100	--	--	53	53	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)
Chromium	No	µg/L	2/24/2012	10/10/2013	2	2	100	--	--	2.3	5.2	2.4	1	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	2/24/2012	2/24/2012	1	1	100	--	--	5.4	5.4	2.4	1	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	2/24/2012	10/10/2013	2	1	50	4.0	4.0	1.9	1.9	0.81	1	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	10/10/2013	10/10/2013	1	1	100	--	--	3.1	3.1	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	µg/L	10/10/2013	10/10/2013	1	1	100	--	--	3.6	3.6	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	µg/L	2/24/2012	10/10/2013	2	1	50	4.0	4.0	1.2	1.2	1.6	0	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Selenium	No	µg/L	10/10/2013	10/10/2013	1	1	100	--	--	5.9	5.9	10.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	µg/L	2/24/2012	10/10/2013	2	2	100	--	--	298	377	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 E-6. Groundwater Summary Statistics for Semiworks Exposure Area – Unconfined Aquifer

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	µg/L	10/10/2013	10/10/2013	1	1	100	--	--	6.1	6.1	9.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL
Vanadium	No	µg/L	2/24/2012	10/10/2013	2	2	100	--	--	12	13	11.5	2	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	2/24/2012	10/10/2013	2	1	50	5.0	5.0	6.6	6.6	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)
Anions																	
Chloride	No	µg/L	9/1/2010	10/10/2013	3	3	100	--	--	15,800	20,100	15,630	3	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Fluoride	No	µg/L	9/1/2010	10/10/2013	3	3	100	--	--	106	214	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	µg/L	9/1/2010	10/10/2013	3	3	100	--	--	27,500	41,300	26,871	3	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	0	40 CFR 141 – federal MCL
Nitrite	No	µg/L	9/1/2010	10/10/2013	3	1	33.33	118	131	200	200	93.7	1	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	9/1/2010	10/10/2013	3	3	100	--	--	95,500	118,000	47,014	3	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – secondary 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

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Table E-7. Groundwater Summary Statistics for LERF Exposure Area – Unconfined Aquifer

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																	
Gross alpha	No	pCi/L	1/30/2008	7/18/2013	44	11	25	-2.8	4.8	1.7	11	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	1/30/2008	7/18/2013	44	40	90.91	-0.95	9.7	6.7	480	3.1	40	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	No toxicity value
Iodine-129	No	pCi/L	1/30/2008	7/18/2013	35	13	37.14	-0.033	0.63	0.20	0.62	9.00E-07	13	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	0	40 CFR 141 – federal MCL
Tritium	No	pCi/L	1/30/2008	7/18/2013	44	14	31.82	-57	250	340	1,000	119	14	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Volatile Organic Compounds																	
Carbon tetrachloride	No	µg/L	1/14/2009	1/17/2013	31	2	6.45	1.0	1.0	2.3	2.4	--	--	--	0.63	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Antimony	No	µg/L	1/30/2008	1/30/2008	1	1	100	--	--	0.32	0.32	55.1	0	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	0	40 CFR 141 – federal MCL
Arsenic	No	µg/L	7/13/2009	1/17/2013	32	32	100	--	--	2.5	5.5	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	32	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	1/30/2008	7/18/2013	39	39	100	--	--	47	89	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	1/30/2008	7/18/2013	39	22	56.41	4.0	14	5.3	39	2.4	22	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	1/30/2008	7/18/2013	39	5	12.82	4.0	14	5.5	8.0	2.4	5	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	1/30/2008	7/18/2013	39	2	5.13	4.0	9.0	4.0	4.2	0.81	2	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	1/30/2008	7/18/2013	39	32	82.05	18	38	23	1,090	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	µg/L	1/30/2008	7/18/2013	39	12	30.77	4.0	6.0	4.1	41	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	µg/L	1/30/2008	7/18/2013	39	26	66.67	4.0	4.0	5.6	25	1.6	26	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Silver	No	µg/L	1/30/2008	7/18/2013	38	1	2.63	4.0	7.0	7.5	7.5	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	µg/L	1/30/2008	7/18/2013	39	39	100	--	--	297	806	323	37	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-7. Groundwater Summary Statistics for LERF Exposure Area – Unconfined Aquifer

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	µg/L	1/30/2008	7/18/2013	39	36	92.31	12	17	8.2	28	11.5	29	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	1/30/2008	7/18/2013	39	14	35.9	4.0	9.0	5.0	14	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)
Anions																	
Chloride	No	µg/L	1/30/2008	7/18/2013	39	39	100	--	--	19,900	96,600	15,630	39	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Fluoride	No	µg/L	1/30/2008	7/18/2013	39	36	92.31	48	116	100	349	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	µg/L	1/30/2008	7/18/2013	39	39	100	--	--	14,600	57,500	26,871	29	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	16	40 CFR 141 – federal MCL
Nitrite	No	µg/L	1/30/2008	7/18/2013	39	4	10.26	66	576	156	526	93.7	4	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	1/30/2008	7/18/2013	39	39	100	--	--	103,000	279,000	47,014	39	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	11	40 CFR 141 – secondary 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
LERF = Liquid Effluent Retention Facility

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Table E-8. Groundwater Summary Statistics for Gable Mountain Pond Exposure Area – Unconfined Aquifer

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																	
Gross alpha	No	pCi/L	6/5/2008	4/11/2013	15	2	13.33	-1.0	7.2	2.8	3.2	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	5/6/2008	4/11/2013	16	16	100	--	--	5.3	1,100	3.1	16	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	No toxicity value
Strontium-90	No	pCi/L	5/6/2008	7/22/2013	24	18	75	-4.7	1.8	16	522	0.0010	18	DOE/RL-96-61 Rev. 0, Table ES-1	8.0	18	40 CFR 141 – federal MCL
Tritium	No	pCi/L	5/6/2008	4/11/2013	19	1	5.26	-180	250	3,200	3,200	119	1	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Metals																	
Antimony	No	µg/L	5/6/2008	5/21/2012	2	1	50	4.0	4.0	72	72	55.1	1	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	1	40 CFR 141 – federal MCL
Arsenic	No	µg/L	6/9/2009	6/9/2009	1	1	100	--	--	4.7	4.7	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	5/6/2008	8/22/2012	9	9	100	--	--	8.1	68	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	5/6/2008	8/22/2012	9	3	33.33	3.1	13	30	42	2.4	3	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	5/6/2008	7/27/2012	8	1	12.5	3.1	13	5.3	5.3	2.4	1	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	5/6/2008	8/22/2012	9	2	22.22	4.0	6.0	5.9	6.0	0.81	2	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	5/6/2008	8/22/2012	9	9	100	--	--	39	6,250	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	µg/L	5/6/2008	8/22/2012	9	8	88.89	4.0	4.0	3.7	142	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	µg/L	5/6/2008	8/22/2012	9	5	55.56	4.0	13	6.6	22	1.6	5	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Strontium	No	µg/L	5/6/2008	8/22/2012	9	9	100	--	--	205	1,440	323	7	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Vanadium	No	µg/L	5/6/2008	8/22/2012	9	3	33.33	5.0	12	5.4	8.1	11.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	5/6/2008	8/22/2012	9	4	44.44	5.0	9.0	5.0	45	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)

Table E-8. Groundwater Summary Statistics for Gable Mountain Pond Exposure Area – Unconfined Aquifer

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																	
Chloride	No	µg/L	5/6/2008	7/22/2013	24	24	100	--	--	8,750	243,000	15,630	19	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Fluoride	No	µg/L	5/6/2008	7/22/2013	24	16	66.67	46	250	49	153	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	µg/L	5/6/2008	7/22/2013	24	24	100	--	--	6,820	173,000	26,871	19	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	16	40 CFR 141 – federal MCL
Nitrite	No	µg/L	5/6/2008	7/22/2013	24	5	20.83	84	2,500	132	263	93.7	5	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	5/6/2008	7/22/2013	24	24	100	--	--	19,900	281,000	47,014	19	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	5	40 CFR 141 – secondary 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

Table E-9. Groundwater Summary Statistics for 200-BP-5 West Exposure Area – Unconfined Aquifer

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																	
Americium-241	No	pCi/L	2/6/2008	12/15/2010	18	4	22.22	-0.13	0.087	0.092	0.62	7.70E-05	4	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Cobalt-60	No	pCi/L	2/6/2008	4/3/2013	69	6	8.7	-7.3	6.9	2.9	9.9	0.023	6	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	2/6/2008	4/9/2013	60	36	60	-1.6	3.5	1.5	15	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	2/6/2008	4/9/2013	62	60	96.77	-0.062	2.9	3.2	3,800	3.1	60	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	2/6/2008	4/9/2013	78	28	35.9	-0.11	2.8	0.31	4.0	9.00E-07	28	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	18	40 CFR 141 – federal MCL
Neptunium-237	No	pCi/L	2/6/2008	9/14/2010	12	2	16.67	-0.052	0.076	0.054	0.57	--	--	--	15	0	40 CFR 141 – federal MCL
Plutonium-239/240	No	pCi/L	2/6/2008	9/14/2010	17	1	5.88	-0.039	0.061	0.052	0.052	--	--	--	15	0	40 CFR 141 – federal MCL
Strontium-90	No	pCi/L	2/6/2008	5/9/2012	33	2	6.06	-7.5	0.72	2.9	180	0.0010	2	DOE/RL-96-61 Rev. 0, Table ES-1	8.0	1	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	2/6/2008	5/1/2013	98	84	85.71	-13	7.2	8.3	5,800	0.83	84	DOE/RL-96-61 Rev. 0, Table ES-1	900	32	40 CFR 141 – federal MCL
Tritium	No	pCi/L	2/6/2008	5/1/2013	96	76	79.17	-99	240	200	20,000	119	76	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Volatile Organic Compounds																	
Carbon disulfide	No	µg/L	2/6/2008	4/3/2013	22	2	9.09	0.050	1.0	0.056	2.4	--	--	--	800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	µg/L	2/6/2008	4/3/2013	22	2	9.09	0.063	1.0	2.0	5.4	--	--	--	0.63	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	µg/L	2/6/2008	4/3/2013	22	3	13.64	0.10	1.0	0.11	0.66	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Semivolatile Organic Compounds																	
Bis(2-ethylhexyl) phthalate	No	µg/L	2/6/2008	9/14/2010	11	5	45.45	0.70	3.4	2.0	2.9	--	--	--	6.0	0	40 CFR 141 – federal MCL
Tributyl phosphate	No	µg/L	2/6/2008	9/14/2010	12	3	25	0.48	1.0	0.60	1.7	--	--	--	9.7	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons – diesel range	No	µg/L	4/26/2010	12/15/2010	6	2	33.33	70	70	74	270	--	--	--	500	0	WAC 173-340-900, Table 720-1

Table E-9. Groundwater Summary Statistics for 200-BP-5 West Exposure Area – Unconfined Aquifer

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
Metals																	
Aluminum	No	µg/L	2/6/2008	4/3/2013	19	11	57.89	5.0	10	7.2	7,180	7.1	11	DOE/RL-96-61 Rev. 0, Table ES-1	16,000		WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	µg/L	5/5/2008	4/3/2013	16	2	12.5	0.60	4.0	52	59	55.1	1	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	2	40 CFR 141 – federal MCL
Arsenic	No	µg/L	2/6/2008	4/3/2013	30	23	76.67	0.80	4.9	3.1	8.1	7.9	1	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	23	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	2/6/2008	4/3/2013	60	60	100	--	--	12	330	105	2	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Beryllium	No	µg/L	2/6/2008	4/3/2013	57	1	1.75	0.10	4.0	0.12	0.12	2.3	0	DOE/RL-96-61 Rev. 0, Table ES-1	4.0	0	40 CFR 141 – federal MCL
Cadmium	No	µg/L	2/6/2008	4/3/2013	60	5	8.33	0.10	4.1	0.20	35	0.92	2	DOE/RL-96-61 Rev. 0, Table ES-1	5.0	2	40 CFR 141 – federal MCL
Chromium	No	µg/L	2/6/2008	4/3/2013	60	24	40	3.1	14	3.2	140	2.4	24	DOE/RL-96-61 Rev. 0, Table ES-1	100	1	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	2/6/2008	4/3/2013	62	16	25.81	1.0	14	2.0	27	2.4	14	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Cobalt	No	µg/L	2/6/2008	4/3/2013	59	11	18.64	0.10	4.1	0.14	34	0.92	7	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	6	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	2/6/2008	4/3/2013	59	9	15.25	0.20	6.0	0.30	68	0.81	8	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	2/6/2008	4/3/2013	27	6	22.22	2.0	3.7	2.3	9.3	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	2/6/2008	4/3/2013	60	53	88.33	9.0	38	20	18,900	570	13	DOE/RL-96-61 Rev. 0, Table ES-1	11,200	4	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	µg/L	4/26/2010	4/3/2013	8	7	87.5	0.10	0.10	0.38	8.5	0.92	6	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Lithium	No	µg/L	4/26/2010	12/15/2010	6	5	83.33	4.0	4.0	8.8	15	11.3	2	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	µg/L	2/6/2008	4/3/2013	60	27	45	3.3	6.0	4.0	1,190	38.5	10	DOE/RL-96-61 Rev. 0, Table ES-1	384	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Mercury	No	µg/L	2/6/2008	12/15/2010	17	3	17.65	0.050	0.10	0.073	0.64	0.0030	3	DOE/RL-96-61 Rev. 0, Table ES-1	2.0	0	40 CFR 141 – federal MCL

Table E-9. Groundwater Summary Statistics for 200-BP-5 West Exposure Area – Unconfined Aquifer

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	µg/L	4/26/2010	4/3/2013	8	8	100	--	--	0.19	11	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	µg/L	2/6/2008	4/3/2013	60	13	21.67	4.0	67	5.8	78	1.6	13	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Selenium	No	µg/L	4/26/2010	4/3/2013	8	6	75	2.0	3.3	1.5	4.2	10.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	µg/L	2/6/2008	4/3/2013	60	60	100	--	--	33	545	323	19	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Uranium	No	µg/L	2/6/2008	5/1/2013	67	66	98.51	0.10	0.10	0.27	22	9.9	11	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL
Vanadium	No	µg/L	2/6/2008	4/3/2013	60	48	80	12	17	5.0	29	11.5	46	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	2/6/2008	4/3/2013	60	28	46.67	4.0	9.0	4.3	5,450	21.8	11	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	2	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Chloride	No	µg/L	2/6/2008	5/1/2013	100	100	100	--	--	7,860	27,800	15,630	52	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Cyanide	No	µg/L	2/6/2008	5/1/2013	87	74	85.06	4.0	4.0	4.0	195	8.4	54	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	69	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	µg/L	2/6/2008	5/1/2013	100	97	97	60	105	71	832	1,047	0	DOE/RL-96-61 Rev. 0, Table ES-1	960		WAC 173-340-720(4)(b)(iii)(A) and (B)
Nitrate	No	µg/L	2/6/2008	5/1/2013	100	96	96	168	421	248	322,000	26,871	61	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	37	40 CFR 141 – federal MCL
Nitrite	No	µg/L	2/6/2008	5/1/2013	99	21	21.21	9.9	2,500	136	555	93.7	21	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	2/6/2008	5/1/2013	100	100	100	--	--	15,200	180,000	47,014	73	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – secondary 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

Table E-10. Groundwater Summary Statistics for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area – Unconfined Aquifer

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																	
Americium-241	No	pCi/L	4/11/2010	12/17/2010	12	1	8.33	-0.24	0.084	0.086	0.086	7.70E-05	1	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	4/8/2008	4/20/2012	25	10	40	-1.2	1.9	1.7	3.4	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	4/8/2008	4/9/2013	27	27	100	--	--	4.2	110	3.1	27	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	4/8/2008	4/9/2013	31	15	48.39	-0.0042	1.1	0.22	0.80	9.00E-07	15	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	0	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	4/8/2008	4/9/2013	32	25	78.13	-13	1.6	9.5	150	0.83	25	DOE/RL-96-61 Rev. 0, Table ES-1	900	0	40 CFR 141 – federal MCL
Tritium	No	pCi/L	4/8/2008	10/1/2013	45	38	84.44	-110	130	2,500	17,000	119	38	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Metals																	
Arsenic	No	µg/L	4/11/2010	12/5/2011	14	14	100	--	--	3.6	15	7.9	6	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	14	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	4/8/2008	10/1/2013	36	36	100	--	--	9.5	43	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Boron	No	µg/L	4/11/2010	12/17/2010	12	1	8.33	19	41	29	29	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	µg/L	4/8/2008	10/1/2013	36	18	50	1.0	14	1.1	18	2.4	15	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	4/8/2008	10/1/2013	36	16	44.44	0.50	14	1.7	19	2.4	15	DOE/RL-96-61 Rev. 0, Table ES-1	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	No	µg/L	4/8/2008	10/1/2013	36	2	5.56	0.20	6.0	20	118	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	µg/L	4/11/2010	12/5/2011	14	6	42.86	2.0	3.7	8.3	13	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	4/8/2008	10/1/2013	36	29	80.56	18	38	40	5,220	570	8	DOE/RL-96-61 Rev. 0, Table ES-1	11,200	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Lead	No	µg/L	4/11/2010	12/17/2010	12	2	16.67	0.20	0.20	0.25	0.82	0.92	0	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Lithium	No	µg/L	4/11/2010	12/17/2010	12	8	66.67	4.0	4.0	4.0	13	11.3	3	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)

Table E-10. Groundwater Summary Statistics for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area – Unconfined Aquifer

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	µg/L	4/8/2008	10/1/2013	36	15	41.67	4.0	7.0	6.0	275	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	µg/L	4/11/2010	12/17/2010	12	12	100	--	--	3.3	5.8	3.2	12	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	µg/L	4/8/2008	10/1/2013	36	2	5.56	4.0	67	5.0	8.0	1.6	2	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Selenium	No	µg/L	4/11/2010	12/17/2010	12	9	75	0.60	0.98	0.76	1.8	10.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Strontium	No	µg/L	4/8/2008	12/11/2012	35	35	100	--	--	111	261	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	µg/L	4/8/2008	12/5/2011	11	11	100	--	--	1.7	6.2	9.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL
Vanadium	No	µg/L	4/8/2008	10/1/2013	36	28	77.78	12	17	9.9	31	11.5	26	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	4/8/2008	10/1/2013	36	23	63.89	4.0	9.0	4.0	590	21.8	12	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Chloride	No	µg/L	4/8/2008	10/1/2013	45	45	100	--	--	6,360	10,300	15,630	0	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Fluoride	No	µg/L	4/8/2008	10/1/2013	45	45	100	--	--	300	789	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	µg/L	4/8/2008	10/1/2013	45	45	100	--	--	1,970	30,500	26,871	7	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	0	40 CFR 141 – federal MCL
Nitrite	No	µg/L	4/8/2008	10/1/2013	45	8	17.78	9.9	131	170	305	93.7	8	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	4/8/2008	10/1/2013	45	45	100	--	--	19,800	53,900	47,014	5	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – secondary 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

Table E 11. Groundwater Summary Statistics for 200-BP-5 Near-River Exposure Area - Unconfined Aquifer

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																	
Americium-241	No	pCi/L	4/9/2010	11/29/2010	6	2	33.33	-0.0091	0.085	0.090	0.13	7.70E-05	2	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Carbon-14	No	pCi/L	10/27/2008	11/22/2013	24	8	33.33	-9.49	5.0	179	436	--	--	--	2,000	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	5/5/2008	11/22/2013	20	5	25	-0.70	2.4	1.8	3.8	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	5/5/2008	11/22/2013	22	21	95.45	2.7	2.7	4.6	80	3.1	21	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	4/9/2010	4/26/2012	12	2	16.67	-0.041	0.18	0.21	0.25	9.00E-07	2	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	0	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	10/27/2008	11/22/2013	34	28	82.35	-10	2.4	7.7	120	0.83	28	DOE/RL-96-61 Rev. 0, Table ES-1	900	0	40 CFR 141 – federal MCL
Tritium	No	pCi/L	2/8/2008	11/22/2013	50	37	74	-120	240	230	15,000	119	37	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Uranium-233/234	No	pCi/L	9/19/2010	1/7/2011	2	2	100	--	--	0.48	0.67	--	--	--	--	--	--
Uranium-235	No	pCi/L	9/19/2010	1/7/2011	2	1	50	0.0097	0.0097	0.048	0.048	--	--	--	--	--	--
Uranium-238	No	pCi/L	9/19/2010	1/7/2011	2	2	100	--	--	0.41	0.53	--	--	--	--	--	--
Volatile Organic Compounds																	
Chloroform	No	µg/L	10/22/2009	1/7/2011	17	7	41.18	0.10	1.0	0.11	0.36	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Trichloroethene	No	µg/L	10/22/2009	1/7/2011	17	14	82.35	0.21	1.0	2.5	3.9	--	--	--	0.54	11	CLARC guidance*
Total Petroleum Hydrocarbons																	
Total petroleum hydrocarbons – diesel range	No	µg/L	4/9/2010	1/7/2011	9	1	11.11	70	70	180	180	--	--	--	500	0	WAC 173-340-900, Table 720-1
Metals																	
Aluminum	No	µg/L	10/22/2009	1/6/2014	34	7	20.59	5.0	20	15	37	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)
Aluminum	Yes	µg/L	10/22/2009	1/6/2014	34	1	2.94	5.0	20	366	366	7.1	1	DOE/RL-96-61 Rev. 0, Table ES-1	87	1	Clean Water Act – freshwater CCC
Arsenic	No	µg/L	10/22/2009	1/6/2014	34	32	94.12	0.40	0.80	1.3	4.8	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	32	WAC 173-340-720(4)(b)(iii)(A) and (B)
Arsenic	Yes	µg/L	10/22/2009	1/6/2014	34	32	94.12	0.40	0.80	1.3	5.0	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	32	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E 11. Groundwater Summary Statistics for 200-BP-5 Near-River Exposure Area - Unconfined Aquifer

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	µg/L	2/8/2008	1/6/2014	41	41	100	--	--	16	36	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Barium	Yes	µg/L	2/8/2008	1/6/2014	41	41	100	--	--	17	37	105	0	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Boron	No	µg/L	3/5/2010	1/6/2014	24	12	50	19	41	8.0	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)
Boron	Yes	µg/L	3/5/2010	1/6/2014	24	10	41.67	19	41	7.7	50	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	µg/L	10/22/2009	1/6/2014	34	2	5.88	0.10	0.20	0.10	0.11	0.92	0	DOE/RL-96-61 Rev. 0, Table ES-1	5	0	40 CFR 141 – federal MCL
Chromium	No	µg/L	2/8/2008	1/6/2014	40	34	85	3.0	13	0.83	8.7	2.4	32	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	2/8/2008	1/6/2014	40	34	85	2.8	13	0.68	14	2.4	32	DOE/RL-96-61 Rev. 0, Table ES-1	65	0	Clean Water Act – freshwater CCC
Cobalt	No	µg/L	2/8/2008	1/6/2014	39	2	5.13	0.050	4.0	0.10	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)
Cobalt	Yes	µg/L	2/8/2008	1/6/2014	39	12	30.77	0.10	4.0	0.12	0.76	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	µg/L	2/8/2008	1/6/2014	41	9	21.95	0.20	6.0	0.22	4.7	0.81	4	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Copper	Yes	µg/L	2/8/2008	1/6/2014	41	2	4.88	0.10	6.0	0.25	0.63	0.81	0	DOE/RL-96-61 Rev. 0, Table ES-1	9.0	0	Clean Water Act – freshwater CCC
Hexavalent chromium	No	µg/L	10/22/2009	1/6/2014	31	16	51.61	2.0	3.7	2.4	9.7	--	--	--	10	0	WAC 173-201A
Hexavalent chromium	Yes	µg/L	10/22/2009	1/6/2014	25	12	48	2.0	2.0	2.4	8.9	--	--	--	10	0	WAC 173-201A
Iron	No	µg/L	2/8/2008	1/6/2014	32	25	78.13	38	64	20	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)
Iron	Yes	µg/L	2/8/2008	1/6/2014	32	8	25	16	43	19	48	570	0	DOE/RL-96-61 Rev. 0, Table ES-1	1,000	0	Clean Water Act – freshwater CCC
Lead	No	µg/L	10/22/2009	1/6/2014	34	8	23.53	0.10	0.20	0.18	16	0.92	4	DOE/RL-96-61 Rev. 0, Table ES-1	15	1	40 CFR 141 – federal MCL
Lead	Yes	µg/L	10/22/2009	1/6/2014	34	7	20.59	0.050	0.20	0.19	2.3	0.92	2	DOE/RL-96-61 Rev. 0, Table ES-1	2.1	1	WAC 173-201A
Lithium	No	µg/L	3/5/2010	1/7/2011	14	11	78.57	4.0	15	4.9	19	11.3	2	DOE/RL-96-61 Rev. 0, Table 5-2	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E 11. Groundwater Summary Statistics for 200-BP-5 Near-River Exposure Area - Unconfined Aquifer

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	Yes	µg/L	3/5/2010	1/7/2011	14	11	78.57	4.0	15	5.0	18	11.3	2	DOE/RL-96-61 Rev. 0, Table 5-2	32	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	µg/L	2/8/2008	1/6/2014	34	20	58.82	4.0	6.0	0.34	70	38.5	3	DOE/RL-96-61 Rev. 0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	Yes	µg/L	2/8/2008	1/6/2014	34	16	47.06	4.0	6.0	0.22	66	38.5	2	DOE/RL-96-61 Rev. 0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	µg/L	3/5/2010	1/6/2014	31	31	100	--	--	1.5	7.3	3.2	18	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	Yes	µg/L	3/5/2010	1/6/2014	31	31	100	--	--	1.5	8.0	3.2	20	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Nickel	No	µg/L	2/8/2008	1/6/2014	34	7	20.59	0.20	13	0.33	0.97	1.6	0	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Nickel	Yes	µg/L	2/8/2008	1/6/2014	34	8	23.53	0.10	13	0.22	4.0	1.6	1	DOE/RL-96-61 Rev. 0, Table ES-1	52	0	Clean Water Act – freshwater CCC
Selenium	No	µg/L	10/22/2009	1/6/2014	34	20	58.82	0.60	4.0	0.65	3.4	10.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Selenium	Yes	µg/L	10/22/2009	1/6/2014	34	20	58.82	0.60	2.8	0.61	3.2	10.5	0	DOE/RL-96-61 Rev. 0, Table ES-1	5.0	0	Clean Water Act – freshwater CCC
Strontium	No	µg/L	2/8/2008	1/6/2014	34	34	100	--	--	124	308	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	Yes	µg/L	2/8/2008	1/6/2014	34	34	100	--	--	125	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)
Thallium	No	µg/L	10/22/2009	1/6/2014	34	1	2.94	0.050	0.55	1.8	1.8	1.7	1	DOE/RL-96-61 Rev. 0, Table ES-1	0.50	1	40 CFR 141 – federal MCLG
Thallium	Yes	µg/L	10/22/2009	1/6/2014	34	2	5.88	0.050	0.10	1.4	1.4	1.7	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.50	2	40 CFR 141 – federal MCLG
Tin	No	µg/L	3/5/2010	1/6/2014	31	3	9.68	0.10	1.0	0.066	0.17	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)
Tin	Yes	µg/L	3/5/2010	1/6/2014	31	4	12.9	0.05	1.0	0.14	1.9	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	µg/L	10/22/2009	1/6/2014	22	22	100	--	--	0.12	2.9	9.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL
Uranium	Yes	µg/L	10/22/2009	1/6/2014	11	11	100	--	--	0.11	3.1	9.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL

Table E 11. Groundwater Summary Statistics for 200-BP-5 Near-River Exposure Area - Unconfined Aquifer

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	µg/L	2/8/2008	1/6/2014	34	21	61.76	7.0	17	0.63	26	11.5	16	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Vanadium	Yes	µg/L	2/8/2008	1/6/2014	34	22	64.71	7.0	17	0.50	31	11.5	15	DOE/RL-96-61 Rev. 0, Table ES-1	80		WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	2/8/2008	1/6/2014	34	12	35.29	4.0	9.0	2.1	1,270	21.8	7	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	Yes	µg/L	2/8/2008	1/6/2014	34	12	35.29	2.0	9.0	1.8	281	21.8	7	DOE/RL-96-61 Rev. 0, Table ES-1	91	6	WAC 173-201A
Anions																	
Chloride	No	µg/L	2/8/2008	11/22/2013	50	50	100	--	--	2,260	15,200	15,630	0	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Fluoride	No	µg/L	2/8/2008	11/22/2013	50	48	96	60	250	61	462	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	µg/L	2/8/2008	11/22/2013	49	49	100	--	--	1,790	28,200	26,871	2	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	0	40 CFR 141 – federal MCL
Nitrite	No	µg/L	2/8/2008	11/22/2013	49	7	14.29	9.9	2,500	30	285	93.7	6	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	2/8/2008	11/22/2013	50	50	100	--	--	19,500	60,100	47,014	21	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – secondary federal MCL

Sources:
40 CFR 141, “National Primary Drinking Water Regulations.”
DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*.
WAC 173-201A, “Water Quality Standards for Surface Waters of the State of Washington.”
WAC 173-340-720, “Model Toxics Control Act—Cleanup,” “Groundwater Cleanup Standards.”
* CLARC guidance from CLARC 2014 data tables (“Groundwater – Method B, Method A, and ARARs, Trichloroethylene”).
CCC = criteria continuous concentration
MCL = maximum contaminant level
MCLG = maximum contaminant level guideline

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Table E-12. Groundwater Summary Statistics for 200-BP-5 Confined Exposure Area – Unconfined Aquifer

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																	
Americium-241	No	pCi/L	2/14/2008	12/17/2013	20	4	20	-5.70E-02	0.22	0.056	0.11	7.70E-05	4	DOE/RL-96-61 Rev. 0, Table ES-1	15	0	40 CFR 141 – federal MCL
Carbon-14	No	pCi/L	2/14/2008	12/17/2013	20	1	5	-4.66E+00	6.5	35	35	--	--	--	2,000	0	40 CFR 141 – federal MCL
Gross alpha	No	pCi/L	2/6/2008	12/17/2013	72	33	45.83	0.0060	2.1	1.4	5.4	--	--	--	15	0	40 CFR 141 – federal MCL
Gross beta	No	pCi/L	2/6/2008	12/17/2013	72	71	98.61	3.5	3.5	4.6	800	3.1	71	DOE/RL-96-61 Rev. 0, Table ES-1	4 mrem/yr	--	40 CFR 141 – federal MCL
Iodine-129	No	pCi/L	2/6/2008	12/17/2013	61	11	18.03	-2.56E-01	0.49	0.18	3.2	9.00E-07	11	DOE/RL-96-61 Rev. 0, Table ES-1	1.0	5	40 CFR 141 – federal MCL
Plutonium-239/240	No	pCi/L	2/14/2008	12/17/2013	20	3	15	-1.80E-01	0.073	0.056	0.17	--	--	--	15.0	0	40 CFR 141 – federal MCL
Strontium-90	No	pCi/L	2/14/2008	12/17/2013	36	5	13.89	-7.10E+00	1.2	1.2	4.6	0.0010	5	DOE/RL-96-61 Rev. 0, Table ES-1	8.0	0	40 CFR 141 – federal MCL
Technetium-99	No	pCi/L	2/6/2008	12/17/2013	68	28	41.18	-1.20E+01	8.0	6.7	1,300	0.83	28	DOE/RL-96-61 Rev. 0, Table ES-1	900	6	40 CFR 141 – federal MCL
Tritium	No	pCi/L	2/6/2008	12/17/2013	79	14	17.72	-1.70E+02	140	30	7,000	119	12	DOE/RL-96-61 Rev. 0, Table ES-1	20,000	0	40 CFR 141 – federal MCL
Uranium-234	No	pCi/L	11/4/2008	9/20/2009	2	2	100	0	0	1.2	1.3	--	--	--	--	--	--
Uranium-238	No	pCi/L	11/4/2008	9/20/2009	2	2	100	0	0	0.43	1.1	--	--	--	--	--	--
Volatile Organic Compounds																	
Benzene	No	µg/L	2/14/2008	12/17/2013	21	1	4.76	0.032	1.0	2.5	2.5	--	--	--	0.80	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Carbon tetrachloride	No	µg/L	2/14/2008	12/17/2013	21	1	4.76	0.042	1.0	2.3	2.3	--	--	--	0.63	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Chloroform	No	µg/L	2/14/2008	12/17/2013	21	1	4.76	0.080	1.0	1.3	1.3	--	--	--	1.4	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Toluene	No	µg/L	2/14/2008	12/17/2013	21	1	4.76	0.029	1.0	2.3	2.3	--	--	--	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-12. Groundwater Summary Statistics for 200-BP-5 Confined Exposure Area – Unconfined Aquifer

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	µg/L	2/14/2008	12/17/2013	21	5	23.81	0.70	1.0	0.97	11	--	--	--	6.0	1	40 CFR 141 – federal MCL
Phenol	No	µg/L	2/14/2008	12/17/2013	21	1	4.76	0.48	4.0	0.91	0.91	--	--	--	2,400	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Tributyl phosphate	No	µg/L	2/14/2008	9/22/2010	19	2	10.53	0.48	1.5	1.4	8.4	--	--	--	9.7	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Metals																	
Aluminum	No	µg/L	2/14/2008	12/17/2013	20	11	55	5.0	20	7.8	71	7.1	11	DOE/RL-96-61 Rev. 0, Table ES-1	16,000	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Antimony	No	µg/L	9/16/2008	12/17/2013	10	2	20	0.60	4.0	41	42	55.1	0	DOE/RL-96-61 Rev. 0, Table ES-1	6.0	2	40 CFR 141 – federal MCL
Arsenic	No	µg/L	2/14/2008	12/17/2013	37	37	100	--	--	1.1	5.6	7.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.058	37	WAC 173-340-720(4)(b)(iii)(A) and (B)
Barium	No	µg/L	2/6/2008	12/17/2013	73	73	100	--	--	34	170	105	13	DOE/RL-96-61 Rev. 0, Table ES-1	2,000	0	40 CFR 141 – federal MCL
Boron	No	µg/L	12/17/2013	12/17/2013	2	2	100	--	--	13	18	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	µg/L	2/6/2008	12/17/2013	73	10	13.7	3.1	14	0.24	46	2.4	8	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Chromium	Yes	µg/L	2/6/2008	12/17/2013	72	5	6.94	3.1	14	0.20	17	2.4	3	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Cobalt	No	µg/L	2/6/2008	12/17/2013	72	2	2.78	0.10	4.1	0.12	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	µg/L	2/6/2008	12/17/2013	73	3	4.11	4.0	30	0.26	4.4	0.81	2	DOE/RL-96-61 Rev. 0, Table ES-1	640	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Hexavalent chromium	No	µg/L	2/14/2008	12/17/2013	32	1	3.13	2.0	3.7	3.9	3.9	--	--	--	48	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Iron	No	µg/L	2/6/2008	12/17/2013	70	60	85.71	19	66	27	14,500	570	12	DOE/RL-96-61 Rev. 0, Table ES-1	11,200	1	WAC 173-340-720(4)(b)(iii)(A) and (B)
Manganese	No	µg/L	2/6/2008	12/17/2013	73	60	82.19	4.0	6.0	4.1	383	38.5	34	DOE/RL-96-61 Rev. 0, Table ES-1	384	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Molybdenum	No	µg/L	12/17/2013	12/17/2013	2	2	100	--	--	5.1	5.5	3.2	2	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table E-12. Groundwater Summary Statistics for 200-BP-5 Confined Exposure Area – Unconfined Aquifer

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	µg/L	2/6/2008	12/17/2013	73	11	15.07	4.0	67	0.54	39	1.6	9	DOE/RL-96-61 Rev. 0, Table ES-1	100	0	40 CFR 141 – federal MCL
Silver	No	µg/L	2/6/2008	12/17/2013	73	2	2.74	0.10	7.0	4.0	17	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	µg/L	2/6/2008	12/17/2013	71	71	100	--	--	159	363	323	2	DOE/RL-96-61 Rev. 0, Table ES-1	9,600	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Thallium	No	µg/L	2/14/2008	12/17/2013	21	1	4.76	0.050	0.10	0.065	0.065	1.7	0	DOE/RL-96-61 Rev. 0, Table ES-1	0.50	0	40 CFR 141 – federal MCLG
Uranium	No	µg/L	2/6/2008	12/17/2013	63	63	100	--	--	1.00	5.9	9.9	0	DOE/RL-96-61 Rev. 0, Table ES-1	30	0	40 CFR 141 – federal MCL
Vanadium	No	µg/L	2/6/2008	12/17/2013	73	36	49.32	4.1	50	5.6	29	11.5	17	DOE/RL-96-61 Rev. 0, Table ES-1	80	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Zinc	No	µg/L	2/6/2008	12/17/2013	73	37	50.68	4.0	20	5.0	811	21.8	12	DOE/RL-96-61 Rev. 0, Table ES-1	4,800	0	WAC 173-340-720(4)(b)(iii)(A) and (B)
Anions																	
Chloride	No	µg/L	2/6/2008	12/17/2013	80	80	100	--	--	3,140	26,100	15,630	5	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – federal MCL
Cyanide	No	µg/L	2/6/2008	12/17/2013	47	7	14.89	2.0	5.0	4.4	31	8.4	4	DOE/RL-96-61 Rev. 0, Table ES-1	4.8	6	WAC 173-340-720(4)(b)(iii)(A) and (B)
Fluoride	No	µg/L	2/6/2008	12/17/2013	80	64	80	46	250	52	592	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	µg/L	2/6/2008	12/17/2013	79	74	93.67	168	319	103	41,300	26,871	5	DOE/RL-96-61 Rev. 0, Table ES-1	45,000	0	40 CFR 141 – federal MCL
Nitrite	No	µg/L	2/6/2008	12/17/2013	79	16	20.25	9.9	164	126	417	93.7	16	DOE/RL-96-61 Rev. 0, Table ES-1	3,300	0	40 CFR 141 – federal MCL
Sulfate	No	µg/L	2/6/2008	12/17/2013	80	80	100	--	--	3,170	57,500	47,014	3	DOE/RL-96-61 Rev. 0, Table ES-1	250,000	0	40 CFR 141 – secondary 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 guideline

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Appendix F

Fate and Transport Modeling

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Attachment 2. ECF-HANFORD-13-0030, *Initial Groundwater Plume Development to Support Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* F-Att-2-1

Attachment 3. ECF-HANFORD-13-0031, *Fate and Transport Modeling for Baseline Conditions for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* F-Att-3-1

Attachment 4. ECF-HANFORD-13-0037, *Development of Source Terms for Inclusion in Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* F-Att-4-1

Model Package Report:

Attachment 5. CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model* F-Att-5-1

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F1 Fate and Transport Modeling Support Documentation

This appendix consists of a compilation of four environmental calculation files (ECFs) and one model package report in support of fate and transport modeling for the 200-BP-5 Groundwater Operable Unit remedial investigation/feasibility study. The compilation of these documents is specified below, and each document appears, in its entirety, as a respective attachment to this appendix. These documents are provided on CD.

F2 Environmental Calculation Files

The following ECFs are included as attachments to this appendix:

- ECF-Hanford-13-0029, 2015, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.
- ECF-Hanford-13-0030, 2015, *Initial Groundwater Plume Development to Support Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.
- ECF-Hanford-13-0031, 2015, *Fate and Transport Modeling for Baseline Conditions for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.
- ECF-Hanford-13-0037, 2015, *Development of Source Terms for Inclusion in Fate and Transport Modeling for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

F3 Model Package Report

The following model package report is included as an attachment to this appendix:

- CP-57037, 2015, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

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Appendix G

Groundwater Risk Assessment ECFs and Supporting Information

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Attachment 2 ECF-Hanford-13-0034, *Exposure Point Concentrations for Future Conditions for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* G-Att-2-1

Attachment 3 ECF-Hanford-13-0035, *Tap Water Risk Assessment for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units* G-Att-3-1

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Terms

BCA	bias-corrected accelerated bootstrap method
BEHP	bis(2-ethylhexyl) phthalate
BTV	background threshold value
CAS	Chemical Abstracts Service
Cr(VI)	hexavalent chromium
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DOE	U.S. Department of Energy
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
GIABS	gastrointestinal absorption factor
GOF	goodness of fit
HI	hazard index
HEAST	Health Effects Assessment Summary Tables
HQ	hazard quotient
IRIS	Integrated Risk Information System
KM	Kaplan-Meier
Kp	dermal permeability constant
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
ND	nondetect
NTU	nephelometric turbidity unit
OU	operable unit
PCB	polychlorinated biphenyl
ROS	regression on order statistics
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbon
UCL	upper confidence limit

UPL	upper prediction limit
VOC	volatile organic compound
WMA	waste management area

G1 Risk Characterization Results of the Native American Risk Assessments

Several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. The U.S. Department of Energy (DOE) 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 200-BP-5 Groundwater Operable Unit (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 to 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.

Potentially complete exposure pathways 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 for other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (e.g., 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 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 from nonvolatile compounds

A complete description of each Tribal use exposure scenarios is provided in ECF-HANFORD-13-0036, *Native American Risk Assessment for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, which is provided as an attachment to this appendix. ECF-HANFORD-13-0036 describes the methodology, assumptions, inputs, and the calculation of risks and hazards, and it also discusses the results of the groundwater risk assessment for each of the Native American scenarios.

G1.1 200-BP-5 Operable Unit — Summary of the Confederated Tribes of the Umatilla Indian Reservation Groundwater Risk Assessment

This section summarizes the results for each of the exposure pathways associated with the use of groundwater as a drinking water source and the use of groundwater to generate steam in a sweat lodge by the CTUIR, where the groundwater source is from the 200-BP-5 OU.

G1.1.1 Confederated Tribes of the Umatilla Indian Reservation – Use of 200-BP-5 Operable Unit Groundwater as a Potential Drinking Water Source

Potential exposure to 200-BP-5 OU groundwater as a drinking water source is evaluated under the CTUIR exposure scenario. Potential routes of exposure to groundwater include ingestion, dermal contact,[1] and inhalation of volatiles during household activities. Table G-1 provides a summary of the CTUIR risk estimates by exposure route for each exposure area evaluated in the 200-BP-5 OU. Additional detail including analyte-specific risk contributions is provided in the calculation spreadsheets presented in ECF-HANFORD-13-0036 (provided as an attachment to this appendix).

G1.1.1.1 Low-Level Waste Management Area 1 Exposure Area

The total cumulative excess lifetime cancer risk (ELCR) for the Low-Level Waste Management Area (LLWMA)-1 exposure area is 1.5×10^{-3}. The total ELCR for the LLWMA-1 exposure area is 4.2×10^{-4} for nonradiological analytes and 1.1×10^{-3} for radiological analytes, both of which are greater than the U.S. Environmental Protection Agency (EPA) upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (8.3×10^{-4} and 56 percent contribution), tritium (1.6×10^{-4} and 11 percent contribution), cobalt-60 (3.9×10^{-5} and 2.6 percent contribution), and iodine-129 (3.4×10^{-5} and 2.3 percent contribution). Contribution to ELCR is elevated for arsenic (4.2×10^{-4} and 28 percent contribution), where measured concentrations are within natural background values.

The hazard index (HI) for the LLWMA-1 exposure area is 111, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (hazard quotient [HQ] of 100 and 90 percent contribution) and nitrate (HQ of 1.5 and 1.3 percent contribution). Contribution to HI is elevated for antimony (HQ of 6.8 and 6.2 percent contribution), where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.1.2 Low-Level Waste Management Area 2 and 216-B-63 Trench Exposure Area

The total cumulative ELCR for the LLWMA-2 exposure area is 9.8×10^{-4}. The total ELCR for the LLWMA-2 and 216-B-63 Trench wexposure area is 7.4×10^{-4} for nonradiological analytes and 2.4×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (2.1×10^{-4} and 21 percent contribution), iodine-129 (2.0×10^{-5} and 2 percent contribution), and tritium (1.3×10^{-5} and 1.3 percent contribution). Contribution to ELCR is elevated for arsenic (7.4×10^{-4} and 75 percent contribution), where measured concentrations are within natural background values.

The HI for the LLWMA-2 and 216-B-63 Trench exposure area is 54, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 41 and 77 percent contribution). Contribution to the noncancer HI is elevated for arsenic (HQ of 1.6 and 3 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 1.6 and 3 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

[1] The dermal contact exposure route is only evaluated for nonradionuclide analytes.

Table G-1. CTUIR Exposure Scenario — Summary of Risk Estimates from Use of 200-BP-5 OU Groundwater as a Potential Drinking Water Source

Exposure Route	LLWMA-1		LLWMA-2 and 216-B-63 Trench		WMA B-BX-BY Tank Farms		WMA C Tank Farm		B Plant		Semiworks		LERF		Gable Mountain Pond		200-BP-5 West		200-BP-5 Far-Field Area (North of Gable Gap)		200-BP-5 Near-River Area		200-BP-5 Confined	
	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI
Nonradionuclide Analytes																								
Ingestion	4.2E-04	24	7.4E-04	18	4.2E-03	54	5.8E-04	11	3.9E-04	16	3.5E-04	1.9	4.0E-04	2.1	4.1E-04	13	5.4E-04	21	1.1E-03	4.5	2.8E-04	2.1	2.9E-04	9.1
Dermal	1.6E-06	0.26	2.7E-06	0.33	3.7E-05	0.46	3.0E-06	0.28	1.5E-06	0.39	1.3E-06	0.06	3.1E-06	0.09	1.5E-06	0.33	5.8E-06	0.36	4.1E-06	0.12	1.6E-06	0.09	6.6E-06	0.25
Inhalation	1.5E-06	87	—	36	2.7E-05	200	5.5E-06	4.3	—	4.3	—	—	6.9E-06	0.01	—	—	1.5E-05	45	—	—	5.9E-06	0.46	3.2E-05	6.0
Total	4.2E-04	111	7.4E-04	54	4.2E-03	255	5.8E-04	16	4.0E-04	20	3.5E-04	1.9	4.1E-04	2.2	4.1E-04	13	5.6E-04	66	1.1E-03	4.7	2.9E-04	2.7	3.3E-04	15
Radionuclide Analytes																								
Ingestion	9.4E-04	—	2.3E-04	—	1.1E-02	—	1.6E-03	—	1.1E-02	—	9.5E-05	—	7.5E-06	—	1.2E-03	—	9.6E-04	—	1.1E-04	—	1.3E-04	—	1.5E-04	—
Inhalation	1.3E-04	—	9.9E-06	—	2.0E-04	—	1.9E-05	—	9.1E-05	—	1.3E-04	—	1.1E-05	—	5.5E-05	—	1.2E-04	—	2.2E-04	—	2.2E-04	—	3.0E-05	—
Total	1.1E-03	—	2.4E-04	—	1.1E-02	—	1.7E-03	—	1.1E-02	—	2.2E-04	—	1.8E-05	—	1.2E-03	—	1.1E-03	—	3.3E-04	—	3.5E-04	—	1.8E-04	—
Total cumulative ELCR*	1.5E-03	—	9.8E-04	—	1.5E-02	—	2.2E-03	—	1.2E-02	—	5.7E-04	—	4.2E-04	—	1.6E-03	—	1.6E-03	—	1.4E-03	—	6.4E-04	—	5.1E-04	—

Note: "—" indicates HI or ELCR is not applicable.

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index
LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
WMA = waste management area

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G1.1.1.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

The total cumulative ELCR for the Waste Management Area (WMA) B-BX-BY Tank Farms exposure area is 1.5×10^{-2}. The total ELCR for the WMA B-BX-BY Tank Farms exposure area is 4.2×10^{-3} for nonradiological analytes and 1.1×10^{-2} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are uranium-234 (4.0×10^{-3} and 26 percent contribution), uranium-238 (3.6×10^{-3} and 23 percent contribution), technetium-99 (3.0×10^{-3} and 19 percent contribution), methyl methanesulfonate (2.0×10^{-3} and 13 percent contribution), n-nitrosodi-n-dipropylamine (1.5×10^{-3} and 9.4 percent contribution), tritium (2.5×10^{-4} and 1.6 percent contribution), and uranium-235 (1.8×10^{-4} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (7.8×10^{-4} and 5.1 percent contribution), where measured concentrations are within natural background values.

The HI for the WMA B-BX-BY Tank Farms exposure area is 255, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 230 and 90 percent contribution), uranium (HQ of 8.1 and 3.2 percent contribution), and nitrate (HQ of 4.8 and 1.9 percent contribution). Contribution to HI is elevated for antimony (HQ of 6.5 and 2.6 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.1.4 Waste Management Area C Tank Farm Exposure Area

The total cumulative ELCR for the WMA C Tank Farm exposure area is 2.2×10^{-3}. The total ELCR for the WMA C Tank Farm exposure area is 5.8×10^{-4} for nonradiological analytes and 1.7×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (1.6×10^{-3} and 70 percent contribution), iodine-129 (6.5×10^{-5} and 2.9 percent contribution), and tritium (2.4×10^{-5} and 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (5.7×10^{-4} and 25 percent contribution), where measured concentrations are within natural background values.

The HI for the WMA C Tank Farm exposure area is 16, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 4.9 and 31 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are cobalt, cadmium, nitrate, and vanadium. Contribution to HI is elevated for arsenic (HQ of 1.3 and 8 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 6.8 and 43 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.1.5 B Plant Exposure Area

The total cumulative ELCR for the B Plant exposure area is 1.2×10^{-2}. The total ELCR for the B Plant exposure area is 4.0×10^{-4} for nonradiological analytes and 1.1×10^{-2} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (6.0×10^{-3} and 52 percent contribution), cesium-137 (4.0×10^{-3} and 35 percent contribution), plutonium-239/240 (3.9×10^{-4} and 3.4 percent contribution), and technetium-99 (3.7×10^{-4} and 3.2 percent contribution). Contribution to ELCR is elevated for arsenic (4.0×10^{-4} and 3.4 percent contribution), where measured concentrations are within natural background values.

The HI for the B Plant exposure area is 20, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 5.0 and 24 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are arsenic, fluoride, nitrate, cadmium, uranium, and vanadium. Contribution to HI is elevated for antimony (HQ of 6.5 and 2.6 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.1.6 Semiworks Exposure Area

The total cumulative ELCR for the Semiworks exposure area is 5.7×10^{-4}. The total ELCR for the Semiworks exposure area is 3.5×10^{-4} for nonradiological analytes and 2.2×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (1.7×10^{-4} and 29 percent contribution), iodine-129 (2.6×10^{-5} and 4.5 percent contribution), technetium-99 (1.6×10^{-5} and 2.8 percent contribution), and strontium-90 (1.5×10^{-5} and 2.6 percent contribution). Contribution to ELCR is elevated for arsenic (3.5×10^{-4} and 61 percent contribution), where measured concentrations are within natural background values.

The HI for the Semiworks exposure area is 1.9, which is greater than the EPA target HI of 1. All individual analytes (nitrate, fluoride, vanadium, hexavalent chromium [Cr(VI)], uranium, selenium, molybdenum, nitrite, strontium, and barium) that contribute greater than 1 percent of the HI also report an HQ less than 1.

G1.1.1.7 Liquid Effluent Retention Facility Exposure Area

The total cumulative ELCR for the Liquid Effluent Retention Facility (LERF) exposure area is 4.2×10^{-4}. The total ELCR for the LERF exposure area is 4.1×10^{-4} for nonradiological analytes and 1.8×10^{-5} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are carbon tetrachloride (1.8×10^{-5} and 4.2 percent contribution), tritium (1.4×10^{-5} and 3.3 percent contribution), and iodine-129 (4.5×10^{-6} and 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (3.9×10^{-4} and 91 percent contribution), where measured concentrations are within natural background values.

The HI for the LERF exposure area is 2.2, which is greater than the EPA target HI of 1. All individual analytes (nitrate, fluoride, vanadium, Cr(VI), silver, nitrite, strontium, carbon tetrachloride, nickel, and manganese) that contribute greater than 1 percent of the HI also report an HQ less than 1.

G1.1.1.8 Gable Mountain Pond Exposure Area

The total cumulative ELCR for the Gable Mountain Pond exposure area is 1.6×10^{-3}. The total ELCR for the Gable Mountain Pond exposure area is 4.1×10^{-4} for nonradiological analytes and 1.2×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (1.1×10^{-3} and 71 percent contribution), and tritium (7.1×10^{-5} and 4.4 percent contribution). Contribution to ELCR is elevated for arsenic (4.1×10^{-4} and 25 percent contribution), where measured concentrations are within natural background values.

The HI for the Gable Mountain Pond exposure area is 13, which is greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include arsenic, nitrate, iron, and manganese. Contribution to HI is elevated for antimony (HQ of 10 and

79 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.1.9 200-BP-5 West Exposure Area

The total cumulative ELCR for the 200-BP-5 west exposure area is 1.6×10^{-3}. The total ELCR for the 200-BP-5 west exposure area is 5.6×10^{-4} for nonradiological analytes and 1.1×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (4.5×10^{-4} and 28 percent contribution), strontium-90 (4.4×10^{-4} and 27 percent contribution), tritium (1.5×10^{-4} and 9.1 percent contribution), and carbon tetrachloride (2.0×10^{-5} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (5.3×10^{-4} and 32 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 west exposure area is 66, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 52, 78 percent contribution). The remaining individual analyte that contributes greater than 1 percent of the HI but reports an HQ less than 1 is nitrate. Contribution to the noncancer HI is elevated for arsenic (HQ of 1.2 and 1.8 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 8.6 and 13 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.1.10 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

The total cumulative ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area is 1.4×10^{-3}. The total ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area is 1.1×10^{-3} for nonradiological analytes and 3.3×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (2.8×10^{-4} and 20 percent contribution), and technetium-99 (3.9×10^{-5} and 2.7 percent contribution). Contribution to ELCR is elevated for arsenic (1.1×10^{-3} and77 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 far-field (north of Gable Gap) exposure area is 4.7, which is greater than the EPA target HI of 1. Contribution to HI is elevated for arsenic (HQ of 2.4 and 52 percent contribution), where measured concentrations are within natural background values. The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are fluoride, Cr(VI), lithium, vanadium, nitrate, copper, iron, manganese, uranium, zinc, and molybdenum.

G1.1.1.11 200-BP-5 Near-River Exposure Area

The total cumulative ELCR for the 200-BP-5 near-river exposure area is 6.4×10^{-4}. The total ELCR for the 200-BP-5 near-river exposure area is 2.9×10^{-4} for nonradiological analytes and 3.5×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (2.8×10^{-4} and 44 percent contribution), carbon-14 (4.3×10^{-5} and 6.8 percent contribution), technetium-99 (1.6×10^{-5} and 2.5 percent contribution), and trichloroethene (9.2×10^{-6} and 1.4 percent contribution). Contribution to ELCR is elevated for arsenic (2.8×10^{-4} and 43 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 near-river exposure area is 2.7, which is greater than the EPA target HI of 1. All individual analytes (trichloroethene, lithium, fluoride, nitrate, vanadium, Cr(VI), molybdenum, uranium, nitrite, manganese, and zinc) that contribute greater than 1 percent of the HI also report an HQ less than 1.

G1.1.1.12 200-BP-5 Confined Exposure Area

The total cumulative ELCR for the 200-BP-5 confined exposure area is 6.4×10^{-4}. The total ELCR for the 200-BP-5 confined exposure area is 3.3×10^{-4} for nonradiological analytes and 1.8×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (9.3×10^{-5} and 18 percent contribution), tritium (3.9×10^{-5} and 7.7 percent contribution), benzene (1.9×10^{-5} and 3.6 percent contribution), carbon tetrachloride (1.8×10^{-5} and 3.5 percent contribution), chloroform (1.7×10^{-5} and 3.4 percent contribution), iodine-129 (1.3×10^{-5} and 2.5 percent contribution), strontium-90 (1.2×10^{-5} and 2.4 percent contribution), uranium-234 (9.0×10^{-6} and 1.8 percent contribution), uranium-238 (6.5×10^{-6} and 1.3 percent contribution), and bis(2-ethylhexyl) phthalate (BEHP) (6.2×10^{-6} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (2.7×10^{-4} and 52 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 confined exposure area is 15, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 6.9 and 45 percent contribution) and antimony (HQ of 6.1 and 40 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are arsenic, silver, iron, fluoride, manganese, and cobalt. Contribution to HI is elevated for antimony (HQ of 6.1 and 40 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.1.2 Confederated Tribes of the Umatilla Indian Reservation Use of 200-BP-5 Operable Unit Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to 200-BP-5 OU groundwater as a source of steam in a sweat lodge is evaluated under the CTUIR exposure 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, nonvolatiles, and condensed liquid while spending time in a sweat lodge. Table G-2 provides a summary of the CTUIR risk estimates by exposure route for each exposure area evaluated in the 200-BP-5 OU. Additional detail, including analyte-specific risk contributions, is provided in the calculation spreadsheets presented in ECF-HANFORD-13-0036 (provided as an attachment to this appendix).

G1.1.2.1 Low-Level Waste Management Area 1 Exposure Area

The total cumulative ELCR for the LLWMA-1 exposure area is 5.8×10^{-3}. The total ELCR for the LLWMA-1 exposure area is 5.6×10^{-3} for nonradiological analytes and 2.0×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (5.3×10^{-3} and 93 percent contribution) and technetium-99 (1.9×10^{-4} and 3.3 percent contribution). Contribution to ELCR is elevated for arsenic (1.7×10^{-4} and 3 percent contribution), where measured concentrations are within natural background values.

Table G-2. CTUIR Exposure Scenario — Summary of Risk Estimates from Use of 200-BP-5 OU Groundwater in a Sweat Lodge

Exposure Route	LLWMA-1		LLWMA-2 and 216-B-63 Trench		WMA B-BX-BY Tank Farms		WMA C Tank Farm		B Plant		Semiworks		LERF		Gable Mountain Pond		200-BP-5 West		200-BP-5 Far-Field Area (North of Gable Gap)[a]		200-BP-5 Near-River Area		200-BP-5 Confined	
	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI
Nonradionuclide Analytes – Inhalation in Sweat Lodge																								
Inhalation in Sweat Lodge																								
Volatile and semivolatiles (vapor)	1.4E-07	9	—	3.6	2.6E-06	20	5.3E-07	0.42	—	0.43	—	—	6.7E-07	<0.01	—	—	1.5E-06	4.5	—	—	5.7E-07	0.05	3.1E-06	0.60
Nonvolatile (aerosol)	5.6E-03	13	6.5E-03	12	2.0E-02	120	4.2E-03	19	4.0E-03	18	3.9E-03	6.8	4.8E-03	8.6	3.9E-03	22	4.4E-03	52	8.4E-03	19	4.4E-03	7.5	4.5E-03	19
Total	5.6E-03	21	6.5E-03	15	2.0E-02	140	4.2E-03	19	4.0E-03	19	3.9E-03	6.8	4.8E-03	8.6	3.9E-03	22	4.4E-03	56	8.4E-03	19	4.4E-03	7.6	4.5E-03	19
Dermal Exposure in Sweat Lodge																								
Volatile and semivolatiles (vapor only)	6.5E-12	<0.01	—	<0.01	1.0E-09	<0.01	3.5E-10	<0.01	—	<0.01	—	—	6.2E-10	<0.01	—	—	7.1E-10	<0.01	—	—	2.5E-10	<0.01	1.2E-09	<0.01
Nonvolatile (vapor and aqueous condensate)	1.8E-06	0.31	3.2E-06	0.40	1.9E-05	1.9	2.5E-06	0.50	1.7E-06	0.42	1.5E-06	0.07	1.7E-06	0.10	1.7E-06	0.40	2.6E-06	0.39	4.7E-06	0.15	1.2E-06	0.08	1.9E-06	0.29
Total	1.8E-06	0.31	3.2E-06	0.40	1.9E-05	1.9	2.5E-06	0.50	1.7E-06	0.42	1.5E-06	0.07	1.7E-06	0.10	1.7E-06	0.40	2.6E-06	0.39	4.7E-06	0.15	1.2E-06	0.08	1.9E-06	0.29
Total nonradionuclide	5.6E-03	22	6.5E-03	16	2.0E-02	141	4.2E-03	20	4.0E-03	19	3.9E-03	6.9	4.8E-03	8.7	3.9E-03	23	4.4E-03	57	8.4E-03	19	4.4E-03	7.6	4.5E-03	20
Radionuclide Analytes																								
Inhalation in Sweat Lodge																								
Volatile and semivolatiles (vapor)	1.0E-05	—	7.9E-07	—	1.6E-05	—	1.5E-06	—	7.3E-06	—	1.0E-05	—	8.8E-07	—	4.4E-06	—	9.3E-06	—	1.8E-05	—	1.7E-05	—	2.4E-06	—
Nonvolatile (aerosol)	1.9E-04	—	4.8E-05	—	5.3E-02	—	3.9E-04	—	6.3E-03	—	2.1E-05	—	8.1E-08	—	9.5E-05	—	2.3E-04	—	1.9E-05	—	8.3E-05	—	1.5E-04	—
Total radionuclide	2.0E-04	—	4.9E-05	—	5.3E-02	—	3.9E-04	—	6.3E-03	—	3.1E-05	—	9.6E-07	—	9.9E-05	—	2.4E-04	—	3.7E-05	—	1.0E-04	—	1.5E-04	—
Total cumulative ELCR*	5.8E-03	—	6.6E-03	—	7.3E-02	—	4.6E-03	—	1.0E-02	—	3.9E-03	—	4.8E-03	—	4.0E-03	—	4.6E-03	—	8.4E-03	—	4.5E-03	—	4.6E-03	—

Note: "—" indicates HI or ELCR is not applicable.

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index
LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
WMA = waste management area

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The HI for the LLWMA-1 exposure area is 22, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 8.7 and 40 percent contribution), uranium (HQ of 4.7 and 22 percent contribution), vanadium (HQ of 1.5 and 6.7 percent contribution), and barium (HQ of 1.2 and 5.7 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are Cr(VI), nickel, cobalt, cadmium, and manganese. Contribution to HI is elevated for arsenic (HQ of 2.7 and 13 percent contribution), where measured concentrations are within natural background values.

G1.1.2.2 Low-Level Waste Management Area 2 and the 216-B-63 Trench Exposure Area

The total cumulative ELCR for the LLWMA-2 and the 216-B-63 Trench exposure area is 6.6×10^{-3}. The total ELCR for the LLWMA-2 exposure area is 6.5×10^{-3} for nonradiological analytes and 4.9×10^{-5} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (6.2×10^{-3} and 94 percent contribution). Contribution to ELCR is elevated for arsenic (3.1×10^{-4} and 4.7 percent contribution), where measured concentrations are within natural background values.

The HI for the LLWMA-2 and 216-B-63 Trench exposure area is 16, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 3.6 and 23 percent contribution), vanadium (HQ of 1.8 and 12 percent contribution), and nickel (HQ of 1.6 and 10 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are barium, manganese, Cr(VI), uranium, and antimony. Contribution to HI is elevated for arsenic (HQ of 4.8 and 31 percent contribution), where measured concentrations are within natural background values.

G1.1.2.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

The total cumulative ELCR for the WMA B-BX-BY Tank Farms exposure area is 7.3×10^{-2}. The total ELCR for the WMA B-BX-BY Tank Farms exposure area is 2.0×10^{-2} for nonradiological analytes and 5.3×10^{-2} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are uranium-234 (2.8×10^{-2} and 39 percent contribution), uranium-238 (2.3×10^{-2} and 31 percent contribution), Cr(VI) (1.9×10^{-2} and 26 percent contribution), and uranium-235 (1.2×10^{-3} and 1.6 percent contribution).

The HI for the WMA B-BX-BY Tank Farms exposure area is 141, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are uranium (HQ of 90 and 64 percent contribution), cyanide (HQ of 20 and 14 percent contribution), cobalt (HQ of 6.6 and 4.7 percent contribution), cadmium (HQ of 5.1 and 3.6 percent contribution), nickel (HQ of 4.9 and 3.5 percent contribution), manganese (HQ of 3.0 and 2.1 percent contribution), Cr(VI) (HQ of 2.5 and 1.8 percent contribution), and barium (HQ of 2.1 and 1.5 percent contribution). Contribution to the noncancer HI is elevated for arsenic (HQ of 5.1 and 3.6 percent contribution), where measured concentrations are within natural background values.

G1.1.2.4 Waste Management Area C Tank Farm Exposure Area

The total cumulative ELCR for the WMA C Tank Farm exposure area is 4.6×10^{-3}. The total ELCR for the WMA C Tank Farm exposure area is 4.2×10^{-3} for nonradiological analytes and 3.9×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}.

The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (3.6×10^{-3} and 78 percent contribution), technetium-99 (3.6×10^{-4} and 7.7 percent contribution), cobalt (3.0×10^{-4}, 6.4 percent contribution), and cadmium (6.0×10^{-5} and 1.3 percent contribution). Contribution to ELCR is elevated for arsenic (2.4×10^{-4} and 5.1 percent contribution), where measured concentrations are within natural background values.

The HI for the WMA C Tank Farm exposure area is 20, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cobalt (HQ of 5.7 and 29 percent contribution), cadmium (HQ of 3.4 and 17 percent contribution), and vanadium (HQ of 1.5 and 7.6 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than or equal to 1 are nickel, barium, uranium, manganese, Cr(VI), cyanide, and di-n-octylphthalate. Contribution to HI is elevated for arsenic (HQ of 3.7 and 19 percent contribution), where measured concentrations are within natural background values.

G1.1.2.5 B Plant Exposure Area

The total cumulative ELCR for the B Plant exposure area is 1.0×10^{-2}. The total ELCR for the B Plant exposure area is 4.0×10^{-3} for nonradiological analytes and 6.3×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are plutonium-239/240 (4.3×10^{-3} and 41 percent contribution), Cr(VI) (3.8×10^{-3} and 36 percent contribution), uranium-233/234 (5.3×10^{-4} and 5.1 percent contribution), strontium-90 (5.0×10^{-4} and 4.8 percent contribution), and uranium-238 (3.3×10^{-4} and 3.2 percent contribution). Contribution to ELCR is elevated for arsenic (1.6×10^{-4} and 1.6 percent contribution), where measured concentrations are within natural background values.

The HI for the B Plant exposure area is 19, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are uranium (HQ of 5.0 and 26 percent contribution), cadmium (HQ of 4.4 and 23 percent contribution), manganese (HQ of 1.6 and 8.4 percent contribution), vanadium (HQ of 1.6 and 8.3 percent contribution), and barium (HQ of 1.2 and 6.4 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are nickel, fluoride, Cr(VI), cyanide, and antimony. Contribution to HI is elevated for arsenic (HQ of 2.6 and 14 percent contribution), where measured concentrations are within natural background values.

G1.1.2.6 Semiworks Exposure Area

The total cumulative ELCR for the Semiworks exposure area is 3.9×10^{-3}. The total ELCR for the Semiworks exposure area is 3.9×10^{-3} for nonradiological analytes and 3.1×10^{-5} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (3.8×10^{-3} and 95 percent contribution). Contribution to ELCR is elevated for arsenic (1.4×10^{-4} and 3.7 percent contribution), where measured concentrations are within natural background values.

The HI for the Semiworks exposure area is 6.9, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are barium (HQ of 1.4 and 21 percent contribution), uranium (HQ of 1.3 and 19 percent contribution), and vanadium (HQ of 1.1 and 16 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are Cr(VI), fluoride, and nickel.

Contribution to the noncancer HI is elevated for arsenic (HQ of 2.3 and 33 percent contribution), where measured concentrations are within natural background values.

G1.1.2.7 Liquid Effluent Retention Facility Exposure Area

The total cumulative ELCR for the LERF exposure area is 4.8×10^{-3}. The total ELCR for the LERF exposure area is 4.8×10^{-3} for nonradiological analytes and 9.6×10^{-7} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is less than the EPA lower target threshold of 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (4.6×10^{-3} and 96 percent contribution). Contribution to ELCR is elevated for arsenic (1.6×10^{-4} and 3.4 percent contribution), where measured concentrations are within natural background values.

The HI for the LERF exposure area is 8.7, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 1.7 and 19 percent contribution), vanadium (HQ of 1.6 and 18 percent contribution), and barium (HQ of 1.1 and 13 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than or equal to 1 are nickel, Cr(VI), and fluoride. Contribution to HI is elevated for arsenic (HQ of 2.5 and 29 percent contribution), where measured concentrations are within natural background values.

G1.1.2.8 Gable Mountain Pond Exposure Area

The total cumulative ELCR for the Gable Mountain Pond exposure area is 4×10^{-3}. The total ELCR for the Gable Mountain Pond exposure area is 3.9×10^{-3} for nonradiological analytes and 9.9×10^{-5} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (3.7×10^{-3} and 92 percent contribution), strontium-90 (9.5×10^{-5} and 2.4 percent contribution), and nickel (4.7×10^{-5} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (1.7×10^{-4} and 4.2 percent contribution), where measured concentrations are within natural background values.

The HI for the Gable Mountain Pond exposure area is 23, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 16 and 68 percent contribution) and nickel (HQ of 2.1 and 9 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are barium, vanadium, Cr(VI), and antimony. Contribution to HI is elevated for arsenic (HQ of 2.7 and 12 percent contribution), where measured concentrations are within natural background values.

G1.1.2.9 200-BP-5 West Exposure Area

The total cumulative ELCR for the 200-BP-5 west exposure area is 4.6×10^{-3}. The total ELCR for the 200-BP-5 west exposure area is 4.4×10^{-3} for nonradiological analytes and 2.4×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (3.8×10^{-3} and 83 percent contribution), cobalt (2.5×10^{-4} and 5.5 percent contribution), and technetium-99 (1.0×10^{-4} and 2.2 percent contribution). Contribution to ELCR is elevated for arsenic (2.2×10^{-4} and 4.7 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 west exposure area is 57, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 25 and 44 percent contribution), aluminum (HQ of 9.5 and 17 percent contribution), cobalt (HQ of 4.8 and 8.5 percent contribution), cyanide (HQ of 4.5 and 7.9 percent contribution), cadmium (HQ of 2.4 and 4.2 percent contribution), uranium (HQ of 1.9 and 3.4 percent contribution), vanadium (HQ of 1.5 and 2.6 percent contribution), nickel (HQ of 1.2 and 2.1 percent contribution), and barium (HQ of 1.2 and 2 percent contribution). Contribution to the noncancer HI is elevated for arsenic (HQ of 3.5 and 6.1 percent contribution), where measured concentrations are within natural background values.

G1.1.2.10 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

The total cumulative ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area is 4.6×10^{-3}. The total ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area is 8.4×10^{-3} for nonradiological analytes and 3.7×10^{-5} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (7.9×10^{-3} and 94 percent contribution). Contribution to ELCR is elevated for arsenic (4.6×10^{-4} and 5.4 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 far-field (north of Gable Gap) exposure area is 19, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 6.9 and 36 percent contribution), vanadium (HQ of 1.7 and 8.8 percent contribution), and Cr(VI) (HQ of 1.1 and 5.5 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are uranium, nickel, barium, and fluoride. Contribution to HI is elevated for arsenic (HQ of 7.2 and 38 percent contribution), where measured concentrations are within natural background values.

G1.1.2.11 200-BP-5 Near-River Exposure Area

The total cumulative ELCR for the 200-BP-5 near-river exposure area is 4.5×10^{-3}. The total ELCR for the 200-BP-5 near-river exposure area is 4.4×10^{-3} for nonradiological analytes and 1.0×10^{-4} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is equal to the EPA upper target risk threshold of 1×10^{-4}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (4.2×10^{-3} and 95 percent contribution). Contribution to ELCR is elevated for arsenic (1.1×10^{-4} and 2.5 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 near-river exposure area is 7.6, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 2.4 and 32 percent contribution) and vanadium (HQ of 1.3 and 16 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are Cr(VI), uranium, barium, cobalt, fluoride, and cadmium. Contribution to HI is elevated for arsenic (HQ of 1.8 and 23 percent contribution), where measured concentrations are within natural background values.

G1.1.2.12 200-BP-5 Confined Exposure Area

The total cumulative ELCR for the 200-BP-5 confined exposure area is 4.6×10^{-3}. The total ELCR for the 200-BP-5 confined exposure area is 4.5×10^{-3} for nonradiological analytes and 1.5×10^{-4} for radiological

analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (4.3×10^{-3} and 92 percent contribution), cobalt (6.4×10^{-5} and 1.4 percent contribution), and uranium-234 (6.4×10^{-5} and 1.4 percent contribution). Contribution to ELCR is elevated for arsenic (1.1×10^{-4} and 2.4 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 confined exposure area is 20, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 11 and 56 percent contribution), barium (HQ of 1.6 and 8 percent contribution), and cobalt (HQ of 1.2 and 6.3 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are vanadium, nickel, uranium, cyanide, and Cr(VI). Contribution to the noncancer HI is elevated for arsenic (HQ of 1.7 and 8.9 percent contribution), where measured concentrations are within natural background values.

G1.2 200-BP-5 Operable Unit — 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 the use of groundwater to generate steam in a sweat lodge by the Yakama Nation, where the groundwater source is the 200-BP-5 OU.

G1.2.1 Yakama Nation Use of 200-BP-5 Operable Unit Groundwater as a Potential Drinking Water Source

Potential exposure to 200-BP-5 OU groundwater as a drinking water source is evaluated under the Yakama Nation exposure scenario. Potential routes of exposure to groundwater include ingestion, dermal contact,[2] and inhalation of volatiles during household activities. Table G-3 provides a summary of the Yakama Nation risk estimates by exposure route for each exposure area evaluated in the 200-BP-5 OU. Additional detail including analyte-specific risk contributions is provided in the calculation spreadsheets presented in ECF-HANFORD-13-0036 (provided as an attachment to this appendix).

G1.2.1.1 Low-Level Waste Management Area 1 Exposure Area

The total cumulative ELCR for the LLWMA-1 exposure area is 1.6×10^{-3}. The total ELCR for the LLWMA-1 exposure area is 4.6×10^{-4} for nonradiological analytes and 1.1×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (8.5×10^{-4} and 55 percent contribution), tritium (1.7×10^{-4} and 11 percent contribution), cobalt-60 (4.0×10^{-5} and 2.6 percent contribution), and iodine-129 (3.4×10^{-5} and 2.2 percent contribution). Contribution to ELCR is elevated for arsenic (4.6×10^{-4} and 29 percent contribution), where measured concentrations are within natural background values.

The HI for the LLWMA-1 exposure area is 111, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 100 and 90 percent contribution) and nitrate (HQ of 1.5 and 1.3 percent contribution). Contribution to HI is elevated for antimony (HQ of 6.8 and 6.2 percent contribution), where measured concentrations reflect false-positive results from the use of EPA Method 6010.

[2] The dermal contact exposure route is only evaluated for nonradionuclide analytes.

G1.2.1.2 Low-Level Waste Management Area 2 and 216-B-63 Trench Exposure Area

The total cumulative ELCR for the LLWMA-2 and 216-B-63 Trench exposure area is 1.1×10^{-3}. The total ELCR for the LLWM-2 and 216-B-63 Trench exposure area is 8.1×10^{-4} for nonradiological analytes and 2.5×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (2.2×10^{-4} and 20 percent contribution), iodine-129 (2.0×10^{-5} and 1.9 percent contribution), and tritium (1.3×10^{-5} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (8.1×10^{-4} and 76 percent contribution), where measured concentrations are within natural background values.

The HI for the LLWMA-2 and 216-B-63 Trench exposure area is 54, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 41 and 77 percent contribution). Contribution to HI is elevated for arsenic (HQ of 1.6 and 3 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 9.6 and 18 percent contribution), where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.1.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

The total cumulative ELCR for the WMA B-BX-BY Tank Farms exposure area is 1.6×10^{-2}. The total ELCR for the WMA B-BX-BY Tank Farms exposure area is 4.6×10^{-3} for nonradiological analytes and 1.1×10^{-2} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are uranium-234 (4.1×10^{-3} and 26 percent contribution), uranium-238 (3.7×10^{-3} and 23 percent contribution), technetium-99 (3.1×10^{-3} and 19 percent contribution), methyl methanesulfonate (2.1×10^{-3} and 13 percent contribution), n-nitrosodi-n-dipropylamine (1.6×10^{-3} and 9.8 percent contribution), tritium (2.6×10^{-4} and 1.6 percent contribution), and uranium-235 (1.8×10^{-4} and 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (8.5×10^{-4} and 5.3 percent contribution), where measured concentrations are within natural background values.

The HI for the WMA B/BX/BY Tank Farms exposure area is 255, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 230 and 90 percent contribution), uranium (HQ of 8.1 and 3.2 percent contribution), antimony (HQ of 6.5 and 2.6 percent contribution), and nitrate (HQ of 4.8 and 1.9 percent contribution). Contribution to HI is elevated for antimony (HQ of 6.5 and 2.6 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.1.4 Waste Management Area C Tank Farm Exposure Area

The total cumulative ELCR for the WMA C Tank Farm exposure area is 2.3×10^{-3}. The total ELCR for the WMA C Tank Farm exposure area is 6.3×10^{-4} for nonradiological analytes and 1.7×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (1.6×10^{-3} and 69 percent contribution), iodine-129 (6.6×10^{-5} and 2.8 percent contribution), and tritium (2.5×10^{-5} and 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (6.2×10^{-4} and 27 percent contribution), where measured concentrations are within natural background values.

Table G-3. Yakima Nation Exposure Scenario — Summary of Risk Estimates from Use of 200-BP-5 OU Groundwater as a Potential Drinking Water Source

Exposure Route	LLWMA-1		LLWMA-2 and 216-B-63 Trench		WMA B-BX-BY Tank Farms		WMA C Tank Farm		B Plant		Semiworks		LERF		Gable Mountain Pond		200-BP-5 West		200-BP-5 Far-Field Area (North of Gable Gap)		200-BP-5 Near-River Area		200-BP-5 Confined	
	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI
Nonradionuclide Analytes																								
Ingestion	4.6E-04	24	8.0E-04	18	4.5E-03	54	6.2E-04	11	4.3E-04	16	3.8E-04	1.9	4.3E-04	2.1	4.4E-04	13	5.9E-04	21	1.2E-03	4.5	3.0E-04	2.1	3.2E-04	9.1
Dermal	1.6E-06	0.31	2.7E-06	0.35	3.7E-05	0.57	3.0E-06	0.28	1.5E-06	0.39	1.3E-06	0.06	3.0E-06	0.09	1.5E-06	0.33	5.8E-06	0.38	4.1E-06	0.12	1.6E-06	0.09	6.6E-06	0.26
Inhalation	1.5E-06	87	—	36	2.7E-05	200	5.5E-06	4.3	—	4.3	—	—	6.9E-06	0.01	—	—	1.5E-05	45	—	—	5.9E-06	0.46	3.2E-05	6.0
Total	4.6E-04	111	8.1E-04	54	4.6E-03	255	6.3E-04	16	4.3E-04	20	3.8E-04	1.9	4.4E-04	2.2	4.4E-04	13	6.1E-04	66	1.2E-03	4.7	3.1E-04	2.7	3.5E-04	15
Radionuclide Analytes																								
Ingestion	9.6E-04	—	2.4E-04	—	1.1E-02	—	1.7E-03	—	1.1E-02	—	9.7E-05	—	7.7E-06	—	1.2E-03	—	9.8E-04	—	1.1E-04	—	1.4E-04	—	1.5E-04	--
Inhalation	1.3E-04	—	1.0E-05	—	2.1E-04	—	1.9E-05	—	9.5E-05	—	1.4E-04	—	1.1E-05	—	5.8E-05	—	1.2E-04	—	2.3E-04	—	2.3E-04	—	3.2E-05	--
Total	1.1E-03	—	2.5E-04	—	1.1E-02	—	1.7E-03	—	1.1E-02	—	2.3E-04	—	1.9E-05	—	1.2E-03	—	1.1E-03	—	3.4E-04	—	3.6E-04	—	1.8E-04	--
Total cumulative ELCR*	1.6E-03	—	1.1E-03	—	1.6E-02	—	2.3E-03	—	1.2E-02	—	6.1E-04	—	4.6E-04	—	1.7E-03	—	1.7E-03	—	1.5E-03	—	6.7E-04	—	5.4E-04	--

Note: "—" indicates HI or ELCR is not applicable.

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index
LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
WMA = waste management area

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The HI for the WMA C Tank Farm exposure area is 16, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 4.9 and 31 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are cobalt, cadmium, nitrate, and vanadium. Contribution to HI is elevated for arsenic (HQ of 1.3 and 8 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 6.8 and 43 percent contribution), where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.1.5 B Plant Exposure Area

The total cumulative ELCR for the B Plant exposure area is 1.2×10^{-2}. The total ELCR for the B Plant exposure area is 4.3×10^{-4} for nonradiological analytes and 1.1×10^{-2} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (6.2×10^{-3} and 52 percent contribution), cesium-137 (4.1×10^{-3} and 35 percent contribution), plutonium-239/240 (4.0×10^{-4} and 3.4 percent contribution), and technetium-99 (3.8×10^{-4} and 3.2 percent contribution). Contribution to ELCR is elevated for arsenic (4.3×10^{-4} and 3.6 percent contribution), where measured concentrations are within natural background values.

The HI for the B Plant exposure area is 20, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 5.0 and 24 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are arsenic, fluoride, nitrate, cadmium, uranium, and vanadium. Contribution to HI is elevated for antimony (HQ of 11 and 54 percent contribution), where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.1.6 Semiworks Exposure Area

The total cumulative ELCR for the Semiworks exposure area is 6.1×10^{-4}. The total ELCR for the Semiworks exposure area is 3.8×10^{-4} for nonradiological analytes and 2.3×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (1.7×10^{-4} and 28 percent contribution), iodine-129 (2.6×10^{-5} and 4.3 percent contribution), technetium-99 (1.7×10^{-5} and 2.7 percent contribution), and strontium-90 (1.5×10^{-5} and 2.5 percent contribution). Contribution to ELCR is elevated for arsenic (3.8×10^{-4} and 62 percent contribution), where measured concentrations are within natural background values.

The HI for the Semiworks exposure area is 1.9, which is greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include nitrate, fluoride, vanadium, Cr(VI), uranium, selenium, molybdenum, nitrite, strontium, and barium.

G1.2.1.7 Liquid Effluent Retention Facility Exposure Area

The total cumulative ELCR for the LERF exposure area is 4.6×10^{-4}. The total ELCR for the LERF exposure area is 4.4×10^{-4} for nonradiological analytes and 1.9×10^{-5} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are carbon tetrachloride (1.9×10^{-5} and 4.1 percent contribution) and tritium (1.5×10^{-5} and 3.2 percent

contribution). Contribution to ELCR is elevated for arsenic (4.2×10^{-4} and 92 percent contribution), where measured concentrations are within natural background values.

The HI for the LERF exposure area is 2.2, which is greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include nitrate, fluoride, vanadium, Cr(VI), silver, nitrite, strontium, nickel, and manganese.

G1.2.1.8 Gable Mountain Pond Exposure Area

The total cumulative ELCR for the Gable Mountain Pond exposure area is 1.7×10^{-3}. The total ELCR for the Gable Mountain Pond exposure area is 4.4×10^{-4} for nonradiological analytes and 1.2×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (1.2×10^{-3} and 69 percent contribution) and tritium (7.4×10^{-5} and 4.4 percent contribution). Contribution to ELCR is elevated for arsenic (4.4×10^{-4} and 26 percent contribution), where measured concentrations are within natural background values.

The HI for the Gable Mountain Pond exposure area is 13, which is greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include arsenic, nitrate, iron, and manganese. Contribution to HI is elevated for antimony (HQ of 10 and 79 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.1.9 200-BP-5 West Exposure Area

The total cumulative ELCR for the 200-BP-5 west exposure area is 1.7×10^{-3}. The total ELCR for the 200-BP-5 west exposure area is 6.1×10^{-4} for nonradiological analytes and 1.1×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (4.6×10^{-4} and 27 percent contribution), strontium-90 (4.5×10^{-4} and 26 percent contribution), tritium (1.5×10^{-4} and 9 percent contribution), and carbon tetrachloride (2.0×10^{-5} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (5.8×10^{-4} and 34 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 west exposure area is 66, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 52, 78 percent contribution). The remaining individual analyte that contributes greater than 1 percent of the HI but report an HQ less than 1 is nitrate. Contribution to the noncancer HI is elevated for arsenic (HQ of 1.2 and 1.8 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 8.6 and 13 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.1.10 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

The total cumulative ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area is 1.5×10^{-3}. The total ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area is 1.2×10^{-3} for nonradiological analytes and 3.4×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (2.9×10^{-4} and 19 percent contribution) and technetium-99 (4.0×10^{-5} and 2.6 percent contribution). Contribution to ELCR is elevated for arsenic (1.2×10^{-3} and 78 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 far-field (north of Gable Gap) exposure area is 4.7, which is greater than the EPA target HI of 1. Contribution to the HI is elevated for arsenic (HQ of 2.4 and 52 percent contribution), where measured concentrations are within natural background values. The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include fluoride, Cr(VI), lithium, vanadium, nitrate, copper, iron, manganese, uranium, zinc, and molybdenum.

G1.2.1.11 200-BP-5 Near-River Exposure Area

The total cumulative ELCR for the 200-BP-5 near-river exposure area is 6.7×10^{-4}. The total ELCR for the 200-BP-5 near-river exposure area is 3.1×10^{-4} for nonradiological analytes and 3.6×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (2.9×10^{-4} and 43 percent contribution), carbon-14 (4.4×10^{-5} and 6.6 percent contribution), technetium-99 (1.6×10^{-5} and 2.4 percent contribution), and trichloroethene (9.6×10^{-6} and 1.4 percent contribution). Contribution to ELCR is elevated for arsenic (3.0×10^{-4} and 44 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 near-river exposure area is 2.7, which is greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include lithium, fluoride, nitrate, vanadium, Cr(VI), molybdenum, uranium, nitrite, manganese, and zinc.

G1.2.1.12 200-BP-5 Confined Exposure Area

The total cumulative ELCR for the 200-BP-5 confined exposure area is 5.4×10^{-4}. The total ELCR for the 200-BP-5 confined exposure area is 3.5×10^{-4} for nonradiological analytes and 1.8×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (9.5×10^{-5} and 18 percent contribution), tritium (4.0×10^{-5} and 7.5 percent contribution), benzene (1.9×10^{-5}, 3.6 percent contribution), carbon tetrachloride (1.9×10^{-5} and 3.5 percent contribution), chloroform (1.8×10^{-5} and 3.3 percent contribution), iodine-129 (1.3×10^{-5} and 2.4 percent contribution), strontium-90 (1.3×10^{-5} and 2.3 percent contribution), uranium-234 (9.2×10^{-6} and 1.7 percent contribution), uranium-238 (6.6×10^{-6} and 1.2 percent contribution), and BEHP (6.4×10^{-6} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (2.9×10^{-4} and 53 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 confined exposure area is 15, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 6.9 and 45 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 and include arsenic, silver, iron, fluoride, manganese, and cobalt. Contribution to HI is elevated for antimony (HQ of 6.1 and 40 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.2 Yakama Nation Use of 200-BP-5 Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to 200-BP-5 OU groundwater as a source of steam in a sweat lodge is evaluated under the Yakama Nation exposure 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. Tables G-4 and G-5 provide summaries of the Yakama Nation risk estimates by exposure route for each exposure area evaluated in the 200-BP-5 OU.

Table G-4 summarizes cancer risk and noncancer hazards that include exposure from dermal contact with aerosolized nonvolatiles and inhalation of aerosolized nonvolatiles. Table G-5 summarizes risk estimates without exposure from dermal contact with aerosolized nonvolatiles and inhalation of aerosolized nonvolatiles. Additional detail including analyte-specific risk contributions is provided in the calculation spreadsheets presented in ECF-HANFORD-13-0036 (provided as an attachment to this appendix).

G1.2.2.1 Low-Level Waste Management Area 1 Exposure Area

The total cumulative ELCR for the LLWMA-1 exposure area *with* contributions from aerosolized nonvolatile analytes is 4.3×10^{-2}. The total ELCR for the LLWMA-1 exposure area *with* contributions from aerosolized nonvolatile analytes is 4.1×10^{-2} for nonradiological analytes and 1.5×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (3.9×10^{-2} and 93 percent contribution) and technetium-99 (1.4×10^{-3} and 3.3 percent contribution). Contribution to ELCR is elevated for arsenic (1.3×10^{-3} and 3.1 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the LLWMA-1 exposure area *without* contributions from aerosolized nonvolatile analytes is 9.1×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.4×10^{-5} for nonradiological analytes and 7.7×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (7.7×10^{-5} and 84 percent contribution) and chloroform (1.1×10^{-6} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (1.3×10^{-5} and 14 percent contribution), where measured concentrations are within natural background values.

The HI for the LLWMA-1 exposure area *with* contributions from aerosolized nonvolatile analytes is 158, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 63 and 40 percent contribution), uranium (HQ of 34 and 22 percent contribution), vanadium (HQ of 11 and 6.7 percent contribution), barium (HQ of 9.0 and 5.7 percent contribution), Cr(VI) (HQ of 5.2 and 3.3 percent contribution), nickel (HQ of 3.9 and 2.5 percent contribution), cobalt (HQ of 3.9 and 2.5 percent contribution), cadmium (HQ of 2.5 and 1.6 percent contribution), and manganese (HQ of 1.9 and 1.2 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 20 and 13 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 65, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 63 and 97 percent contribution) and antimony (HQ of 1.4 and 2.2 percent contribution).

Table G-4. Yakima Nation Exposure Scenario — Summary of Risk Estimates from Use of 200-BP-5 OU Groundwater in a Sweat Lodge (with Aerosolized Nonvolatile Analytes)

Exposure Route	LLWMA-1		LLWMA-2 and 216-B-63 Trench		WMA B-BX-BY Tank Farms		WMA C Tank Farm		B Plant		Semiworks		LERF		Gable Mountain Pond Exposure Area		200-BP-5 West		200-BP-5 Far-Field Area (North of Gable Gap)		200-BP-5 Near-River Area		200-BP-5 Confined	
	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI
Nonradionuclide Analytes																								
Inhalation in Sweat Lodge																								
Volatile and semivolatiles (vapor)	1.1E-06	63	—	26	1.9E-05	145	4.0E-06	3.1	—	3.1	—	—	5.0E-06	0.01	—	—	1.1E-05	32	—	—	4.3E-06	0.33	2.3E-05	4.4
Nonvolatile (aerosol)	4.1E-02	93	4.8E-02	86	1.4E-01	869	3.1E-02	136	3.0E-02	132	2.9E-02	50	3.5E-02	62	2.9E-02	163	3.2E-02	377	6.1E-02	138	3.2E-02	55	3.3E-02	136
Total	4.1E-02	156	4.8E-02	112	1.4E-01	1,013	3.1E-02	139	3.0E-02	135	2.9E-02	50	3.5E-02	62	2.9E-02	163	3.2E-02	409	6.1E-02	138	3.2E-02	55	3.3E-02	140
Dermal Exposure in Sweat Lodge																								
Volatile and semivolatiles (vapor only)	4.7E-11	<0.01	—	<0.01	7.2E-09	<0.01	2.6E-09	<0.01	—	<0.01	—	—	4.4E-09	<0.01	—	—	5.1E-09	<0.01	—	—	1.8E-09	<0.01	8.4E-09	<0.01
Nonvolatile (vapor and aqueous condensate)	1.3E-05	2.2	2.3E-05	2.8	1.4E-04	14	1.8E-05	3.5	1.2E-05	2.9	1.1E-05	0.50	1.2E-05	0.70	1.3E-05	2.8	1.9E-05	2.7	3.4E-05	1.0	8.5E-06	0.57	1.4E-05	2.0
Total	1.3E-05	2.2	2.3E-05	2.8	1.4E-04	14	1.8E-05	3.5	1.2E-05	2.9	1.1E-05	0.50	1.2E-05	0.70	1.3E-05	2.8	1.9E-05	2.7	3.4E-05	1.0	8.5E-06	0.57	1.4E-05	2.0
Total nonradionuclide	4.1E-02	158	4.8E-02	114	1.4E-01	1,027	3.1E-02	142	3.0E-02	138	2.9E-02	50	3.5E-02	63	2.9E-02	165	3.2E-02	412	6.1E-02	139	3.2E-02	56	3.3E-02	142
Radionuclide Analytes																								
Inhalation in Sweat Lodge																								
Volatile and semivolatiles (vapor)	7.7E-05	—	5.9E-06	—	1.2E-04	—	1.1E-05	—	5.5E-05	—	7.8E-05	—	6.6E-06	—	3.3E-05	—	7.0E-05	—	1.3E-04	—	1.3E-04	—	1.8E-05	—
Nonvolatile (aerosol)	1.5E-03	—	3.6E-04	—	3.7E-01	—	2.9E-03	—	4.7E-02	—	1.6E-04	—	6.1E-07	—	7.1E-04	—	1.7E-03	—	1.5E-04	—	6.2E-04	—	1.1E-03	—
Total radionuclide	1.5E-03	—	3.7E-04	—	3.7E-01	—	2.9E-03	—	4.7E-02	—	2.3E-04	—	7.2E-06	—	7.4E-04	—	1.8E-03	—	2.8E-04	—	7.5E-04	—	1.2E-03	—
Total cumulative ELCR*	4.3E-02	—	4.8E-02	—	5.1E-01	—	3.4E-02	—	7.7E-02	—	2.9E-02	—	3.5E-02	—	3.0E-02	—	3.4E-02	—	6.2E-02	—	3.3E-02	—	3.4E-02	—

Note: "—" indicates HI or ELCR is not applicable.

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index
LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
WMA = waste management area

Table G-5. Yakima Nation Exposure Scenario — Summary of Risk Estimates from Use of 200-BP-5 OU Groundwater in a Sweat Lodge (without Aerosolized Nonvolatile Analytes)

Exposure Route	LLWMA-1		LLWMA-2 and 216-B-63 Trench		WMA B-BX-BY Tank Farms		WMA C Tank Farm		B Plant		Semiworks		LERF		Gable Mountain Pond		200-BP-5 West		200-BP-5 Far-Field Area (North of Gable Gap)		200-BP-5 Near-River Area		200-BP-5 Confined	
	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI	ELCR	HI
Nonradionuclide Analytes																								
Inhalation in Sweat Lodge																								
Volatile and semivolatiles (vapor)	1.1E-06	63	—	26	1.9E-05	145	4.0E-06	3.1	—	3.1	—	—	5.0E-06	0.01	—	—	1.1E-05	32	—	—	4.3E-06	0.33	2.3E-05	4.4
Nonvolatile (aerosol)	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]	—[b]
Total	1.1E-06	63	—	26	1.9E-05	145	4.0E-06	3.1	—	3.1	—	—	5.0E-06	0.01	—	—	1.1E-05	32	—	—	4.3E-06	0.33	2.3E-05	4.4
Dermal Exposure in Sweat Lodge																								
Volatile and semivolatiles (vapor only)	4.7E-11	<0.01	—	<0.01	7.2E-09	<0.01	2.6E-09	<0.01	—	<0.01	—	—	4.4E-09	<0.01	—	—	5.1E-09	<0.01	—	—	1.8E-09	<0.01	8.4E-09	<0.01
Nonvolatile (aqueous condensate only)	1.3E-05	2.2	2.3E-05	2.8	1.4E-04	14	1.8E-05	3.5	1.2E-05	2.9	1.1E-05	0.50	1.2E-05	0.70	1.3E-05	2.8	1.9E-05	2.7	3.4E-05	1.0	8.5E-06	0.57	1.4E-05	2.0
Total	1.3E-05	2.2	2.3E-05	2.8	1.4E-04	14	1.8E-05	3.5	1.2E-05	2.9	1.1E-05	0.50	1.2E-05	0.70	1.3E-05	2.8	1.9E-05	2.7	3.4E-05	1.0	8.5E-06	0.57	1.4E-05	2.0
Total nonradionuclide	1.4E-05	65	2.3E-05	29	1.6E-04	158	2.2E-05	6.6	1.2E-05	6.1	1.1E-05	0.50	1.7E-05	0.70	1.3E-05	2.8	3.0E-05	35	3.4E-05	1.0	1.3E-05	0.90	3.7E-05	6.4
Radionuclide Analytes																								
Inhalation in Sweat Lodge																								
Volatile and semivolatiles (vapor)	7.7E-05	—	5.9E-06	—	1.2E-04	—	1.1E-05	—	5.5E-05	—	7.8E-05	—	6.6E-06	—	3.3E-05	—	7.0E-05	—	1.3E-04	—	1.3E-04	—	1.8E-05	—
Nonvolatile (aerosol)	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—	—[b]	—
Total radionuclide	7.7E-05	—	5.9E-06	—	1.2E-04	—	1.1E-05	—	5.5E-05	—	7.8E-05	—	6.6E-06	—	3.3E-05	—	7.0E-05	—	1.3E-04	—	1.3E-04	—	1.8E-05	—
Total cumulative ELCR[a]	9.1E-05	—	2.9E-05	—	2.7E-04	—	3.3E-05	—	6.7E-05	—	8.9E-05	—	2.4E-05	—	4.6E-05	—	9.9E-05	—	1.7E-04	—	1.4E-04	—	5.5E-05	—

Note: "—" indicates HI or ELCR is not applicable.

a. Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.

b. Aqueous condensate contribution only (aerosol nonvolatile-phase contribution excluded).

CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
HI = hazard index
LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
WMA = waste management area

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G1.2.2.2 Low-Level Waste Management Area 2 and 216-B-63 Trench Exposure Area

The total cumulative ELCR for the LLWMA-2 and 216-B-63 Trench exposure area *with* contributions from aerosolized nonvolatile analytes is 4.8×10^{-2}. The total ELCR for the LLWMA-2 and 216-B-63 Trench source exposure area *with* contributions from aerosolized nonvolatile analytes is 4.8×10^{-2} for nonradiological analytes and 3.7×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (4.5×10^{-2} and 94 percent contribution). Contribution to ELCR is elevated for arsenic (2.3×10^{-3} and 4.7 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the LLWMA-2 and 216-B-63 Trench exposure area *without* contributions from aerosolized nonvolatile analytes is 2.9×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 2.3×10^{-5} for nonradiological analytes and 5.9×10^{-6} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is tritium (5.9×10^{-6} and 21 percent contribution). Contribution to ELCR is elevated for arsenic (2.3×10^{-5} and 79 percent contribution), where measured concentrations are within natural background values.

The HI for the LLWMA-2 and 216-B-63 Trench source exposure area *with* contributions from aerosolized nonvolatile analytes is 114, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 26 and 23 percent contribution), vanadium (HQ of 13 and 12 percent contribution), nickel (HQ of 12 and 10 percent contribution), barium (HQ of 6.8 and 5.9 percent contribution), manganese (HQ of 6.3 and 5.5 percent contribution), Cr(VI) (HQ of 6.0 and 5.2 percent contribution), and uranium (HQ of 5.9 and 5.1 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 35 and 31 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 2.0; 1.7 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

The HI *without* contributions from aerosolized nonvolatile analytes is 29, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 26 and 90 percent contribution). The remaining individual analyte that contributes greater than 1 percent of the HI but reports an HQ less than 1 is Cr(VI). Contribution to HI is elevated for antimony (HQ of 2.0 and 6.8 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.2.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

The total cumulative ELCR for the WMA B-BX-BY Tank Farms exposure area *with* contributions from aerosolized nonvolatile analytes is 5.1×10^{-1}. The total ELCR for the WMA B-BX-BY Tank Farms source exposure area *with* contributions from aerosolized nonvolatile analytes is 1.4×10^{-1} for nonradiological analytes and 3.7×10^{-1} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are uranium-234 (1.9×10^{-1} and 38 percent contribution), uranium-238 (1.6×10^{-1} and 31 percent contribution), Cr(VI) (1.3×10^{-1} and 26 percent contribution), and uranium-235 (8.6×10^{-3} and 1.7 percent contribution).

The total cumulative ELCR for the WMA B-BX-BY Tank Farms exposure area *without* contributions from aerosolized nonvolatile analytes is 2.7×10^{-4}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.6×10^{-4} for nonradiological analytes and 1.2×10^{-4} for radiological

analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (1.2×10^{-4} and 43 percent contribution), n-nitrosodi-n-dipropylamine (1.0×10^{-4} and 37 percent contribution), chloroform (1.2×10^{-5} and 4.3 percent contribution), methyl methanesulfonate (8.4×10^{-6} and 3.1 percent contribution), and carbon tetrachloride (7.6×10^{-6} and 2.8 percent contribution). Contribution to ELCR is elevated for arsenic (2.4×10^{-5} and 8.8 percent contribution), where measured concentrations are within natural background values.

The HI for the WMA B-BX-BY Tank Farms exposure area *with* contributions from aerosolized nonvolatile analytes is 1,027, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are uranium (HQ of 656 and 64 percent contribution), cyanide (HQ of 145 and 14 percent contribution), cobalt (HQ of 48 and 4.7 percent contribution), cadmium (HQ of 37 and 3.6 percent contribution), nickel (HQ of 35 and 3.5 percent contribution), manganese (HQ of 22 and 2.1 percent contribution), Cr(VI) (HQ of 18 and 1.8 percent contribution), and barium (HQ of 15 and 1.5 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 37 and 3.6 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 158, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 145 and 91 percent contribution), cadmium (HQ of 7.8 and 4.9 percent contribution), and di-n-octylphthalate (HQ of 2.4 and 1.5 percent contribution).

G1.2.2.4 Waste Management Area C Tank Farm Exposure Area

The total cumulative ELCR for the WMA C Tank Farm exposure area *with* contributions from aerosolized nonvolatile analytes is 3.4×10^{-2}. The total ELCR for the WMA C Tank Farm exposure area *with* contributions from aerosolized nonvolatile analytes is 3.1×10^{-2} for nonradiological analytes and 2.9×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (2.7×10^{-2} and 78 percent contribution), technetium-99 (2.7×10^{-3} and 7.8 percent contribution), cobalt (2.2×10^{-3} and 6.5 percent contribution), and cadmium (4.5×10^{-4} and 1.3 percent contribution). Contribution to ELCR is elevated for arsenic (1.8×10^{-3} and 5.1 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the WMA C Tank Farm exposure area *without* contributions from aerosolized nonvolatile analytes is 3.3×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 2.2×10^{-5} for nonradiological analytes and 1.1×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (1.1×10^{-5} and 34 percent contribution), carbon tetrachloride (2.8×10^{-6} and 8.5 percent contribution), chloroform (1.1×10^{-6} and 3.4 percent contribution), and tributyl phosphate (3.7×10^{-7} and 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (1.8×10^{-5} and 53 percent contribution), where measured concentrations are within natural background values.

The HI for the WMA C Tank Farm source exposure area *with* contributions from aerosolized nonvolatile analytes is 142, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cobalt (HQ of 41 and 29 percent contribution), cadmium (HQ of 25 and 17 percent contribution), vanadium (HQ of 11 and 7.6 percent contribution), nickel (HQ of 7.4 and 5.2 percent contribution), barium (HQ of 6.9 and

4.9 percent contribution), uranium (HQ of 6.7 and 4.7 percent contribution), manganese (HQ of 6.4 and 4.5 percent contribution), Cr(VI) (HQ of 3.5 and 2.5 percent contribution), and cyanide (HQ of 3.0 and 2.1 percent contribution). Contribution to noncancer HI is elevated for arsenic (HI of 27 and 19 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 6.6, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are cyanide (HQ of 3.0 and 47 percent contribution) and di-n-octylphthalate (HQ of 1.4 and 22 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are Cr(VI) and vanadium. Contribution to HI is elevated for antimony (HQ of 1.4 and 21 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.2.5 B Plant Exposure Area

The total cumulative ELCR for the B Plant exposure area *with* contributions from aerosolized nonvolatile analytes is 7.7×10^{-2}. The total ELCR for the B Plant exposure area *with* contributions from aerosolized nonvolatile analytes is 3.0×10^{-2} for nonradiological analytes and 4.7×10^{-2} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are plutonium-239/240 (3.2×10^{-2} and 41 percent contribution), Cr(VI) (2.8×10^{-2} and 36 percent contribution), uranium-233/234 (4.0×10^{-3} and 5.2 percent contribution), strontium-90 (3.7×10^{-3} and 4.9 percent contribution), and uranium-238 (2.5×10^{-3} and 3.2 percent contribution). Contribution to ELCR is elevated for arsenic (1.2×10^{-3} and 1.6 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the B Plant exposure area *without* contributions from aerosolized nonvolatile analytes is 6.7×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.2×10^{-5} for nonradiological analytes and 5.5×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is tritium (5.5×10^{-5} and 82 percent contribution). Contribution to ELCR is elevated for arsenic (1.2×10^{-5} and 18 percent contribution), where measured concentrations are within natural background values.

The HI for the B Plant exposure area *with* contributions from aerosolized nonvolatile analytes is 138, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are uranium (HQ of 36 and 26 percent contribution), cadmium (HQ of 32 and 23 percent contribution), manganese (HQ of 12 and 8.4 percent contribution), vanadium (HQ of 11 and 8.3 percent contribution), barium (HQ of 8.8 and 6.4 percent contribution), nickel (HQ of 5.8 and 4.2 percent contribution), fluoride (HQ of 4.3 and 3.1 percent contribution), Cr(VI) (HQ of 3.6 and 2.6 percent contribution), and cyanide (HQ of 3.1 and 2.3 percent contribution). Contribution to noncancer HI is elevated for arsenic (19, 14 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 2.3 and 1.6 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

The HI *without* contributions from aerosolized nonvolatile analytes is 6.1, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 3.1 and 52 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are Cr(VI) and

vanadium. Contribution to HI is elevated for antimony (HQ of 2.3 and 37 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.2.6 Semiworks Exposure Area

The total cumulative ELCR for the Semiworks exposure area *with* contributions from aerosolized nonvolatile analytes is 2.9×10^{-2}. The total ELCR for the Semiworks exposure area *with* contributions from aerosolized nonvolatile analytes is 2.9×10^{-2} for nonradiological analytes and 2.3×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (2.8×10^{-2} and 95 percent contribution). Contribution to ELCR is elevated for arsenic (1.1×10^{-3} and 3.7 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the Semiworks exposure area *without* contributions from aerosolized nonvolatile analytes is 8.9×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.1×10^{-5} for nonradiological analytes and 7.8×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is tritium (7.8×10^{-5} and 88 percent contribution). Contribution to ELCR is elevated for arsenic (1.1×10^{-5} and 12 percent contribution), where measured concentrations are within natural background values.

The HI for the Semiworks exposure area *with* contributions from aerosolized nonvolatile analytes is 50, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are barium (HQ of 10 and 21 percent contribution), uranium (HQ of 9.5 and 19 percent contribution), vanadium (HQ of 8.0 and 16 percent contribution), and Cr(VI) (HQ of 3.6 and 7.2 percent contribution). The individual analytes that contributes greater than 1 percent of the HI but reports an HQ less than or equal to 1 are fluoride and nickel. Contribution to noncancer HI is elevated for arsenic (HQ of 17 and 33 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 0.5, which is less than the EPA target HI of 1. All individual analytes report an HQ less than 1.

G1.2.2.7 Liquid Effluent Retention Facility Exposure Area

The total cumulative ELCR for the LERF exposure area *with* contributions from aerosolized nonvolatile analytes is 3.5×10^{-2}. The total ELCR for the LERF exposure area *with* contributions from aerosolized nonvolatile analytes is 3.5×10^{-2} for nonradiological analytes and 7.2×10^{-6} for radiological analytes. The nonradiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4} and the radiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (3.4×10^{-2} and 96 percent contribution). Contribution to ELCR is elevated for arsenic (1.2×10^{-3} and 3.4 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the LERF exposure area *without* contributions from aerosolized nonvolatile analytes is 2.4×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.7×10^{-5} for nonradiological analytes and 6.6×10^{-6} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (6.6×10^{-6} and 28 percent contribution) and carbon tetrachloride (5.0×10^{-6} and 21 percent contribution). Contribution to

ELCR is elevated for arsenic (1.2×10^{-5} and 51 percent contribution), where measured concentrations are within natural background values.

The HI for the LERF exposure area *with* contributions from aerosolized nonvolatile analytes is 63, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 1 and 19 percent contribution), vanadium (HQ of 11 and 18 percent contribution), barium (HQ of 8.2 and 13 percent contribution), nickel (HQ of 7.5 and 12 percent contribution), Cr(VI) (HQ of 4.4, 7 percent contribution), and fluoride (HQ of 1.2 and 1.9 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 18 and 29 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 0.70, which is less than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1.

G1.2.2.8 Gable Mountain Pond Exposure Area

The total cumulative ELCR for the Gable Mountain Pond exposure area *with* contributions from aerosolized nonvolatile analytes is 3.0×10^{-2}. The total ELCR for the Gable Mountain Pond exposure area *with* contributions from aerosolized nonvolatile analytes is 2.9×10^{-2} for nonradiological analytes and 7.4×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (2.7×10^{-2} and 92 percent contribution), strontium-90 (7.1×10^{-4} and 2.4 percent contribution), and nickel (3.5×10^{-4} and 1.2 percent contribution). Contribution to ELCR is elevated for arsenic (1.3×10^{-3} and 4.2 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the Gable Mountain Pond exposure area *without* contributions from aerosolized nonvolatile analytes is 4.6×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.3×10^{-5} for nonradiological analytes and 3.3×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is tritium (3.3×10^{-5} and 73 percent contribution). Contribution to ELCR is elevated for arsenic (1.3×10^{-5} and 27 percent contribution), where measured concentrations are within natural background values.

The HI for the Gable Mountain Pond exposure area *with* contributions from aerosolized nonvolatile analytes is 165, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 113 and 68 percent contribution), nickel (HQ of 15 and 9 percent contribution), barium (HQ of 6.5 and 3.9 percent contribution), vanadium (HQ of 5.1 and 3.1 percent contribution), and Cr(VI) (HQ of 3.5 and 2.1 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 19 and 12 percent contribution), where measured concentrations are within natural background values. Contribution to HI is elevated for antimony (HQ of 2.2 and 1.3 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

The HI *without* contributions from aerosolized nonvolatile analytes is 2.8, which is greater than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1 are Cr(VI), manganese, and vanadium. Contribution to HI is elevated for antimony (HQ of 2.2 and 77 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.2.2.9 200-BP-5 West Exposure Area

The total cumulative ELCR for the 200-BP-5 west exposure area *with* contributions from aerosolized nonvolatile analytes is 3.4×10^{-2}. The total ELCR for the 200-BP-5 west exposure area *with* contributions from aerosolized nonvolatile analytes is 3.2×10^{-2} for nonradiological analytes and 1.8×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (2.8×10^{-2} and 83 percent contribution), cobalt (1.9×10^{-3} and 5.6 percent contribution), and technetium-99 (7.7×10^{-4} and 2.2 percent contribution). Contribution to ELCR is elevated for arsenic (1.6×10^{-3} and 4.8 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the 200-BP-5 west exposure area *without* contributions from aerosolized nonvolatile analytes is 9.9×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 3.0×10^{-5} for nonradiological analytes and 7.0×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (7.0×10^{-5} and 70 percent contribution), chloroform (5.5×10^{-6} and 5.5 percent contribution), carbon tetrachloride (5.5×10^{-6} and 5.5 percent contribution), and BEHP (1.6×10^{-6} and 1.6 percent contribution). Contribution to ELCR is elevated for arsenic (1.6×10^{-5} and 17 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 west exposure area *with* contributions from aerosolized nonvolatile analytes is 412, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 183 and 45 percent contribution), aluminum (HQ of 69 and 17 percent contribution), cobalt (HQ of 35 and 8.6 percent contribution), cyanide (HQ of 32 and 7.9 percent contribution), cadmium (HQ of 17 and 4.2 percent contribution), uranium (HQ of 14 and 3.4 percent contribution), vanadium (HQ of 11 and 2.6 percent contribution), nickel (HQ of 8.8 and 2.1 percent contribution), and barium (HQ of 8.4 and 2 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 25 and 6.1 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 35, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 32 and 92 percent contribution) and antimony (HQ of 1.8 and 5 percent contribution).

G1.2.2.10 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

The total cumulative ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area *with* contributions from aerosolized nonvolatile analytes is 6.2×10^{-2}. The total ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area *with* contributions from aerosolized nonvolatile analytes is 6.1×10^{-2} for nonradiological analytes and 2.8×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (5.8×10^{-2} and 94 percent contribution). Contribution to ELCR is elevated for arsenic (3.4×10^{-3} and 5.5 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the 200-BP-5 far-field (north of Gable Gap) exposure area *without* contributions from aerosolized nonvolatile analytes is 9.9×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 3.4×10^{-5} for nonradiological analytes and 1.3×10^{-4} for radiological analytes. The nonradiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6} and the

radiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is tritium (1.3×10^{-4} and 80 percent contribution). Contribution to ELCR is elevated for arsenic (3.4×10^{-5} and 20 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 far-field (north of Gable Gap) exposure area *with* contributions from aerosolized nonvolatile analytes is 139, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 50 and 36 percent contribution), vanadium (HQ of 12 and 8.8 percent contribution), Cr(VI) (HQ of 7.7 and 5.5 percent contribution), uranium (HQ of 6.6 and 4.7 percent contribution), nickel (HQ of 3.7, and 2.6 percent contribution), barium (HQ of 3.2 and 2.3 percent contribution), and fluoride (HQ of 2.9 and 2.1 percent contribution). Contribution to noncancer HI is elevated for arsenic (HI of 53 and 38 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 1.0, which is equal to the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1.

G1.2.2.11 200-BP-5 Near-River Exposure Area

The total cumulative ELCR for the 200-BP-5 near-river exposure area *with* contributions from aerosolized nonvolatile analytes is 6.2×10^{-2}. The total ELCR for the 200-BP-5 near-river exposure area *with* contributions from aerosolized nonvolatile analytes is 3.2×10^{-2} for nonradiological analytes and 7.5×10^{-4} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is Cr(VI) (3.1×10^{-2} and 95 percent contribution). Contribution to ELCR is elevated for arsenic (8.5×10^{-4} and 2.6 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the 200-BP-5 near-river exposure area *without* contributions from aerosolized nonvolatile analytes is 1.7×10^{-4}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 1.3×10^{-5} for nonradiological analytes and 1.3×10^{-4} for radiological analytes. The nonradiological ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6} and the radiological ELCR is greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (1.3×10^{-4} and 91 percent contribution), trichloroethene (2.7×10^{-6} and 1.9 percent contribution), and chloroform (1.6×10^{-6} and 1.1 percent contribution). Contribution to ELCR is elevated for arsenic (8.5×10^{-6} and 5.9 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 near-river exposure area *with* contributions from aerosolized nonvolatile analytes is 56, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 18 and 32 percent contribution), vanadium (HQ of 9.1 and 16 percent contribution), Cr(VI) (HQ of 4.1 and 7.3 percent contribution), uranium (HQ of 3.6 and 6.5 percent contribution), barium (HQ of 3.6 and 6.4 percent contribution), cobalt (HQ of 1.4 and 2.6 percent contribution), and fluoride (HQ of 1.1 and 2.1 percent contribution). Contribution to noncancer HI is elevated for arsenic (HQ of 13 and 23 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 0.9, which is less than the EPA target HI of 1. All individual analytes that contribute greater than 1 percent of the HI also report an HQ less than 1.

G1.2.2.12 200-BP-5 Confined Exposure Area

The total cumulative ELCR for the 200-BP-5 confined exposure area *with* contributions from aerosolized nonvolatile analytes is 3.4×10^{-2}. The total ELCR for the 200-BP-5 confined exposure area *with* contributions from aerosolized nonvolatile analytes is 3.3×10^{-2} for nonradiological analytes and 1.2×10^{-3} for radiological analytes, both of which are greater than the EPA upper target risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are Cr(VI) (3.2×10^{-2} and 92 percent contribution), cobalt (4.8×10^{-4} and 1.4 percent contribution), and uranium-234 (4.8×10^{-4} and 1.4 percent contribution). Contribution to ELCR is elevated for arsenic (8.2×10^{-4} and 2.4 percent contribution), where measured concentrations are within natural background values.

The total cumulative ELCR for the 200-BP-5 confined exposure area *without* contributions from aerosolized nonvolatile analytes is 5.5×10^{-5}. The total ELCR *without* contributions from aerosolized nonvolatile analytes is 3.7×10^{-5} for nonradiological analytes and 1.8×10^{-5} for radiological analytes, both of which are within the EPA range of 1×10^{-4} to 1×10^{-6}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are tritium (1.8×10^{-5} and 33 percent contribution), chloroform (1.1×10^{-5} and 20 percent contribution), benzene (7.1×10^{-6} and 13 percent contribution), carbon tetrachloride (5.0×10^{-6} and 9.1 percent contribution), tributyl phosphate (3.1×10^{-6} and 5.7 percent contribution), and BEHP (2.4×10^{-6} and 4.3 percent contribution). Contribution to ELCR is elevated for arsenic (8.2×10^{-6} and 15 percent contribution), where measured concentrations are within natural background values.

The HI for the 200-BP-5 confined exposure area *with* contributions from aerosolized nonvolatile analytes is 142, which is greater than the EPA target HI of 1. The primary contributors to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) are manganese (HQ of 80 and 56 percent contribution), barium (HQ of 11 and 8 percent contribution), cobalt (HQ of 8.9 and 6.3 percent contribution), vanadium (HQ of 7.1 and 5 percent contribution), nickel (HQ of 5.4 and 3.8 percent contribution), uranium (HQ of 5.1 and 3.6 percent contribution), cyanide (HQ of 4.3 and 3.1 percent contribution), and Cr(VI) (HQ of 4.1 and 2.9 percent contribution). Contribution to noncancer HI is elevated for arsenic (HI of 13 and 8.9 percent contribution), where measured concentrations are within natural background values.

The HI *without* contributions from aerosolized nonvolatile analytes is 6.4, which is greater than the EPA target HI of 1. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) is cyanide (HQ of 4.3 and 68 percent contribution). The remaining individual analytes that contribute greater than 1 percent of the HI but report an HQ less than 1 are Cr(VI), vanadium, manganese, and silver. Contribution to HI is elevated for antimony (HQ of 1.3 and 20 percent contribution) where measured concentrations reflect false-positive results from the use of EPA Method 6010.

G1.3 Comparison of Native American and EPA Tap Water Risk Characterization Results

Summaries of the 200-BP-5 OU risk estimates and HIs for each of the Native American scenarios and the EPA tap water scenario are provided in Table G-6. Results are provided for ingestion, dermal contact, and inhalation of volatiles during household activities.

Exposure parameters for the Native American scenarios and the EPA tap water scenario differ as summarized in Table G-7. As a result, EPA tap water scenario has a lower total ELCR and HI than the Native American scenarios.

Table G-6. Comparison of Exposure Parameters for Native American Exposure Scenarios and EPA Tap Water Scenario

Exposure Parameter	Exposure Scenario					
	CTUIR[a]		Yakama Nation[b]		EPA Tap Water[c]	
	Adult	Child	Adult	Child	Adult	Child
Body weight (kg)	70	15	70	16	80	15
Drinking water ingestion rate (L/d)	4	1	4	2	2.5	0.78
Exposure duration (years)	70	6	70	6	20	6
Inhalation rate (m^3/d)	25	15	26	16	20	10
Exposure frequency (d/yr)	365		365		350	

a. *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (Harris and Harper, 2004) and *Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments* (Harris, 2008)

b. *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment* (Ridolfi, 2007)

c. OSWER Directive 9200.1-120, *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors*; OSWER Directive 9285.6-03, *Risk Assessment Guidance For Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance*; and EPA/600/P-95/002Fa, *Exposure Factors Handbook Volume 1: General Factors*.

CTUIR = Confederated Tribes of the Umatilla Indian Reservation

EPA = U.S. Environmental Protection Agency

G1.3.1 Low-Level Management Area 1 Exposure Area

For the LLWMA-1 exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 1.5×10^{-3} and 1.6×10^{-3}, respectively. The total cumulative ELCR for the EPA tap water scenario is 3.2×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). The primary contributor to risk for the Native American scenarios and the EPA tap water scenario is technetium-99. Tritium is also a primary contributor to risk for the Native American scenarios.

The total HI is 111 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 96. Cyanide is the primary contributor to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario. Nitrate is also a primary contributor to the noncancer HI for the Native American scenarios.

G1.3.2 Low-Level Waste Management Area 2 and 216-B-63 Trench Exposure Area

For the LLWMA-2 and 216-B-63 Trench exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 9.8×10^{-4} and 1.1×10^{-3}, respectively. The total cumulative ELCR for the EPA tap water scenario is 2.1×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). The primary

contributor to risk for the Native American scenarios is technetium-99. There are no primary contributors to risk for the EPA tap water scenario.

The total HI is 54 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 44. Cyanide is the primary contributor to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario.

G1.3.3 Waste Management Area B-BX-BY Tank Farms Exposure Area

For the WMA B-BY-BY Tank Farms exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 1.5×10^{-2} and 1.6×10^{-2}, respectively. The total cumulative ELCR for the EPA tap water scenario is 3.2×10^{-3}. All scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Primary contributors to risk for the Native American scenarios and the EPA tap water scenario are technetium-99, uranium-234, and uranium-238. Uranium-235 and tritium are also primary contributors to risk for the Native American scenarios.

The total HI is 255 for both the CTUIR scenario and the Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 221. Cyanide, uranium, and nitrate are the primary contributors to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario.

G1.3.4 Waste Management Area C Tank Farm Exposure Area

For the WMA C Tank Farm exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 2.2×10^{-3} and 2.3×10^{-3}, respectively. The total cumulative ELCR for the EPA tap water scenario is 4.6×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Technetium-99 is the primary contributor to risk for the Native American scenarios and the EPA tap water scenario.

The total HI is 16 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 10. Cyanide is the primary contributor to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario.

G1.3.5 B Plant Exposure Area

For the B Plant exposure area, the total cumulative ELCR is 1.2×10^{-2} for both the CTUIR and Yakama Nation exposure scenarios. The total cumulative ELCR for the EPA tap water scenario is 2.3×10^{-3}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Primary contributors to risk for the Native American scenarios and the EPA tap water scenario are strontium-90 and cesium-137. Plutonium-239/240 and technetium-99 are also primary contributors to risk for the Native American scenarios.

The total HI is 20 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 13. Cyanide is the primary contributor to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario.

G1.3.6 Semiworks Exposure Area

For the Semiworks exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 5.7×10^{-4} and 6.1×10^{-4}, respectively. The total cumulative ELCR for the EPA tap water scenario is 1.3×10^{-4}. All scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Tritium is the primary contributor to risk for the Native American scenarios. There are no primary contributors to risk for the EPA tap water exposure scenario.

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
LLWMA-1 Exposure Area											
CTUIR	Nonradiological	4.2×10^{-4}	24	1.6×10^{-6}	0.26	1.5×10^{-6}	87	4.2×10^{-4}	**Technetium-99 (ELCR = 8.3×10^{-4}; 56%)**	111	**Cyanide (HQ = 100; 90%)**
	Radiological	9.4×10^{-4}	—	—	—	1.3×10^{-4}	—	1.1×10^{-3}	**Tritium (ELCR = 1.6×10^{-4}; 11%)**	—	**Nitrate (HQ = 1.5; 1.3%)**
	Total	1.4×10^{-3}	24	1.6×10^{-6}	0.26	1.3×10^{-4}	87	1.5×10^{-3}	Cobalt-60 (ELCR = 3.9×10^{-5}; 2.6%) Iodine-129 (ELCR = 3.4×10^{-5}; 2.3%)	111	
Yakama Nation	Nonradiological	4.6×10^{-4}	24	1.6×10^{-6}	0.31	1.5×10^{-6}	87	4.6×10^{-4}	**Technetium-99 (ELCR = 8.5×10^{-4}; 55%)**	111	**Cyanide (HQ = 100; 90%)**
	Radiological	9.6×10^{-4}	—	—	—	1.3×10^{-4}	—	1.1×10^{-3}	**Tritium (ELCR = 1.7×10^{-4}; 11%)**	—	**Nitrate (HQ = 1.5; 1.3%)**
	Total	1.4×10^{-3}	24	1.6×10^{-6}	0.31	1.3×10^{-4}	87	1.6×10^{-3}	Cobalt-60 (ELCR = 4.0×10^{-5}; 2.6%) Iodine-129 (ELCR = 3.4×10^{-5}; 2.2%)	111	
EPA tap water	Nonradiological	9.3×10^{-5}	13	5.4×10^{-7}	0.26	5.3×10^{-7}	84	9.4×10^{-5}	**Technetium-99 (ELCR = 1.7×10^{-4}; 53%)**	96	**Cyanide (HQ = 90; 94%)**
	Radiological	1.9×10^{-4}	—	—	—	3.4×10^{-5}	—	2.2×10^{-4}	Tritium (ELCR = 4.1×10^{-5}; 13%) Cobalt-60 (ELCR = 7.8×10^{-6}; 2.5%)	—	
	Total	2.8×10^{-4}	13	5.4×10^{-7}	0.26	3.5×10^{-5}	84	3.2×10^{-4}	Iodine-129 (ELCR = 6.7×10^{-6}; 2.1%)	96	
LLWMA-2 and 216-B-63 Trench Exposure Area											
CTUIR	Nonradiological	7.4×10^{-4}	18	2.7×10^{-6}	0.33	—	36	7.4×10^{-4}	**Technetium-99 (ELCR = 2.1×10^{-4}; 21%)**	54	**Cyanide (HQ = 41; 77%)**
	Radiological	2.3×10^{-4}	—	—	—	9.9×10^{-6}	—	2.4×10^{-4}	Iodine-129 (ELCR = 2.0×10^{-5}; 2.0%) Tritium (ELCR = 1.3×10^{-5}; 1.3%)	—	
	Total	9.7×10^{-4}	18	2.7×10^{-6}	0.33	9.9×10^{-6}	36	9.8×10^{-4}		54	
Yakama Nation	Nonradiological	8.0×10^{-4}	18	2.7×10^{-6}	0.35	—	36	8.1×10^{-4}	**Technetium-99 (ELCR = 2.2×10^{-4}; 20%)**	54	**Cyanide (HQ = 41; 77%)**
	Radiological	2.4×10^{-4}	—	—	—	1.0×10^{-5}	—	2.5×10^{-4}	Iodine-129 (ELCR = 2.0×10^{-5}; 1.9%) Tritium (ELCR = 1.3×10^{-5}; 1.2%)	—	
	Total	1.0×10^{-3}	18	2.7×10^{-6}	0.35	1.0×10^{-5}	36	1.1×10^{-3}		54	
EPA tap water	Nonradiological	1.6×10^{-4}	9.3	9.1×10^{-7}	0.29	--	34	1.6×10^{-4}	Technetium-99 (ELCR = 4.2×10^{-5}; 20%) Iodine-129 (ELCR = 3.9×10^{-6}; 1.8%) Tritium (ELCR = 3.1×10^{-6}; 1.5%)	44	**Cyanide (HQ = 37; 85%)**
	Radiological	4.7×10^{-5}	—	—	—	2.6×10^{-6}	—	4.9×10^{-5}		—	
	Total	2.1×10^{-4}	9.3	9.1×10^{-7}	0.29	2.6×10^{-6}	34	2.1×10^{-4}		44	
WMA B-BX-BY Tank Farms Exposure Area											
CTUIR	Nonradiological	4.2×10^{-3}	54	3.7×10^{-5}	0.46	2.7×10^{-5}	200	4.2×10^{-3}	**Uranium-234 (ELCR = 4.0×10^{-3}; 26%)**	255	**Cyanide (HQ = 230; 90%)**
	Radiological	1.1×10^{-2}	—	—	—	2.0×10^{-4}	—	1.1×10^{-2}	**Uranium-238 (ELCR = 3.6×10^{-3}; 23%)**	—	**Uranium (HQ = 8.1; 3.2%)**
	Total	1.5×10^{-2}	54	3.7×10^{-5}	0.46	2.3×10^{-4}	200	1.5×10^{-2}	**Technetium-99 (ELCR = 3.0×10^{-3}; 19%)** **Tritium (ELCR = 2.5×10^{-4}; 1.6%)** **Uranium-235 (ELCR = 1.8×10^{-4}; 1.2%)**	255	**Nitrate (HQ = 4.8; 1.9%)**
Yakama Nation	Nonradiological	4.5×10^{-3}	54	3.7×10^{-5}	0.57	2.7×10^{-5}	200	4.6×10^{-3}	**Uranium-234 (ELCR = 4.1×10^{-3}, 26%)**	255	**Cyanide (HQ = 230, 90%)**
	Radiological	1.1×10^{-2}	—	—	—	2.1×10^{-4}	—	1.1×10^{-2}	**Uranium-238 (ELCR = 3.7×10^{-3}, 23%)**	—	**Uranium (HQ = 8.1, 3.2%)**
	Total	1.6×10^{-2}	54	3.7×10^{-5}	0.57	2.4×10^{-4}	200	1.6×10^{-2}	**Technetium-99 (ELCR = 3.1×10^{-3}, 19%)** **Tritium (ELCR = 2.6×10^{-4}, 1.6%)** **Uranium-235 (ELCR = 1.8×10^{-4}, 1.1%)**	255	**Nitrate (HQ = 4.8, 1.9%)**

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
EPA tap water	Nonradiological	9.2×10^{-4}	29	1.3×10^{-5}	0.48	9.5×10^{-6}	192	9.4×10^{-4}	**Uranium-234 (ELCR = 8.1×10^{-4}; 25%)** **Uranium-238 (ELCR = 7.2×10^{-4}; 22%)** **Technetium-99 (ELCR = 6.0×10^{-4}; 19%)** Tritium (ELCR = 6.3×10^{-5}; 2.0%) Uranium-235 (ELCR = 3.6×10^{-5}; 1.1%)	221	**Cyanide (HQ = 208; 94%)** **Uranium (HQ = 4.2; 1.9%)** **Nitrate (HQ = 2.5; 1.2%)**
	Radiological	2.2×10^{-3}	—	—	—	5.2×10^{-5}	—	2.3×10^{-3}		—	
	Total	3.1×10^{-3}	29	1.3×10^{-5}	0.48	6.2×10^{-5}	192	3.2×10^{-3}		221	
WMA C Tank Farm Exposure Area											
CTUIR	Nonradiological	5.8×10^{-4}	11	3.0×10^{-6}	0.28	5.5×10^{-6}	4.3	5.8×10^{-4}	**Technetium-99 (ELCR = 1.6×10^{-3}; 70%)** Iodine-129 (ELCR = 6.5×10^{-5}; 2.9%) Tritium (ELCR = 2.4×10^{-5}; 1.1%)	16	**Cyanide (HQ = 4.9; 31%)** Cobalt (HQ = 0.76; 4.9%) Cadmium (HQ = 0.49; 3.1%) Nitrate (HQ = 0.36; 2.3%) Vanadium (HQ = 0.22; 1.4%)
	Radiological	1.6×10^{-3}	—	—	—	1.9×10^{-5}	—	1.7×10^{-3}		—	
	Total	2.2×10^{-3}	11	3.0×10^{-6}	0.28	2.5×10^{-5}	4.3	2.2×10^{-3}		16	
Yakama Nation	Nonradiological	6.2×10^{-4}	11	3.0×10^{-6}	0.28	5.5×10^{-6}	4.3	6.3×10^{-4}	**Technetium-99 (ELCR = 1.6×10^{-3}; 69%)** Iodine-129 (ELCR = 6.6×10^{-5}; 2.8%) Tritium (ELCR = 2.5×10^{-5}; 1.1%)	16	**Cyanide (HQ = 4.9; 31%)** Cobalt (HQ = 0.76; 4.9%) Cadmium (HQ = 0.49; 3.1%) Nitrate (HQ = 0.36; 2.3%) Vanadium (HQ = 0.22; 1.4%)
	Radiological	1.7×10^{-3}	—	—	—	1.9×10^{-5}	—	1.7×10^{-3}		—	
	Total	2.3×10^{-3}	11	3.0×10^{-6}	0.28	2.5×10^{-5}	4.3	2.3×10^{-3}		16	
EPA tap water	Nonradiological	1.3×10^{-4}	5.8	1.0×10^{-6}	0.23	2.0×10^{-6}	4.1	1.3×10^{-4}	**Technetium-99 (ELCR = 3.1×10^{-4}; 68%)** Iodine-129 (ELCR = 1.3×10^{-5}; 2.8%) Tritium (ELCR = 5.9×10^{-6}; 1.3%)	10	**Cyanide (HQ = 4.4; 43%)** Cobalt (HQ = 0.40; 3.9%) Cadmium (HQ = 0.27; 2.6%) Nitrate (HQ = 0.19; 1.9%) Vanadium (HQ = 0.13; 1.2%)
	Radiological	3.3×10^{-4}	—	—	—	4.9×10^{-6}	—	3.3×10^{-4}		—	
	Total	4.6×10^{-4}	5.8	1.0×10^{-6}	0.23	6.9×10^{-6}	4.1	4.6×10^{-4}		10	
B Plant Exposure Area											
CTUIR	Nonradiological	3.9×10^{-4}	16	1.5×10^{-6}	0.39	—	4.3	4.0×10^{-4}	**Strontium-90 (ELCR = 6.0×10^{-3}; 52%)** **Cesium-137 (ELCR = 4.0×10^{-3}; 35%)** **Plutonium-239/240 (ELCR = 3.9×10^{-4}; 3.4%)** **Technetium-99 (ELCR = 3.7×10^{-4}; 3.2%)**	20	**Cyanide (HQ = 5.0, 24%)** Fluoride (HQ = 0.85; 4.2%) Nitrate (HQ = 0.70; 3.4%) Cadmium (HQ = 0.63; 3.1%) Uranium (HQ = 0.44; 2.2%) Vanadium (HQ = 0.23; 1.2%)
	Radiological	1.1×10^{-2}	—	—	—	9.1×10^{-5}	—	1.1×10^{-2}		—	
	Total	1.1×10^{-2}	16	1.5×10^{-6}	0.39	9.1×10^{-5}	4.3	1.2×10^{-2}		20	
Yakama Nation	Nonradiological	4.3×10^{-4}	16	1.5×10^{-6}	0.39	—	4.3	4.3×10^{-4}	**Strontium-90 (ELCR = 6.2×10^{-3}; 52%)** **Cesium-137 (ELCR = 4.1×10^{-3}; 35%)** **Plutonium-239/240 (ELCR = 4.0×10^{-4}; 3.4%)** **Technetium-99 (ELCR = 3.8×10^{-4}; 3.2%)**	20	**Cyanide (HQ = 5.0; 24%)** Fluoride (HQ = 0.85; 4.2%) Nitrate (HQ = 0.70; 3.4%) Cadmium (HQ = 0.63; 3.1%) Uranium (HQ = 0.44; 2.2%) Vanadium (HQ = 0.23; 1.2%)
	Radiological	1.1×10^{-2}	—	—	—	9.5×10^{-5}	—	1.1×10^{-2}		—	
	Total	1.1×10^{-2}	16	1.5×10^{-6}	0.39	9.5×10^{-5}	4.3	1.2×10^{-2}		20	

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
EPA tap water	Nonradiological	8.7×10^{-5}	8.2	4.9×10^{-7}	0.33	--	4.1	8.8×10^{-5}	**Strontium-90 (ELCR = 1.2×10^{-3}; 52%)**	13	**Cyanide (HQ = 4.5; 35%)**
	Radiological	2.2×10^{-3}	—	—	—	2.4×10^{-5}	—	2.2×10^{-3}	**Cesium-137 (ELCR = 8.1×10^{-4}; 35%)**	—	Fluoride (HQ = 0.45; 3.5%)
	Total	2.3×10^{-3}	8.2	4.9×10^{-7}	0.33	2.4×10^{-5}	4.1	2.3×10^{-3}	Plutonium-239/240 (ELCR = 7.8×10^{-5}; 3.4%) Technetium-99 (ELCR = 7.4×10^{-5}; 3.2%) Tritium (ELCR = 2.9×10^{-5}; 1.2%)	13	Cadmium (HQ = 0.34; 2.7%) Nitrate (HQ = 0.37; 2.9%) Uranium (HQ = 0.23; 1.8%)
Semiworks Exposure Area											
CTUIR	Nonradiological	3.5×10^{-4}	1.9	1.3×10^{-6}	0.06	—	—	3.5×10^{-4}	**Tritium (ELCR = 1.7×10^{-4}; 29%)** Iodine-129 (ELCR = 2.6×10^{-5}; 4.5%) Technetium-99 (ELCR = 1.6×10^{-5}; 2.8%) Strontium-90 (ELCR = 1.5×10^{-5}; 2.6%)	1.9	Nitrate (HQ = 0.33; 17%) Fluoride (HQ = 0.20; 10%) Vanadium (HQ = 0.16; 8.4%) Cr(VI) (HQ = 0.13; 6.8%) Uranium (HQ = 0.12; 6.0%) Selenium (HQ = 0.07; 3.5%) Molybdenum (HQ = 0.04; 2.1%) Nitrite (HQ = 0.04; 2.0%) Strontium (HQ = 0.04; 1.8%) Barium (HQ = 0.02; 1.3%)
	Radiological	9.5×10^{-5}	—	—	—	1.3×10^{-4}	—	2.2×10^{-4}		—	
	Total	4.4×10^{-4}	1.9	1.3×10^{-6}	0.06	1.3×10^{-4}	—	5.7×10^{-4}		1.9	
Yakama Nation	Nonradiological	3.8×10^{-4}	1.9	1.3×10^{-6}	0.06	—	—	3.8×10^{-4}	**Tritium (ELCR = 1.7×10^{-4}; 28%)** Iodine-129 (ELCR = 2.6×10^{-5}; 4.3%) Technetium-99 (ELCR = 1.7×10^{-5}; 2.7%) Strontium-90 (ELCR = 1.5×10^{-5}; 2.5%)	1.9	Nitrate (HQ = 0.33; 17%) Fluoride (HQ = 0.20; 10%) Vanadium (HQ = 0.16; 8.4%) Cr(VI) (HQ = 0.13; 6.8%) Uranium (HQ = 0.12; 6.0%) Selenium (HQ = 0.07; 3.5%) Molybdenum (HQ = 0.04; 2.1%) Nitrite (HQ = 0.04; 2.0%) Strontium (HQ = 0.04; 1.8%) Barium (HQ = 0.02; 1.3%)
	Radiological	9.7×10^{-5}	—	—	—	1.4×10^{-4}	—	2.3×10^{-4}		—	
	Total	4.8×10^{-4}	1.9	1.3×10^{-6}	0.06	1.4×10^{-4}	—	6.1×10^{-4}		1.9	
EPA tap water	Nonradiological	7.7×10^{-5}	0.99	4.3×10^{-7}	0.049	--	—	7.7×10^{-5}	Tritium (ELCR = 4.1×10^{-5}; 32%) Iodine-129 (ELCR = 5.2×10^{-6}; 4.0%) Strontium-90 (ELCR = 3.0×10^{-6}; 2.3%) Technetium-99 (ELCR = 3.3×10^{-6}; 2.5%)	1.0	—
	Radiological	1.9×10^{-5}	—	—	—	3.4×10^{-5}	—	5.3×10^{-5}		—	
	Total	9.6×10^{-5}	0.99	4.3×10^{-7}	0.049	3.4×10^{-5}	—	1.3×10^{-4}		1.0	

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
LERF Exposure Area											
CTUIR	Nonradiological	4.0×10^{-4}	2.1	3.1×10^{-6}	0.09	6.9×10^{-6}	0.01	4.1×10^{-4}	CTET (ELCR = 1.8×10^{-5}; 4.2%) Tritium (ELCR = 1.4×10^{-5}; 3.3%) Iodine-129 (ELCR = 4.5×10^{-6}; 1.1%)	2.2	Nitrate (HQ = 0.34; 15%) Fluoride (HQ = 0.24; 11%) Vanadium (HQ = 0.23; 10%) Cr(VI) (HQ = 0.16; 7.3%) Silver (HQ = 0.09; 4.1%) Nitrite (HQ = 0.06; 2.8%) Strontium (HQ = 0.05; 2.4%) CTET (HQ = 0.05; 2.3%) Antimony (HQ = 0.05; 2.1%) Nickel (HQ = 0.03; 1.4%) Manganese (HQ = 0.03; 1.1%)
	Radiological	7.5×10^{-6}	—	—	—	1.1×10^{-5}	—	1.8×10^{-5}		—	
	Total	4.1×10^{-4}	2.1	3.1×10^{-6}	0.09	1.8×10^{-5}	0.01	4.2×10^{-4}		2.2	
Yakama Nation	Nonradiological	4.3×10^{-4}	2.1	3.0×10^{-6}	0.09	6.9×10^{-6}	0.01	4.4×10^{-4}	CTET (ELCR = 1.9×10^{-5}; 4.1%) Tritium (ELCR = 1.5×10^{-5}; 3.2%)	2.2	Nitrate (HQ = 0.34; 15%) Fluoride (HQ = 0.24; 11%) Vanadium (HQ = 0.23; 10%) Cr(VI) (HQ = 0.16; 7.3%) Silver (HQ = 0.09; 4.1%) Nitrite (HQ = 0.06; 2.8%) Strontium (HQ = 0.05; 2.4%) CTET (HQ = 0.05; 2.3%) Antimony (HQ = 0.05; 2.1%) Nickel (HQ = 0.03; 1.4%) Manganese (HQ = 0.03; 1.1%)
	Radiological	7.7×10^{-6}	—	—	—	1.1×10^{-5}	—	1.9×10^{-5}		--	
	Total	4.4×10^{-4}	2.1	3.0×10^{-6}	0.09	1.8×10^{-5}	0.01	4.6×10^{-4}		2.2	
EPA tap water	Nonradiological	8.8×10^{-5}	1.1	1.0×10^{-6}	0.074	2.5×10^{-6}	0.011	9.1×10^{-5}	CTET (ELCR = 5.1×10^{-6}; 5.3%) Tritium (ELCR = 3.5×10^{-6}; 3.6%)	1.2	Nitrate (HQ = 0.18; 15%) Vanadium (HQ = 0.13; 11%) Fluoride (HQ = 0.13; 10%) Cr(VI) (HQ = 0.097; 8.1%) Silver (HQ = 0.049; 4.1%) CTET (HQ = 0.033; 2.8%) Nitrite (HQ = 0.032; 2.7%) Strontium (HQ = 0.029; 2.4%) Nickel (HQ = 0.017; 1.4%) Manganese (HQ = 0.014; 1.2%)
	Radiological	1.5×10^{-6}	—	—	—	2.9×10^{-6}	—	4.4×10^{-6}		—	
	Total	9.0×10^{-5}	1.1	1.0×10^{-6}	0.074	5.4×10^{-6}	0.011	9.5×10^{-5}		1.2	

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
Gable Mountain Pond Exposure Area											
CTUIR	Nonradiological	4.1×10^{-4}	13	1.5×10^{-6}	0.33	—	—	4.1×10^{-4}	**Strontium-90 (ELCR = 1.1×10^{-3}; 71%)** Tritium (ELCR = 7.1×10^{-5}; 4.4%)	13	Nitrate (HQ = 0.76; 5.8%) Iron (HQ = 0.25; 1.9%) Manganese (HQ = 0.24; 1.8%)
	Radiological	1.2×10^{-3}	—	—	—	5.5×10^{-5}	—	1.2×10^{-3}		—	
	Total	1.6×10^{-3}	13	1.5×10^{-6}	0.33	5.5×10^{-5}	—	1.6×10^{-3}		13	
Yakama Nation	Nonradiological	4.4×10^{-4}	13	1.5×10^{-6}	0.33	—	—	4.4×10^{-4}	**Strontium-90 (ELCR = 1.2×10^{-3}; 69%)** Tritium (ELCR = 7.4×10^{-5}; 4.4%)	13	Nitrate (HQ = 0.76; 5.8%) Iron (HQ = 0.25; 1.9%) Manganese (HQ = 0.24; 1.8%)
	Radiological	1.2×10^{-3}	—	—	—	5.8×10^{-5}	—	1.2×10^{-3}		—	
	Total	1.6×10^{-3}	13	1.5×10^{-6}	0.33	5.8×10^{-5}	—	1.7×10^{-3}		13	
EPA tap water	Nonradiological	9.0×10^{-5}	6.8	5.0×10^{-7}	0.27	--	—	9.0×10^{-5}	**Strontium-90 (ELCR = 2.3×10^{-4}; 68%)** Tritium (ELCR = 1.8×10^{-5}; 5.2%)	7.0	Nitrate (HQ = 0.40; 5.7%) Iron (HQ = 0.13; 1.9%) Manganese (HQ = 0.13; 1.9%) Cr(VI) (HQ = 0.078; 1.1%)
	Radiological	2.3×10^{-4}	—	—	—	1.4×10^{-5}	—	2.5×10^{-4}		—	
	Total	3.23×10^{-4}	6.8	5.0×10^{-7}	0.27	1.4×10^{-5}	—	3.4×10^{-4}		7.0	
200-BP-5 West Exposure Area											
CTUIR	Nonradiological	5.4×10^{-4}	21	5.8×10^{-6}	0.36	1.5×10^{-5}	45	5.6×10^{-4}	**Technetium-99 (ELCR = 4.5×10^{-4}; 28%)** **Strontium-90 (ELCR = 4.4×10^{-4}; 27%)** **Tritium (ELCR = 1.5×10^{-4}; 9.1%)** CTET (ELCR = 2.0×10^{-5}; 1.2%)	66	**Cyanide (HQ = 52; 78%)** Nitrate (HQ = 0.70; 1.1%)
	Radiological	9.6×10^{-4}	—	—	—	1.2×10^{-4}	—	1.1×10^{-3}		—	
	Total	1.5×10^{-3}	21	5.8×10^{-6}	0.36	1.4×10^{-4}	45	1.6×10^{-3}		66	
Yakama Nation	Nonradiological	5.9×10^{-4}	21	5.8×10^{-6}	0.38	1.5×10^{-5}	45	6.1×10^{-4}	**Technetium-99 (ELCR = 4.6×10^{-4}; 27%)** **Strontium-90 (ELCR = 4.5×10^{-4}; 26%)** **Tritium (ELCR = 1.5×10^{-4}; 9.0%)** CTET (ELCR = 2.0×10^{-5}; 1.2%)	66	**Cyanide (HQ = 52; 78%)** Nitrate (HQ = 0.70; 1.1%)
	Radiological	9.8×10^{-4}	—	—	—	1.2×10^{-4}	—	1.1×10^{-3}		—	
	Total	1.6×10^{-3}	21	5.8×10^{-6}	0.38	1.4×10^{-4}	45	1.7×10^{-3}		66	
EPA tap water	Nonradiological	1.2×10^{-4}	11	2.0×10^{-6}	0.32	5.4×10^{-6}	43	1.3×10^{-4}	Technetium-99 (ELCR = 9.0×10^{-5}; 26%) Strontium-90 (ELCR = 8.8×10^{-5}; 25%) Tritium (ELCR = 3.7×10^{-5}; 11%) CTET (ELCR = 5.6×10^{-6}; 1.6%)	54	**Cyanide (HQ = 46; 86%)**
	Radiological	1.9×10^{-4}	—	—	—	3.0×10^{-5}	—	2.2×10^{-4}		—	
	Total	3.1×10^{-4}	11	2.0×10^{-6}	0.32	3.5×10^{-5}	43	3.5×10^{-4}		54	

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
200-BP-5 Far-Field (North of Gable Gap) Exposure Area											
CTUIR	Nonradiological	1.1×10^{-3}	4.5	4.1×10^{-6}	0.12	—	—	1.1×10^{-3}	**Tritium (ELCR = 2.8×10^{-4}; 20%)** Technetium-99 (ELCR = 3.9×10^{-5}; 2.7%)	4.7	Fluoride (HQ = 0.57; 12%) Cr(VI) (HQ = 0.28; 6.1%) Lithium (HQ = 0.27; 5.8%) Vanadium (HQ = 0.25; 5.4%) Nitrate (HQ = 0.17; 3.6%) Copper (HQ = 0.17; 3.6%) Iron (HQ = 0.11; 2.3%) Manganese (HQ = 0.10; 2.2%) Uranium (HQ = 0.08; 1.7%) Zinc (HQ = 0.07; 1.5%) Molybdenum (HQ = 0.06; 1.3%)
	Radiological	1.1×10^{-4}	—	—	—	2.2×10^{-4}	—	3.3×10^{-4}		—	
	Total	1.2×10^{-3}	4.5	4.1×10^{-6}	0.12	2.2×10^{-4}	—	1.4×10^{-3}		4.7	
Yakama Nation	Nonradiological	1.2×10^{-3}	4.5	4.1×10^{-6}	0.12	—	—	1.2×10^{-3}	**Tritium (ELCR = 2.9×10^{-4}; 19%)** Technetium-99 (ELCR = 4.0×10^{-5}; 2.6%)	4.7	Fluoride (HQ = 0.57; 12%) Cr(VI) (HQ = 0.28; 6.1%) Lithium (HQ = 0.27; 5.8%) Vanadium (HQ = 0.25; 5.4%) Nitrate (HQ = 0.17; 3.6%) Copper (HQ = 0.17; 3.6%) Iron (HQ = 0.11; 2.3%) Manganese (HQ = 0.10; 2.2%) Uranium (HQ = 0.08; 1.7%) Zinc (HQ = 0.07; 1.5%) Molybdenum (HQ = 0.06; 1.3%)
	Radiological	1.1×10^{-4}	—	—	—	2.3×10^{-4}	—	3.4×10^{-4}		—	
	Total	1.3×10^{-3}	4.5	4.1×10^{-6}	0.12	2.3×10^{-4}	—	1.5×10^{-3}		4.7	
EPA tap water	Nonradiological	2.4×10^{-4}	2.4	1.4×10^{-6}	0.10	—	—	2.5×10^{-4}	Tritium (ELCR = 7.0×10^{-5}; 22%) Technetium-99 (ELCR = 7.9×10^{-6}; 2.4%)	2.5	Fluoride (HQ = 0.30; 12%) Cr(VI) (HQ = 0.17; 6.8%) Lithium (HQ = 0.14; 5.7%) Vanadium (HQ = 0.14; 5.7%) Copper (HQ = 0.089; 3.6%) Nitrate (HQ = 0.089; 3.6%) Iron (HQ = 0.057; 2.3%) Manganese (HQ = 0.058; 2.3%) Uranium (HQ = 0.042; 1.7%) Zinc (HQ = 0.037; 1.5%) Molybdenum (HQ = 0.032; 1.3%)
	Radiological	2.2×10^{-5}	—	—	—	5.8×10^{-5}	—	8.0×10^{-5}		—	
	Total	2.6×10^{-4}	2.4	1.4×10^{-6}	0.10	5.8×10^{-5}	—	3.3×10^{-4}		2.5	

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
200-BP-5 Near-River Exposure Area											
CTUIR	Nonradiological	2.8×10^{-4}	2.1	1.6×10^{-6}	0.09	5.9×10^{-6}	0.46	2.9×10^{-4}	**Tritium (ELCR = 2.8×10^{-4}; 44%)** Carbon-14 (ELCR = 4.3×10^{-5}; 6.8%) Technetium-99 (ELCR = 1.6×10^{-5}; 2.5%) TCE (ELCR = 9.2×10^{-6}; 1.4%)	2.7	TCE (HQ = 0.69; 26%) Lithium (HQ = 0.29; 11%) Fluoride (HQ = 0.23; 8.6%) Nitrate (HQ = 0.19; 7.2%) Vanadium (HQ = 0.19; 7.0%) Cr(VI) (HQ = 0.15, 5.7%) Molybdenum (HQ = 0.05; 1.9%) Uranium (HQ = 0.04; 1.7%) Nitrite (HQ = 0.04; 1.6%) Manganese (HQ = 0.04; 1.4%) Zinc (HQ = 0.03; 1.2%)
	Radiological	1.3×10^{-4}	—	—	—	2.2×10^{-4}	—	3.5×10^{-4}		—	
	Total	4.1×10^{-4}	2.1	1.6×10^{-6}	0.09	2.3×10^{-4}	0.46	6.4×10^{-4}		2.7	
Yakama Nation	Nonradiological	3.0×10^{-4}	2.1	1.6×10^{-6}	0.09	5.9×10^{-6}	0.46	3.1×10^{-4}	**Tritium (ELCR = 2.9×10^{-4}; 43%)** Carbon-14 (ELCR = 4.4×10^{-5}; 6.6%) Technetium-99 (ELCR = 1.6×10^{-5}; 2.4%) TCE (ELCR = 9.6×10^{-6}; 1.4%)	2.7	TCE (HQ = 0.69; 26%) Lithium (HQ = 0.29; 11%) Fluoride (HQ = 0.23; 8.6%) Nitrate (HQ = 0.19; 7.2%) Vanadium (HQ = 0.19; 7.0%) Cr(VI) (HQ = 0.15; 5.7%) Molybdenum (HQ = 0.05; 1.9%) Uranium (HQ = 0.04; 1.7%) Nitrite (HQ = 0.04; 1.6%) Manganese (HQ = 0.04; 1.4%) Zinc (HQ = 0.03; 1.2%)
	Radiological	1.4×10^{-4}	—	—	—	2.3×10^{-4}	—	3.6×10^{-4}		—	
	Total	4.4×10^{-4}	2.1	1.6×10^{-6}	0.09	2.4×10^{-4}	0.46	6.7×10^{-4}		2.7	
EPA tap water	Nonradiological	6.2×10^{-5}	1.1	5.3×10^{-7}	0.077	2.1×10^{-6}	0.44	6.4×10^{-5}	Tritium (ELCR = 6.9×10^{-5}; 47%) Carbon-14 (ELCR = 8.7×10^{-6}; 5.9%) Technetium-99 (ELCR = 3.2×10^{-6}; 2.2%) TCE (ELCR = 2.6×10^{-6}; 1.8%)	1.6	TCE (HQ = 0.57; 35%) Lithium (HQ = 0.15; 9.4%) Fluoride (HQ = 0.12; 7.4%) Vanadium (HQ = 0.11; 6.5%) Nitrate (HQ = 0.10; 6.2%) Cr(VI) (HQ = 0.090; 5.5%) Molybdenum (HQ = 0.027; 1.7%) Uranium (HQ = 0.024; 1.5%) Nitrite (HQ = 0.022; 1.4%) Manganese (HQ = 0.021; 1.3%)
	Radiological	2.7×10^{-5}	—	—	—	5.7×10^{-5}	—	8.4×10^{-5}		—	
	Total	8.9×10^{-5}	1.1	5.3×10^{-7}	0.077	5.9×10^{-5}	0.44	1.5×10^{-4}		1.6	

Table G-7. Comparison of 200-BP-5 OU Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations

Exposure Scenario	Analyte Type	Drinking Water Ingestion		Dermal Contact with Water		Inhalation of Volatiles		Total			
		ELCR	HI	ELCR	HI	ELCR	HI	Total Cumulative ELCR	Primary Contributors to Risk	HI	Primary Contributors to HI
200-BP-5 Confined Aquifer Exposure Area											
CTUIR	Nonradiological	2.9×10^{-4}	9.1	6.6×10^{-6}	0.25	3.2×10^{-5}	6.0	3.3×10^{-4}	Technetium-99 (ELCR = 9.3×10^{-5}; 18%) Tritium (ELCR = 3.9×10^{-5}; 7.7%) Benzene (ELCR = 1.9×10^{-5}; 3.6%) CTET (ELCR = 1.8×10^{-5}; 3.5%) Chloroform (ELCR = 1.7×10^{-5}; 3.4%) Iodine-129 (ELCR = 1.3×10^{-5}; 2.5%) Strontium-90 (ELCR = 1.2×10^{-5}; 2.4%) Uranium-234 (ELCR = 9.0×10^{-6}; 1.8%) Uranium-238 (ELCR = 6.5×10^{-6}; 1.3%) BEHP (ELCR = 6.2×10^{-6}; 1.2%)	15	**Cyanide (HQ = 6.9; 45%)** Silver (HQ = 0.21; 1.3%) Iron (HQ = 0.20; 1.3%) Fluoride (HQ = 0.20; 1.3%) Manganese (HQ = 0.17; 1.1%) Cobalt (HQ = 0.16; 1.1%)
	Radiological	1.5×10^{-4}	—	—	—	3.0×10^{-5}	—	1.8×10^{-4}		—	
	Total	4.4×10^{-4}	9.1	6.6×10^{-6}	0.25	6.2×10^{-5}	6.0	5.1×10^{-4}		15	
Yakama Nation	Nonradiological	3.2×10^{-4}	9.1	6.6×10^{-6}	0.26	3.2×10^{-5}	6.0	3.5×10^{-4}	Technetium-99 (ELCR = 9.5×10^{-5}; 18%) Tritium (ELCR = 4.0×10^{-5}; 7.5%) Benzene (ELCR = 1.9×10^{-5}; 3.6%) CTET (ELCR = 1.9×10^{-5}; 3.5%) Chloroform (ELCR = 1.8×10^{-5}; 3.3%) Iodine-129 (ELCR = 1.3×10^{-5}; 2.4%) Strontium-90 (ELCR = 1.3×10^{-5}; 2.3%) Uranium-234 (ELCR = 9.2×10^{-6}; 1.7%) Uranium-238 (ELCR = 6.6×10^{-6}; 1.2%) BEHP (ELCR = 6.4×10^{-6}; 1.2%)	15	**Cyanide (HQ = 6.9; 45%)** Silver (HQ = 0.21; 1.3%) Iron (HQ = 0.20; 1.3%) Fluoride (HQ = 0.20; 1.3%) Manganese (HQ = 0.17; 1.1%) Cobalt (HQ = 0.16; 1.1%)
	Radiological	1.5×10^{-4}	—	—	—	3.2×10^{-5}	—	1.8×10^{-4}		—	
	Total	4.7×10^{-4}	9.1	6.6×10^{-6}	0.26	6.4×10^{-5}	6.0	5.4×10^{-4}		15	
EPA tap water	Nonradiological	6.5×10^{-5}	4.8	2.2×10^{-6}	0.22	1.1×10^{-5}	5.8	7.8×10^{-5}	Technetium-99 (ELCR = 1.9×10^{-5}; 16%) Tritium (ELCR = 9.7×10^{-6}; 8.3%) Chloroform (ELCR = 5.9×10^{-6}; 5.1%) Benzene (ELCR = 5.5×10^{-6}; 4.8%) CTET (ELCR = 5.1×10^{-6}; 4.4%) Iodine-129 (ELCR = 2.5×10^{-6}; 2.2%) Strontium-90 (ELCR = 2.5×10^{-6}; 2.1%) Uranium-234 (ELCR = 1.8×10^{-6}; 1.6%) BEHP (ELCR = 1.7×10^{-6}; 1.5%) Uranium-238 (ELCR = 1.3×10^{-6}; 1.1%)	11	**Cyanide (HQ = 6.2; 58%)**
	Radiological	3.0×10^{-5}	—	—	—	8.0×10^{-6}	—	3.8×10^{-5}		—	
	Total	9.5×10^{-5}	4.8	2.2×10^{-6}	0.22	1.9×10^{-5}	5.8	1.2×10^{-4}		11	

Note: **Bold** analytes indicate that the individual ELCR is greater than 1×10^{-4} or has an HQ greater than 1.

BEHP = bis(2-ethylhexyl) phthalate
Cr(VI) = hexavalent chromium
CTET = carbon tetrachloride
CTUIR = Confederated Tribes of the Umatilla Indian Reservation
ELCR = excess lifetime cancer risk
EPA = U.S. Environmental Protection Agency
HI = hazard index
HQ = hazard quotient
LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
TCE = trichloroethene
WMA = waste management area

The total HI is 1.9 for both the CTUIR scenario and the Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 1.0. There are no primary contributors to noncancer HI for the Native American scenarios and EPA tap water exposure scenario.

G1.3.7 Liquid Effluent Retention Facility Exposure Area

For the LERF exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 4.2×10^{-4} and 4.6×10^{-4}, respectively. The total cumulative ELCR for the EPA tap water scenario is 9.5×10^{-5}. Both Native American scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7) and the EPA tap water scenario ELCR is within the EPA range of 1×10^{-4} to 1×10^{-6}. There are no primary contributors to risk for the Native American scenarios and the EPA tap water scenario.

The total HI is 2.2 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 1.2. There are no primary contributors to noncancer HI for the Native American scenarios and EPA tap water exposure scenario.

G1.3.8 Gable Mountain Pond Exposure Area

For the Gable Mountain Pond exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 1.6×10^{-3} and 1.7×10^{-3}, respectively. The total cumulative ELCR for the EPA tap water scenario is 3.4×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Strontium-90 is the primary contributor to risk for the Native American scenarios and the EPA tap water scenario.

The total HI is 13 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 7.0. There are no primary contributors to noncancer HI for the Native American scenarios and EPA tap water exposure scenario.

G1.3.9 200-BP-5 West Exposure Area

For the 200-BP-5 west exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 1.6×10^{-3} and 1.7×10^{-3}, respectively. The total cumulative ELCR for the EPA tap water scenario is 3.5×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Primary contributors to risk for the Native American scenarios are technetium-99, strontium-90, and tritium. There are no primary contributors to risk for the EPA tap water scenario.

The total HI is 66 for the CTUIR scenario and the Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 54. Cyanide is the primary contributor to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario.

G1.3.10 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

For the 200-BP-5 far-field (north of Gable Gap) exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 1.4×10^{-3} and 1.5×10^{-3}, respectively. The total cumulative ELCR for the EPA tap water scenario is 3.3×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Tritium is the primary contributor to risk for the Native American scenarios. There are no primary contributors to risk for the EPA tap water scenario.

The total HI is 4.7 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 2.5. There are no primary contributors to noncancer HI for the Native American scenarios and EPA tap water exposure scenario.

G1.3.11 200-BP-5 Near-River Exposure Area

For the 200-BP-5 near-river exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 6.4×10^{-4} and 6.7×10^{-4}, respectively. The total cumulative ELCR for the EPA tap water scenario is 1.5×10^{-4}. Both Native American scenarios and the EPA tap water scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). Tritium is the primary contributors to risk for the Native American scenarios. There are no primary contributors to risk for the EPA tap water scenario.

The total HI is 2.7 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 1.6. There are no primary contributors to noncancer HI for the Native American scenarios and EPA tap water exposure scenario.

G1.3.12 200-BP-5 Confined Aquifer Exposure Area

For the 200-BP-5 confined aquifer exposure area, the total cumulative ELCRs for the CTUIR and Yakama Nation exposure scenarios are 5.1×10^{-4} and 5.4×10^{-4}, respectively. The total cumulative ELCR for the EPA tap water scenario is 1.2×10^{-4}. All scenario ELCRs are greater than the EPA upper target risk threshold of 1×10^{-4} (Table G-7). There are no primary contributors to risk for the EPA tap water scenario.

The total HI is 15 for both the CTUIR scenario and the Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 11. Cyanide is the primary contributor to the noncancer HI for the Native American scenarios and the EPA tap water exposure scenario.

G2 Uncertainties Associated with the Native American Risk Assessments

The exposure scenarios provided by the CTUIR (Harris and Harper, 2004) and the Yakama Nation (Ridolfi, 2007) represent their traditional activities related to rural land-use patterns involving exposure assumptions that represented subsistence use. Although groundwater within the 200-BP-5 OU is not anticipated to become a source of drinking water, contaminants in groundwater were assessed using the two Native American scenarios to provide estimates of human health risks under the assumption of full-time occupancy in the future. The risks calculated using the Native American scenarios were compared with risks estimated using EPA's standard default assumptions for residential tap water use (i.e., the tap water scenario). The following discussion addresses 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 volatile organic compounds (VOCs) were measured in groundwater and identified as contaminants of potential concern (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. Results from the groundwater risk assessment are presented in Table G-1 through Table G-4. The risks and hazards can be summed to obtain a cumulative estimate of risk and hazard for all groundwater exposure pathways included in the CTUIR and Yakama Nation exposure scenarios.

Exposure parameters for drinking water ingestion, VOC inhalation, and dermal absorption differ between the Native American 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/d [1 gal/d]; EPA tap water, 2.5 L/d [0.66 gal/d]); and inhalation rate (CTUIR, 25 m^3/d [883 ft^3/d], Yakama Nation, 26 m^3/d [918 ft^3/d]; EPA tap water, 20 m^3/d [706 ft^3/d]). 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 ELCRs and HIs for the Native American scenarios may be four- to five-fold greater than for the tap water scenario, drinking water ingestion, VOC inhalation, and dermal absorption exposure pathways. The COPCs are the same between each of the 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 and Yakama Nation resident scenarios. Appendix 4 of the CTUIR exposure scenario (Harris and Harper, 2004) provides equations for estimating air-phase contaminant concentrations for volatile and semivolatile COPCs in the water used to create steam in the lodge, as well as separate equations for 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 200-BP-5 OU is currently contaminated, and withdrawal is prohibited as a result of ICs put in place by DOE (DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA 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.

G3 Additional Supporting Information for the 200-BP-5 Operable Unit Human Health Risk Assessment

Additional supporting information for the 200-BP-5 OU human health risk assessment is provided in Tables G-8 through G-48.

G4 References

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Table G-8. Summary of 200-BP-5 OU Monitoring Wells by Exposure Area

LLWMA-1				
299-E28-26	299-E28-27	299-E28-28[a]	299-E32-10	299-E32-2
299-E32-3	299-E32-4	299-E32-5	299-E32-6	299-E32-7
299-E32-8	299-E32-9	299-E33-265[a]	299-E33-266[a]	299-E33-28
299-E33-29	299-E33-30	299-E33-34[a]	299-E33-35	
LLWMA-2 and 216-B-63 Trench				
299-E27-10[a]	299-E27-11	299-E27-16	299-E27-17	299-E27-18
299-E27-19	299-E27-8	299-E27-9	299-E33-33[a]	299-E33-36
299-E33-37	299-E34-10	299-E34-12	299-E34-2	299-E34-5[c]
299-E34-7[d]	299-E34-8	299-E34-9[a]		
WMA B-BX-BY Tank Farms				
299-E28-8	299-E33-13	299-E33-14	299-E33-15[a]	299-E33-16[a]
299-E33-17[a]	299-E33-18[a]	299-E33-1A[a]	299-E33-2	299-E33-20[a]
299-E33-205[a]	299-E33-21	299-E33-25[b]	299-E33-26	299-E33-3
299-E33-31	299-E33-32	299-E33-334[a]	299-E33-335	299-E33-337[a]
299-E33-338[a]	299-E33-339[a]	299-E33-341[a]	299-E33-342[a]	299-E33-343[a]
299-E33-345[a]	299-E33-38[a]	299-E33-39	299-E33-4[a]	299-E33-41
299-E33-42[a]	299-E33-43	299-E33-44[a]	299-E33-47[a]	299-E33-48[a]
299-E33-49	299-E33-5	299-E33-7	299-E33-9	
WMA C Tank Farm				
299-E27-12	299-E27-13	299-E27-14[a]	299-E27-15[a]	299-E27-155[a]
299-E27-21	299-E27-22	299-E27-23[a]	299-E27-24[a]	299-E27-25
299-E27-4	299-E27-7[a]			
B Plant				
299-E24-25	299-E28-13	299-E28-17	299-E28-18	299-E28-2
299-E28-21	299-E28-23[a]	299-E28-24[a]	299-E28-25[a]	299-E28-30[a]
299-E28-5	299-E28-6	299-E28-7	299E29-54[a]	
Semiworks				
299-E24-25[a]	299-E24-8			

Table G-8. Summary of 200-BP-5 OU Monitoring Wells by Exposure Area

Liquid Effluent Retention Facility				
299-E26-10[a]	299-E26-11	299-E26-77	299-E26-79	
Gable Mountain Pond				
699-53-47A[a]	699-53-47B[a]	699-53-48A	699-54-48	699-54-49
699-55-50C				
200-BP-5 West				
699-47-60	699-48-50B	699-49-55A	699-49-57A[a]	699-50-28B
699-50-56[a]	699-50-59[a]	699-52-55[a]	699-53-55A	699-53-55B[a]
699-53-55C[a]	699-54-45A[a]	699-55-57[a]	699-55-60A	699-57-59
699-59-58	699-60-60			
200-BP-5 Far-Field Area (North of Gable Gap)				
699-61-62	699-61-66	699-62-43F[a]	699-63-55	699-64-62[a]
699-65-50[a]	699-66-58[a]	699-67-51		
200-BP-5 Near-River Area				
199-K-31	699-52-19	699-65-72	699-66-64[a]	699-70-68[a]
699-72-73	699-73-61			
200-BP-5 Confined				
299-E26-8	299-E33-12[a]	299-E33-340	299-E33-40	299-E33-50[a]
699-42-40C	699-45-42	699-49-55B	699-49-57B	699-50-53B
699-52-46A	699-52-55B[a]	699-54-34	699-54-45B	699-56-43
699-56-53				

a. Indicates a location identified for well-specific analysis.
b. Well 299-E33-25 is screened in the unconfined aquifer; however, the last sample collected was on December 4, 2007.
c. Well 299-E34-5 is screened in the unconfined aquifer; however, the last sample collected was on April 11, 2005.
d. Well 299-E34-7 is screened in the unconfined aquifer; however, the last sample collected was on August 11, 2005.
LLWMA = low-level waste management area
WMA = waste management area

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Table G-9. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Basis for Exclusion
1,3-Dichlorobenzene	VOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
1,4-Naphthoquinone	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	2.3	—	—	No toxicity value
1-Naphthylamine	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	1.0	2.0	—	—	No toxicity value
1-Propanol	SVOC	9/19/2010	1/7/2011	2	0	0	µg/L	2,000	2,000	—	—	No toxicity value
2,6-Dichlorophenol	VOC	1/2/2008	11/21/2013	331	0	0	µg/L	0.57	2.1	—	—	No toxicity value
2-Nitrophenol	SVOC	1/2/2008	12/17/2013	413	1	0.24	µg/L	0.47	2.3	0.77	0.77	No toxicity value
2-Picoline	SVOC	1/9/2008	11/21/2013	223	0	0	µg/L	0.90	5.5	—	—	No toxicity value
3+4 Methylphenol (cresol, m+p)	SVOC	1/2/2008	11/21/2013	392	0	0	µg/L	0.47	2.2	—	—	No toxicity value
4-Bromophenylphenyl ether	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
4-Chlorophenylphenyl ether	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
4-Nitrophenol	VOC	1/2/2008	11/21/2013	395	0	0	µg/L	0.60	5.0	—	—	No toxicity value
4-Nitroquinoline-1-oxide	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	5.0	—	—	No toxicity value
Acenaphthylene	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.40	1.0	—	—	No toxicity value
Acetonitrile	VOC	4/2/2008	4/3/2013	191	0	0	µg/L	2.0	4.2	—	—	No toxicity value
Alkalinity	GEN CHEM	1/2/2008	12/23/2013	1,483	1,483	100	µg/L	—	—	31,000	590,000	No toxicity value
alpha,alpha-Dimethylphenethylamine	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	1.0	22	—	—	No toxicity value
Ammonium ion	CATION	1/30/2008	1/17/2013	40	16	40	µg/L	1.8	12	1.8	68	No toxicity value
Antimony-125	RAD	1/9/2008	12/23/2013	795	1	0.13	pCi/L	-3.80E+01	38	4.4	4.4	<3-year half-life
Benzo(ghi)perylene	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.16	1.0	—	—	No toxicity value
Benzothiazole	VOC	1/9/2008	1/17/2013	112	1	0.89	µg/L	0.50	1.0	1.9	1.9	No toxicity value
Beryllium-7	RAD	1/9/2008	12/23/2013	794	1	0.13	pCi/L	-1.10E+02	210	89	89	<3 yr half-life
Bi-carbonate alkalinity	GEN CHEM	11/8/2011	6/6/2012	31	31	100	µg/L	—	—	88,000	156,000	No toxicity value
Bicarbonate	GEN CHEM	11/11/2009	12/23/2013	290	290	100	µg/L	—	—	77,000	200,000	No toxicity value
Bismuth	METAL	3/5/2010	1/7/2011	65	3	4.6	µg/L	23	37	23	28	No toxicity value
Bromide	ANION	4/30/2008	4/3/2013	59	9	15	µg/L	90	500	124	1,440	No toxicity value
Calcium	METAL	1/2/2008	1/6/2014	3,112	3,110	99.9	µg/L	30	35	11,200	1.04E+06	Essential nutrient
Carbonate alkalinity	GEN CHEM	11/11/2009	12/23/2013	321	4	1.3	µg/L	540	1,000	1,400	40,000	No toxicity value
Cesium-134	RAD	1/9/2008	12/23/2013	795	0	0	pCi/L	-6.70E+01	72	—	—	<3-year half-life

Table G-9. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Basis for Exclusion
Chemical oxygen demand	GEN CHEM	7/3/2012	10/15/2012	22	1	4.6	µg/L	10,000	10,000	37,300	37,300	No toxicity value
Chloride	ANION	1/2/2008	12/23/2013	1719	1,719	100	µg/L	—	—	2,260	1.22E+06	No toxicity value
Chloroethane	VOC	4/2/2008	4/3/2013	194	0	0	µg/L	0.085	2.0	—	—	No toxicity value
Chloromethane	VOC	4/2/2008	4/3/2013	194	4	2.1	µg/L	0.036	2.0	0.078	0.14	No toxicity value
Coliform bacteria	COLIFORM	4/2/2008	10/15/2012	24	8	33	Col/ 100 mL	1.0	1.0	1.0	205	No toxicity value
Cyclohexanone	VOC	1/7/2011	1/7/2011	1	0	0	µg/L	5.8	5.8	—	—	No toxicity value
Delta-BHC	PESTICIDE	11/4/2008	2/12/2013	80	0	0	µg/L	0.0060	0.010	—	—	No toxicity value
Dichloroprop	PESTICIDE	7/3/2012	10/3/2012	5	0	0	µg/L	1.2	1.6	—	—	No toxicity value
Dimethyl phthalate	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
Diphenylamine+n-nitrosodiphenylamine	SVOC	7/3/2012	11/21/2013	96	0	0	µg/L	0.90	1.0	—	—	No toxicity value
Dissolved oxygen	GEN CHEM	1/3/2008	12/23/2013	961	961	100	µg/L	—	—	70	323,900	No toxicity value
Endosulfan sulfate	PESTICIDE	11/4/2008	2/12/2013	58	0	0	µg/L	0.0094	0.017	—	—	No toxicity value
Endrin aldehyde	PESTICIDE	11/4/2008	2/12/2013	52	0	0	µg/L	0.0032	0.010	—	—	No toxicity value
Ethanol	SVOC	9/19/2010	1/7/2011	2	0	0	µg/L	2,000	2,000	—	—	No toxicity value
Ethyl cyanide	SVOC	1/9/2008	4/3/2013	302	0	0	µg/L	1.2	4.7	—	—	No toxicity value
Ethyl methanesulfonate	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
Famphur	PESTICIDE	4/2/2008	11/21/2013	115	0	0	µg/L	1.0	50	—	—	No toxicity value
Gross alpha	RAD	1/9/2008	12/17/2013	861	512	59	pCi/L	-2.00E+01	19	1.4	2,300	No toxicity value
Gross beta	RAD	1/9/2008	12/23/2013	1,070	1,060	99	pCi/L	-9.50E-01	9.7	3.2	34,000	No toxicity value
Heptachlorodibenzofurans	FURAN	7/3/2012	10/15/2012	22	0	0	µg/L	2.40E-07	7.90E-07	—	—	No toxicity value
Heptachlorodibenzo-p-dioxins	DIOXIN	7/3/2012	10/15/2012	22	3	14	µg/L	2.80E-07	1.20E-06	3.60E-07	6.70E-07	No toxicity value
Hexachlorodibenzofurans	FURAN	7/3/2012	10/15/2012	22	0	0	µg/L	1.50E-07	4.90E-07	—	—	No toxicity value
Hexachlorodibenzo-p-dioxin	DIOXIN	7/3/2012	10/15/2012	22	10	45	µg/L	3.20E-07	7.40E-07	4.30E-07	2.60E-06	No toxicity value
Hexachloropropene	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	2.5	—	—	No toxicity value
Hydroxylion	GEN CHEM	11/11/2009	12/23/2013	321	0	0	µg/L	540	1,000	—	—	No toxicity value
Iodomethane	VOC	4/2/2008	4/3/2013	187	0	0	µg/L	0.090	2.0	—	—	No toxicity value
Isodrin	PESTICIDE	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
Isosafrole	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	5.7	—	—	No toxicity value

Table G-9. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Basis for Exclusion
Magnesium	METAL	1/2/2008	1/6/2014	3,127	3,125	99.9	µg/L	6.0	7.1	4,020	169,000	Essential nutrient
Methapyrilene	SVOC	4/2/2008	11/21/2013	111	0	0	µg/L	0.90	14	—	—	No toxicity value
O,O,O-Triethyl phosphorothioate	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.1	—	—	No toxicity value
O,O-Diethyl O-2-pyrazinyl phosphorothioate	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	1.0	—	—	No toxicity value
Oil and grease	TPH	4/2/2008	4/2/2008	1	1	100	µg/L	—	—	1,000	1,000	No toxicity value
o-Toluidine	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.90	2.0	—	—	No toxicity value
Oxidation-reduction potential	GEN CHEM	2/6/2008	12/23/2013	583	583	100	mV	—	—	-1.63E+02	510	No toxicity value
Pentachlorodibenzofurans	FURAN	7/3/2012	10/15/2012	22	1	4.6	µg/L	2.90E-07	8.80E-07	8.10E-08	8.10E-08	No toxicity value
Pentachlorodibenzo-p-dioxins	DIOXIN	7/3/2012	10/15/2012	22	2	9.1	µg/L	4.20E-07	1.30E-06	2.30E-07	3.50E-07	No toxicity value
pH measurement	GEN CHEM	1/2/2008	1/6/2014	1,802	1,802	100	Unit-less	—	—	5.8	13	No toxicity value
Phenanthrene	SVOC	4/2/2008	11/21/2013	115	0	0	µg/L	0.10	1.0	—	—	No toxicity value
Phosphate	ANION	4/30/2008	4/3/2013	61	1	1.6	µg/L	229	500	660	660	No toxicity value
Phosphorus	METAL	3/5/2010	1/7/2011	65	31	48	µg/L	55	72	56	148	No toxicity value
Potassium	METAL	1/2/2008	1/6/2014	3,127	3,124	99.9	µg/L	90	1,650	2,050	90,100	Essential nutrient
Potassium-40	RAD	1/9/2008	12/23/2013	795	63	7.9	pCi/L	-3.10E+02	220	24	6,600	Hanford background
Radium-226	RAD	7/15/2010	7/15/2010	1	0	0	pCi/L	16	16	—	—	Hanford background
Radium-228	RAD	4/9/2010	12/17/2010	24	0	0	pCi/L	-8.13E-01	1.0	—	—	Hanford background
Ruthenium-106	RAD	1/9/2008	12/23/2013	794	0	0	pCi/L	-1.00E+02	87	—	—	<3-year half-life
Silicon	METAL	3/5/2010	1/7/2011	65	65	100	µg/L	—	—	6,260	20,100	No toxicity value
Sodium	METAL	1/2/2008	1/6/2014	3,127	3,125	99.9	µg/L	22	28	5,400	5.93E+06	Essential nutrient
Specific conductance	GEN CHEM	1/2/2008	1/6/2014	1801	1801	100	µS/cm	—	—	172	8,166	No toxicity value
Sulfate	ANION	1/2/2008	12/23/2013	1719	1719	100	µg/L	—	—	3,170	631,000	No toxicity value
Sulfide	ANION	12/3/2009	4/3/2013	78	21	27	µg/L	83	1,000	130	1,100	No toxicity value
Temperature	GEN CHEM	1/2/2008	1/6/2014	1802	1802	100	°C	—	—	8.0	28	No toxicity value
Tetrachlorodibenzofurans	FURAN	7/3/2012	10/15/2012	22	4	18	µg/L	3.80E-07	1.30E-06	6.50E-07	1.50E-06	No toxicity value
Tetrachlorodibenzo-p-dioxins	DIOXIN	10/3/2012	10/15/2012	19	2	11	µg/L	6.50E-07	1.90E-06	3.00E-07	1.40E-06	No toxicity value
Thorium	METAL	12/17/2010	1/6/2014	35	0	0	µg/L	0.10	0.20	—	—	No toxicity value
Thorium-228	RAD	1/9/2008	12/17/2013	66	11	17	pCi/L	-1.52E-01	0.76	0.17	1.6	Hanford background

Table G-9. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Basis for Exclusion
Thorium-230	RAD	1/9/2008	12/17/2013	69	9	13	pCi/L	-1.05E-01	0.35	0.096	1.9	Hanford background
Thorium-232	RAD	1/9/2008	12/17/2013	67	1	1.5	pCi/L	-4.34E-02	0.34	0.86	0.86	Hanford background
Titanium	METAL	12/8/2010	4/3/2013	43	0	0	µg/L	4.0	4.1	—	—	No toxicity value
Total alpha energy emitted from radium	RAD	4/9/2010	8/12/2010	16	2	13	pCi/L	-7.20E-02	0.098	0.37	1.0	Hanford background
Total dissolved solids	GEN CHEM	11/29/2011	4/3/2013	3	3	100	µg/L	—	—	284,000	1.24E+06	No toxicity value
Total organic carbon	GEN CHEM	1/2/2008	12/23/2013	576	463	80	µg/L	100	300	112	17,600	No toxicity value
Total organic halides	VOC	1/2/2008	10/10/2013	511	222	43	µg/L	1.8	30	2.2	232	No toxicity value
Total petroleum hydrocarbons – diesel range	TPH	4/2/2008	10/15/2012	51	5	9.8	µg/L	70	72	74	270	No toxicity value
Total petroleum hydrocarbons – gasoline range	TPH	4/2/2008	10/15/2012	27	0	0	µg/L	50	50	—	—	No toxicity value
Total petroleum hydrocarbons – kerosene range	TPH	4/2/2008	10/15/2012	24	0	0	µg/L	70	72	—	—	No toxicity value
trans-1,4-Dichloro-2-butene	VOC	4/2/2008	4/3/2013	187	0	0	µg/L	0.29	2.0	—	—	No toxicity value
Turbidity	GEN CHEM	1/2/2008	1/6/2014	1,802	1,802	100	NTU	—	—	0.050	1,000	No toxicity value

NTU = nephelometric turbidity unit
SVOC = semivolatile organic compound
TPH = total petroleum hydrocarbon
VOC = volatile organic compound

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
1,1,1,2-Tetrachloroethane	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.090	1.0
1,1,1-Trichloroethane	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.067	1.0
1,1,2,2-Tetrachloroethane	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.098	1.0
1,1,2-Trichloroethane	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.063	1.0
1,1-Dichloroethane	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.068	1.0
1,1-Dichloroethene	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.051	1.0
1,2,3,4,6,7,8-Heptachlorodibenzodioxin	DIOXIN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.40E-07	7.40E-07
1,2,3,4,6,7,8-Heptachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.10E-07	6.60E-07
1,2,3,4,7,8,9-Heptachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.80E-07	9.50E-07
1,2,3,4,7,8-Hexachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	1.60E-07	4.20E-07
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	DIOXIN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.30E-07	8.50E-07
1,2,3,6,7,8-Hexachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	1.50E-07	4.60E-07
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	DIOXIN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.40E-07	8.90E-07
1,2,3,7,8,9-Hexachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	1.80E-07	6.40E-07
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	DIOXIN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.20E-07	8.10E-07
1,2,3,7,8-Pentachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.70E-07	9.20E-07
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	DIOXIN	10/3/2012	10/15/2012	19	0	0%	µg/L	3.50E-07	1.30E-06
1,2,3-Trichloropropane	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.15	1.0
1,2,4,5-Tetrachlorobenzene	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
1,2,4-Trichlorobenzene	VOC	1/9/2008	11/21/2013	205	0	0%	µg/L	0.70	2.2
1,2-Dibromo-3-chloropropane	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.41	1.0
1,2-Dibromoethane	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.13	1.0
1,2-Dichlorobenzene	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
1,2-Dichloroethane	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.10	1.0
1,2-Dichloroethene (total)	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.13	1.0
1,2-Dichloropropane	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.077	1.0
1,4-Dichlorobenzene	VOC	1/9/2008	12/17/2013	353	0	0%	µg/L	0.10	1.4
1,4-Dioxane	VOC	4/2/2008	11/21/2013	232	0	0%	µg/L	0.90	10
1-Butanol	VOC	1/9/2008	4/3/2013	302	0	0%	µg/L	12	100

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
2-(2-methyl-4-chlorophenoxy) propionic acid	HERBICIDE	7/3/2012	10/15/2012	22	0	0%	µg/L	130	140
2,3,4,6,7,8-Hexachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	1.30E-07	4.50E-07
2,3,4,6-Tetrachlorophenol	SVOC	1/2/2008	11/21/2013	332	0	0%	µg/L	0.48	2.1
2,3,4,7,8-Pentachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	2.60E-07	8.40E-07
2,3,7,8-Tetrachlorodibenzofuran	FURAN	10/3/2012	10/15/2012	19	0	0%	µg/L	3.80E-07	1.30E-06
2,3,7,8-Tetrachlorodibenzo-p-dioxin	DIOXIN	7/3/2012	10/15/2012	22	0	0%	µg/L	6.50E-07	2.20E-06
2,4,5-T(2,4,5-trichlorophenoxyacetic acid)	HERBICIDE	7/3/2012	10/3/2012	5	0	0%	µg/L	0.14	0.16
2,4,5-TP(2-(2,4,5-trichlorophenoxy)propionic acid) silvex	HERBICIDE	7/3/2012	10/3/2012	5	0	0%	µg/L	0.14	0.15
2,4,5-Trichlorophenol	VOC	1/2/2008	11/21/2013	332	0	0%	µg/L	0.62	2.2
2,4,6-Trichlorophenol	VOC	1/2/2008	11/21/2013	332	0	0%	µg/L	0.48	2.2
2,4-D(2,4-dichlorophenoxyacetic acid)	HERBICIDE	7/3/2012	10/15/2012	22	0	0%	µg/L	1.8	2.0
2,4-DB(4-(2,4-dichlorophenoxy)butanoic acid)	HERBICIDE	7/3/2012	10/15/2012	22	0	0%	µg/L	2.4	2.6
2,4-Dichlorophenol	VOC	1/2/2008	12/17/2013	411	0	0%	µg/L	0.47	2.1
2,4-Dimethylphenol	VOC	1/2/2008	11/21/2013	332	0	0%	µg/L	0.90	2.1
2,4-Dinitrophenol	VOC	1/2/2008	11/21/2013	333	0	0%	µg/L	0.90	10
2,4-Dinitrotoluene	SVOC	1/9/2008	11/21/2013	205	0	0%	µg/L	0.47	1.1
2,6-Dinitrotoluene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.2
2-Acetylaminofluorene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
2-Butanone	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.52	1.0
2-Chloronaphthalene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
2-Chlorophenol	VOC	1/2/2008	11/21/2013	393	0	0%	µg/L	0.47	2.2
2-Methyl-4 chlorophenoxyacetic acid	HERBICIDE	7/3/2012	10/15/2012	22	0	0%	µg/L	120	130
2-Methylnaphthalene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
2-Methylphenol (cresol, o-)	SVOC	1/2/2008	12/17/2013	413	0	0%	µg/L	0.47	2.2
2-Naphthylamine	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	1.0	2.0
2-Nitroaniline	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.0
3,3'-Dichlorobenzidine	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.3
3,3'-Dimethylbenzidine	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	1.0	10
3-Methylcholanthrene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
3-Nitroaniline	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.1
4,4'-DDD (dichlorodiphenyldichloroethane)	PESTICIDE	11/4/2008	2/12/2013	76	0	0%	µg/L	0.0038	0.010
4,4'-DDE (dichlorodiphenyldichloroethylene)	PESTICIDE	11/4/2008	2/12/2013	75	0	0%	µg/L	0.0027	0.020
4,4'-DDT (dichlorodiphenyltrichloroethane)	PESTICIDE	11/4/2008	2/12/2013	76	0	0%	µg/L	0.0056	0.023
4,6-Dinitro-2-methylphenol	VOC	1/2/2008	11/21/2013	332	0	0%	µg/L	0.90	5.0
4-Aminobiphenyl	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	1.0	2.0
4-Chloro-3-methylphenol	VOC	1/2/2008	11/21/2013	393	0	0%	µg/L	0.47	2.4
4-Chloroaniline	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.2
4-Methyl-2-pentanone	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.12	1.0
4-Methylphenol (cresol, p-)	VOC	4/2/2008	7/3/2012	23	0	0%	µg/L	0.10	10
4-Nitroaniline	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.3
5-Nitro-o-toluidine	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	20
7,12-Dimethylbenz[a]anthracene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Acenaphthene	SVOC	1/9/2008	11/21/2013	205	0	0%	µg/L	0.50	2.5
Acrolein	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.52	10
Acrylonitrile	VOC	3/26/2010	4/3/2013	152	0	0%	µg/L	0.58	5.0
Aldrin	PESTICIDE	11/4/2008	2/12/2013	57	0	0%	µg/L	0.0040	0.010
Allyl chloride	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.091	1.0
Alpha-BHC	PESTICIDE	11/4/2008	2/12/2013	76	0	0%	µg/L	0.0025	0.010
Aniline	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.3
Anthracene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.020	1.1
Aramite	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	20
Aroclor 1016	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.090	0.21
Aroclor 1221	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.14	0.21
Aroclor 1232	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.090	0.21
Aroclor 1242	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.090	0.21
Aroclor 1248	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.090	0.21
Aroclor 1254	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.090	0.14
Aroclor 1260	PCB	10/8/2008	10/15/2012	40	0	0%	µg/L	0.090	0.14

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
Azobenzene	VOC	4/2/2008	7/3/2012	8	0	0%	µg/L	1.0	1.0
Benzo(a)anthracene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.063	1.0
Benzo(a)pyrene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.075	1.0
Benzo(b)fluoranthene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.051	1.0
Benzo(k)fluoranthene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.074	1.0
Benzyl alcohol	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC)	PESTICIDE	11/4/2008	2/12/2013	80	0	0%	µg/L	0.010	0.013
Bis(2-chloro-1-methylethyl)ether	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Bis(2-chloroethoxy)methane	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Bis(2-chloroethyl) ether	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Bromodichloromethane	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.082	1.0
Bromoform	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.094	1.0
Bromomethane	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.084	2.0
Carbazole	SVOC	12/17/2009	11/21/2013	104	0	0%	µg/L	0.90	1.0
Chlordane	PESTICIDE	11/4/2008	2/12/2013	80	0	0%	µg/L	0.040	0.23
Chlorobenzene	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.15	1.0
Chlorobenzilate	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Chloroprene	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.085	1.0
Chrysene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.035	1.0
cis-1,2-Dichloroethylene	VOC	1/9/2008	4/3/2013	302	0	0%	µg/L	0.083	1.0
cis-1,3-Dichloropropene	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.070	1.0
Dalapon	HERBICIDE	7/3/2012	10/15/2012	22	0	0%	µg/L	0.94	3.9
Diallate	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.0
Dibenz[a,h]anthracene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.15	1.0
Dibenzofuran	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Dibromochloromethane	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.057	1.0
Dibromomethane	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.14	1.0
Dicamba	HERBICIDE	7/3/2012	10/3/2012	5	0	0%	µg/L	0.28	0.29
Dichlorodifluoromethane	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.070	2.0

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
Dieldrin	PESTICIDE	11/4/2008	2/12/2013	58	0	0%	µg/L	0.0023	0.010
Diethyl ether	VOC	9/19/2010	1/7/2011	2	0	0%	µg/L	0.26	2,000
Diethylphthalate	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Dimethoate	PESTICIDE	4/2/2008	11/21/2013	116	0	0%	µg/L	0.90	1.1
di-n-Butylphthalate	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Dinoseb(2-secButyl-4,6-dinitrophenol)	PESTICIDE	1/2/2008	11/21/2013	332	0	0%	µg/L	0.63	2.4
Diphenylamine	VOC	12/17/2009	12/17/2009	3	0	0%	µg/L	1.0	1.0
Disulfoton	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	3.0
Endosulfan I	PESTICIDE	11/4/2008	2/12/2013	79	0	0%	µg/L	0.0025	0.020
Endosulfan II	PESTICIDE	11/4/2008	2/12/2013	79	0	0%	µg/L	0.0094	0.010
Endrin	PESTICIDE	11/4/2008	2/12/2013	58	0	0%	µg/L	0.0028	0.018
Ethyl acetate	VOC	9/19/2010	1/7/2011	2	0	0%	µg/L	0.18	2,000
Ethyl methacrylate	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.11	1.0
Ethylbenzene	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.061	1.0
Ethylene glycol	SVOC	9/19/2010	1/7/2011	2	0	0%	µg/L	2,000	2,000
Europium-152	RAD	1/9/2008	12/23/2013	808	0	0%	pCi/L	-3.20E+01	37
Europium-155	RAD	1/9/2008	12/23/2013	808	0	0%	pCi/L	-3.10E+01	58
Fluoranthene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.18	1.0
Fluorene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.071	1.0
Gamma-BHC (lindane)	PESTICIDE	11/4/2008	2/12/2013	59	0	0%	µg/L	0.0025	0.010
Heptachlor epoxide	SVOC	11/4/2008	2/12/2013	59	0	0%	µg/L	0.0032	0.017
Heptachlor	PESTICIDE	11/4/2008	2/12/2013	63	0	0%	µg/L	0.0025	0.010
Hexachlorobenzene	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Hexachlorobutadiene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Hexachlorocyclopentadiene	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.5
Hexachloroethane	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Hexachlorophene	PESTICIDE	4/2/2008	11/21/2013	78	0	0%	µg/L	0.90	10
Hexane	VOC	11/4/2008	11/4/2008	1	0	0%	µg/L	0.16	0.16
Indeno(1,2,3-cd)pyrene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.14	1.0

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
Isobutyl alcohol	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	5.0	200
Isophorone	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Kepone	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	20
m-Dinitrobenzene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Methacrylonitrile	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.050	2.0
Methanol	SVOC	9/19/2010	9/19/2010	1	0	0%	µg/L	2,000	2,000
Methoxychlor	PESTICIDE	11/4/2008	2/12/2013	80	0	0%	µg/L	0.0010	0.013
Methyl parathion	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Naphthalene	VOC	1/9/2008	12/17/2013	229	0	0%	µg/L	0.20	2.0
Nickel-63	RAD	5/17/2010	9/2/2010	3	0	0%	pCi/L	0.11	1.8
Niobium-94	RAD	7/15/2010	9/15/2011	3	0	0%	pCi/L	-3.94E-02	7.5
Nitrobenzene	VOC	4/2/2008	11/21/2013	116	0	0%	µg/L	0.90	1.1
Nitrosopyrrolidine	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.0
n-Nitrosodiethylamine	SVOC	4/2/2008	11/21/2013	116	0	0%	µg/L	0.90	1.1
n-Nitrosodimethylamine	SVOC	1/30/2008	11/21/2013	136	0	0%	µg/L	0.72	2.0
n-Nitrosodi-n-butylamine	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
n-Nitrosodiphenylamine	SVOC	4/2/2008	1/7/2011	19	0	0%	µg/L	1.0	1.0
n-Nitrosomethylethylamine	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.0
n-Nitrosomorpholine	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.2
n-Nitrosopiperidine	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Octachlorodibenzo-p-dioxin	DIOXIN	7/3/2012	10/15/2012	21	0	0%	µg/L	2.90E-07	9.60E-05
Parathion	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
p-Dimethylaminoazobenzene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Pentachlorobenzene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.7
Pentachloroethane	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.3
Pentachloronitrobenzene (PCNB)	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	1.0	2.0
Pentachlorophenol	PESTICIDE	1/2/2008	12/17/2013	413	0	0%	µg/L	0.50	2.4
Phenacetin	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Phorate	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	2.9

Table G-10. Summary of Analytes Not Detected in the 200-BP-5 OU

Analyte Name	Analyte Class	Begin Sample Date	End Sample Date	Total Samples	Total Detects	Frequency of Detection	Units	Minimum Detection Limit	Maximum Detection Limit
p-Phenylenediamine	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Pronamide	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Protactinium-231	RAD	11/4/2008	11/4/2008	1	0	0%	pCi/L	-1.70E-02	-1.70E-02
Pyrene	SVOC	1/9/2008	11/21/2013	205	0	0%	µg/L	0.083	1.0
Pyridine	VOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	5.0
Safrol	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Selenium-79	RAD	11/4/2008	11/4/2008	1	0	0%	pCi/L	-4.10E+00	-4.10E+00
Silver-108 metastable	RAD	1/7/2011	9/15/2011	2	0	0%	pCi/L	-7.05E-01	-1.64E-01
Styrene	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.036	1.0
sym-Trinitrobenzene	SVOC	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	5.0
Tetrachloroethene	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.088	1.0
Tetraethyl dithiopyrophosphate (Sulfotepp)	PESTICIDE	4/2/2008	11/21/2013	115	0	0%	µg/L	0.90	1.0
Tetrahydrofuran	VOC	1/9/2008	4/3/2013	302	0	0%	µg/L	1.1	3.2
Tin-126	RAD	7/15/2010	7/15/2010	1	0	0%	pCi/L	14	14
Total cresols	VOC	1/14/2009	1/17/2013	44	0	0%	µg/L	0.50	3.0
Toxaphene	PESTICIDE	11/4/2008	2/12/2013	80	0	0%	µg/L	0.25	0.66
trans-1,2-Dichloroethylene	VOC	1/9/2008	4/3/2013	302	0	0%	µg/L	0.080	1.0
trans-1,3-Dichloropropene	VOC	4/2/2008	4/3/2013	194	0	0%	µg/L	0.080	1.0
Trichloromonofluoromethane	VOC	4/2/2008	4/3/2013	191	0	0%	µg/L	0.041	1.0
Tris-2-chloroethyl phosphate	SVOC	1/9/2008	1/17/2013	112	0	0%	µg/L	0.50	1.0
Vinyl acetate	VOC	4/2/2008	4/3/2013	187	0	0%	µg/L	0.17	2.0
Vinyl chloride	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.032	1.0
Xylenes (total)	VOC	1/9/2008	12/17/2013	308	0	0%	µg/L	0.11	3.0

PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound
VOC = volatile organic compound

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Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	2-Hexanone	591-78-6	24	0	24	0	µg/L	0.22	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Acetone	67-64-1	24	1	23	4.2	µg/L	0.34	2.0	1.0	1.0	0	1.0	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable acetone was not processed.
LLWMA-1	NON-RAD	Acetophenone	98-86-2	22	0	22	0	µg/L	0.90	1.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Aluminum	7429-90-5	19	2	17	11	µg/L	10	21	11	47	0.87	47	95% KM (BCA) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Antimony	7440-36-0	23	3	20	13	µg/L	0.30	0.60	46	50	0.043	47	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an “N/A” value on the output display.
LLWMA-1	NON-RAD	Arsenic	7440-38-2	33	33	0	100	µg/L	—	—	3.3	6.3	0.13	4.8	95% Student’s-t UCL	—
LLWMA-1	NON-RAD	Barium	7440-39-3	226	225	1	99.6	µg/L	4.1	4.1	39	210	0.40	72	95% KM (BCA) UCL	—

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	Benzene	71-43-2	24	0	24	0	µg/L	0.064	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Beryllium	7440-41-7	208	0	208	0	µg/L	0.20	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	22	0	22	0	µg/L	0.90	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Butylbenzyl-phthalate	85-68-7	22	0	22	0	µg/L	0.90	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Cadmium	7440-43-9	226	4	222	1.8	µg/L	0.10	4.1	0.19	4.6	0.63	0.40	95% KM (Chebyshev) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	Carbon disulfide	75-15-0	24	0	24	0	µg/L	0.051	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Carbon tetrachloride	56-23-5	24	0	24	0	µg/L	0.12	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Chloroform	67-66-3	24	1	23	4.2	µg/L	0.10	1.0	0.13	0.13	0	0.13	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable chloroform was not processed.
LLWMA-1	NON-RAD	Chromium	7440-47-3	226	152	74	67	µg/L	5.0	20	3.0	85	0.65	14	95% KM (percentile bootstrap) UCL	—
LLWMA-1	NON-RAD	Cobalt	7440-48-4	225	19	206	8.4	µg/L	0.10	4.1	0.10	5.7	1.8	0.37	95% KM (BCA) UCL	—
LLWMA-1	NON-RAD	Copper	7440-50-8	224	15	209	6.7	µg/L	0.20	6.0	0.25	6.6	1.3	0.88	95% KM (BCA) UCL	—
LLWMA-1	NON-RAD	Cyanide	57-12-5	94	62	32	66	µg/L	4.0	4.0	4.1	558	1.4	139	97.5% KM (Chebyshev) UCL	—
LLWMA-1	NON-RAD	di-n-Octylphthalate	117-84-0	22	0	22	0	µg/L	0.9	1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	Fluoride	16984-48-8	227	225	2	99	µg/L	60	60	105	536	0.28	334	95% KM (t) UCL	—
LLWMA-1	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	226	80	146	35	µg/L	4.0	14	3.1	70	0.93	7.7	95% KM (% bootstrap) UCL	—
LLWMA-1	NON-RAD	Iron	7439-89-6	223	199	24	89	µg/L	18	69	12	349	0.80	82	95% KM (BCA) UCL	—
LLWMA-1	NON-RAD	Lead	7439-92-1	48	18	30	38	µg/L	0.10	0.22	0.11	1.0	0.66	0.24	95% KM (t) UCL	—
LLWMA-1	NON-RAD	Manganese	7439-96-5	226	24	202	11	µg/L	4.0	6.0	0.21	7.6	1.0	1.6	95% KM (t) UCL	—
LLWMA-1	NON-RAD	Mercury	7439-97-6	33	2	31	6.1	µg/L	0.050	0.10	0.11	0.18	0.34	0.18	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Methyl methacrylate	80-62-6	24	0	24	0	µg/L	0.26	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Methyl methanesulfonate	66-27-3	22	0	22	0	µg/L	0.90	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Methylene chloride	75-09-2	24	0	24	0	µg/L	0.27	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	Molybdenum	7439-98-7	19	19	0	100	µg/L	—	—	3.5	8.4	0.22	6.6	95% Student's-t UCL	—
LLWMA-1	NON-RAD	Nickel	7440-02-0	223	114	109	51	µg/L	2.7	9.0	0.59	41	0.76	5.6	95% KM (% bootstrap) UCL	—
LLWMA-1	NON-RAD	Nitrate	14797-55-8	227	227	0	100	µg/L	--	--	31,900	1.05E+06	1.3	180,551	95% Chebyshev (Mean, Sd) UCL	—
LLWMA-1	NON-RAD	Nitrite	14797-65-0	227	56	171	25	µg/L	65	296	125	558	0.38	156	95% KM (% bootstrap) UCL	—
LLWMA-1	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	22	0	22	0	µg/L	0.90	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Octachlorodi-benzofuran	39001-02-0	22	4	18	18	µg/L	3.40E-07	1.30E-06	1.00E-06	1.70E-06	0	1.43E-06	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LLWMA-1	NON-RAD	Phenol	108-95-2	95	0	95	0	µg/L	0.90	2.3	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Selenium	7782-49-2	22	22	0	100	µg/L	—	—	3.1	11	0.28	6.7	95% Student's-t UCL	—
LLWMA-1	NON-RAD	Silver	7440-22-4	221	5	216	2.3	µg/L	0.10	8.0	0.14	18	0.85	6.8	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LLWMA-1	NON-RAD	Strontium	7440-24-6	226	225	1	99.6	µg/L	4.1	4.1	190	1,290	0.52	393	95% KM (BCA) UCL	—

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	Thallium	7440-28-0	22	1	21	4.6	µg/L	0.10	0.10	0.24	0.24	0	0.24	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable thallium was not processed.
LLWMA-1	NON-RAD	Tin	7440-31-5	22	3	19	14	µg/L	0.10	0.10	0.10	0.23	0.47	0.23	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
LLWMA-1	NON-RAD	Toluene	108-88-3	24	0	24	0	µg/L	0.072	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Tributyl phosphate	126-73-8	22	0	22	0	µg/L	0.90	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Trichloroethene	79-01-6	24	0	24	0	µg/L	0.25	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	NON-RAD	Uranium	7440-61-1	206	205	1	99.5	µg/L	0.10	0.10	2.3	159	1.3	22	95% KM (BCA) UCL	—
LLWMA-1	NON-RAD	Vanadium	7440-62-2	225	186	39	83	µg/L	7.0	17	8.4	29	0.25	17	95% KM (BCA) UCL	—

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	NON-RAD	Zinc	7440-66-6	223	15	208	6.7	µg/L	2.0	24	4.0	17	0.42	5.5	95% KM (percentile bootstrap) UCL	—
LLWMA-1	RAD	Cesium-137	10045-97-3	36	0	36	0	pCi/L	-4.90E+00	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	RAD	Cobalt-60	10198-40-0	36	8	28	22	pCi/L	-4.40E+00	12	10	39	0.38	26	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LLWMA-1	RAD	Europium-154	15585-10-1	36	0	36	0	pCi/L	-8.10E+00	25	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	RAD	Iodine-129	15046-84-1	204	140	64	69	pCi/L	-9.83E-02	1.0	0.17	5.2	0.66	2.4	97.5% KM (Chebyshev) UCL	—
LLWMA-1	RAD	Plutonium-238	13981-16-3	4	0	4	0	pCi/L	-7.40E-02	0.059	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-238 was not processed,
LLWMA-1	RAD	Plutonium-239/240	PU-239/240	4	0	4	0	pCi/L	-3.80E-02	0.011	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-239/240 was not processed.

Table G-11. Summary of Groundwater Exposure Point Concentrations for the LLWMA-1 Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-1	RAD	Strontium-90	10098-97-2	11	0	11	0	pCi/L	-8.00E+00	0.56	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-1	RAD	Technetium-99	14133-76-7	205	204	1	99.5	pCi/L	-2.00E-01	-2.00E-01	11	21,000	2.4	3,168	97.5% KM (Chebyshev) UCL	—
LLWMA-1	RAD	Tritium	10028-17-8	206	181	25	88	pCi/L	-1.10E+02	290	210	26,000	0.83	7,417	97.5% KM (Chebyshev) UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
LLWMA = low-level waste management area
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	NON-RAD	2-Hexanone	591-78-6	1	0	1	0	µg/L	0.080	0.080	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable 2-hexanone was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Acetone	67-64-1	1	0	1	0	µg/L	0.56	0.56	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable acetone was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Acetophenone	98-86-2	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable acetophenone was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Antimony	7440-36-0	21	6	15	29	µg/L	4.0	4.0	5.6	114	0.60	65	95% KM (percentile bootstrap) UCL	Warning: There are only six detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Arsenic	7440-38-2	19	19	0	100	µg/L	—	—	4.3	9.9	0.21	8.5	95% Student's-t UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Barium	7440-39-3	154	154	0	100	µg/L	—	—	27	199	0.50	55	95% Modified-t UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Benzene	71-43-2	1	0	1	0	µg/L	0.032	0.032	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable benzene was not processed.

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	NON-RAD	Beryllium	7440-41-7	150	0	150	0	µg/L	0.50	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-2 and 216-B-63 Trench	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable bis(2-ethylhexyl) phthalate was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Butylbenzylphthalate	85-68-7	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable butylbenzylphthalate was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Cadmium	7440-43-9	154	0	154	0	µg/L	0.45	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-2 and 216-B-63 Trench	NON-RAD	Carbon disulfide	75-15-0	1	0	1	0	µg/L	0.029	0.029	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon disulfide was not processed.

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	NON-RAD	Carbon tetrachloride	56-23-5	1	0	1	0	µg/L	0.042	0.042	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon tetrachloride was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Chloroform	67-66-3	1	0	1	0	µg/L	0.080	0.080	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable chloroform was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Chromium	7440-47-3	152	113	39	74	µg/L	4.0	14	3.4	51	0.46	16	95% KM (percentile bootstrap) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Cobalt	7440-48-4	140	0	140	0	µg/L	4.0	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-2 and 216-B-63 Trench	NON-RAD	Copper	7440-50-8	154	7	147	4.6	µg/L	4.0	6.0	4.1	6.1	0.13	5.0	95% KM (percentile bootstrap) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Cyanide	57-12-5	25	5	20	20	µg/L	4.0	5.0	6.2	411	1.6	57	95% KM (t) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	NON-RAD	di-n-Octylphthalate	117-84-0	1	0	1	0	µg/L	5	5	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable di-n-octylphthalate was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Fluoride	16984-48-8	172	162	10	94	µg/L	60	300	53	402	0.31	228	95% KM (t) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	153	63	90	41	µg/L	3.1	14	3.2	54	0.69	8.9	95% KM (% bootstrap) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Iron	7439-89-6	157	144	13	92	µg/L	16	62	20	436	0.91	90	95% KM (BCA) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Lead	7439-92-1	18	4	14	22	µg/L	0.10	0.20	0.16	0.28	0.27	0.23	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Manganese	7439-96-5	154	13	141	8.4	µg/L	0.96	6.0	1.1	19	0.60	5.1	95% KM (percentile bootstrap) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Mercury	7439-97-6	18	3	15	17	µg/L	0.050	0.10	0.052	0.11	0.40	0.063	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an “N/A” value on the output display.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Methyl methacrylate	80-62-6	1	0	1	0	µg/L	0.62	0.62	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methyl methacrylate was not processed.

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	NON-RAD	Methyl methanesulfonate	66-27-3	1	0	1	0	µg/L	5.0	5.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methyl methanesulfonate was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Methylene chloride	75-09-2	1	0	1	0	µg/L	0.091	0.091	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methylene chloride was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Nickel	7440-02-0	154	104	50	68	µg/L	4.0	67	4.0	198	1.8	17	95% KM (BCA) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Nitrate	14797-55-8	172	172	0	100	µg/L	—	—	6,770	452,000	1.4	53,893	95% Chebyshev (Mean, Sd) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Nitrite	14797-65-0	171	31	140	18	µg/L	9.9	2,500	141	368	0.23	159	95% KM (t) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable n-nitrosodi-n-dipropylamine was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Phenol	108-95-2	96	0	96	0	µg/L	0.90	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	NON-RAD	Silver	7440-22-4	154	3	151	2.0	µg/L	4.0	7.0	4.4	15	0.72	4.6	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Strontium	7440-24-6	153	153	0	100	µg/L	—	—	166	963	0.49	340	95% Modified-t UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Toluene	108-88-3	1	0	1	0	µg/L	0.029	0.029	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable toluene was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Tributyl phosphate	126-73-8	1	0	1	0	µg/L	1.1	1.1	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable Tributyl phosphate was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Trichloroethene	79-01-6	1	0	1	0	µg/L	0.11	0.11	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable trichloroethene was not processed.
LLWMA-2 and 216-B-63 Trench	NON-RAD	Uranium	7440-61-1	139	137	2	99	µg/L	0.10	4.6	2.3	7.7	0.20	3.8	95% KM (BCA) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Vanadium	7440-62-2	154	148	6	96	µg/L	7.0	50	11	31	0.19	21	95% KM (percentile bootstrap) UCL	—
LLWMA-2 and 216-B-63 Trench	NON-RAD	Zinc	7440-66-6	154	19	135	12	µg/L	4.0	9.0	4.0	60	1.3	5.7	95% KM (% bootstrap) UCL	—

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	RAD	Cesium-137	10045-97-3	5	0	5	0	pCi/L	-6.40E+00	2.4	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-2 and 216-B-63 Trench	RAD	Cobalt-60	10198-40-0	5	0	5	0	pCi/L	-1.49E+00	1.5	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-2 and 216-B-63 Trench	RAD	Europium-154	15585-10-1	5	0	5	0	pCi/L	-3.00E+00	5.8	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LLWMA-2 and 216-B-63 Trench	RAD	Iodine-129	15046-84-1	122	95	27	78	pCi/L	7.24E-04	1.5	0.22	4.2	0.55	1.4	95% KM (percentile bootstrap) UCL	—
LLWMA-2 and 216-B-63 Trench	RAD	Strontium-90	10098-97-2	4	0	4	0	pCi/L	-5.20E+00	-5.50E-02	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable strontium-90 was not processed.

Table G-12. Summary of Groundwater Exposure Point Concentrations for LLWMA-2 and the 216-B-63 Trench Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LLWMA-2 and 216-B-63 Trench	RAD	Technetium-99	14133-76-7	133	66	67	50	pCi/L	-1.50E+01	8.7	7.1	9,800	3.8	801	97.5% KM (Chebyshev) UCL	—
LLWMA-2 and 216-B-63 Trench	RAD	Tritium	10028-17-8	145	77	68	53	pCi/L	-1.40E+02	341	200	2,200	0.70	572	97.5% KM (Chebyshev) UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
LLWMA = low-level waste management area
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	2-Hexanone	591-78-6	32	0	32	0	µg/L	1.0	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Acetone	67-64-1	62	0	62	0	µg/L	1.0	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Acetophenone	98-86-2	74	1	73	1.4	µg/L	0.90	1.0	1.7	1.7	0	1.7	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable acetophenone was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Aluminum	7429-90-5	36	8	28	22	µg/L	5.0	100	6.2	30	0.50	14	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA B-BX-BY Tank Farms	NON-RAD	Antimony	7440-36-0	106	40	66	38	µg/L	0.10	4.0	0.11	213	0.82	44	95% KM (Chebyshev) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Arsenic	7440-38-2	233	231	2	99	µg/L	0.80	6.4	3.0	99	1.6	8.9	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Barium	7440-39-3	631	630	1	99.8	µg/L	4.0	4.0	3.6	324	0.49	120	95% KM (BCA) UCL	—

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	Benzene	71-43-2	64	0	64	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Beryllium	7440-41-7	608	0	608	0	µg/L	0.10	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	106	9	97	8.5	µg/L	0.70	3.0	1.4	9.6	0.84	1.7	95% KM (t) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA B-BX-BY Tank Farms	NON-RAD	Butylbenzylphthalate	85-68-7	74	1	73	1.4	µg/L	0.90	1.0	2.8	2.8	0	2.8	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable butylbenzylphthalate was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Cadmium	7440-43-9	631	2	629	0.32	µg/L	0.10	4.1	1.7	4.7	0.66	4.7	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	Carbon disulfide	75-15-0	64	0	64	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Carbon tetrachloride	56-23-5	64	4	60	6.3	µg/L	1.0	1.0	1.2	5.9	0.57	3.5	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA B-BX-BY Tank Farms	NON-RAD	Chloroform	67-66-3	64	2	62	3.1	µg/L	1.0	1.0	1.4	1.5	0.049	1.4	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Chromium	7440-47-3	621	512	109	82	µg/L	4.0	14	2.9	356	0.88	36	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Cobalt	7440-48-4	594	31	563	5.2	µg/L	0.20	4.1	0.20	69	1.3	4.7	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Copper	7440-50-8	630	38	592	6.0	µg/L	0.20	30	2.1	166	1.6	6.4	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Cyanide	57-12-5	620	370	250	60	µg/L	3.6	4.0	2.2	1,730	1.1	320	97.5% KM (Chebyshev) UCL	—

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	Di-n-octylphthalate	117-84-0	74	4	70	5.41	µg/L	0.9	1.1	0.95	5.5	0.78	5.5	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA B-BX-BY Tank Farms	NON-RAD	Fluoride	16984-48-8	641	573	68	89	µg/L	30	500	35	1,100	0.50	248	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	616	468	148	76	µg/L	3.1	14	3.6	114	0.66	27	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Iron	7439-89-6	622	507	115	82	µg/L	9.0	70	11	7,070	1.6	351	95% KM (Chebyshev) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Lead	7439-92-1	37	27	10	73	µg/L	0.10	0.51	0.11	2.4	1.1	0.55	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Manganese	7439-96-5	630	243	387	39	µg/L	0.20	6.0	0.91	632	1.6	18	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Mercury	7439-97-6	95	29	66	31	µg/L	0.050	0.10	0.099	1.7	0.87	0.32	95% KM (t) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Methyl methacrylate	80-62-6	32	0	32	0	µg/L	1.0	2.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	Methyl methanesulfonate	66-27-3	74	1	73	1.4	µg/L	0.90	1.0	340	340	0	340	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable methyl methanesulfonate was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Methylene chloride	75-09-2	64	1	63	1.6	µg/L	1.0	1.0	1.8	1.8	0	1.8	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable methylene chloride was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Molybdenum	7439-98-7	4	4	0	100	µg/L	—	—	0.58	4.5	0.56	4.5	Maximum detect	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable molybdenum was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Nickel	7440-02-0	630	189	441	30	µg/L	0.40	67	3.8	4,070	4.1	51	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Nitrate	14797-55-8	642	642	0	100	µg/L	—	—	22,800	1.70E+06	0.89	598,495	95% Chebyshev (Mean, Sd) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Nitrite	14797-65-0	629	105	524	17	µg/L	9.9	591	21	14,400	2.6	191	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	98	2	96	2.0	µg/L	0.50	1.0	2.6	3.5	0.21	3.5	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	Phenol	108-95-2	106	2	104	1.9	µg/L	0.48	2.0	1.1	1.1	0	1.1	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable phenol was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Selenium	7782-49-2	36	35	1	97	µg/L	0.60	0.60	5.5	18	0.34	11	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Silver	7440-22-4	622	21	601	3.4	µg/L	0.10	24	4.0	158	1.9	5.1	95% KM (% bootstrap) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Strontium	7440-24-6	619	619	0	100	µg/L	—	—	46	2,310	0.59	853	95% Chebyshev (Mean, Sd) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Thallium	7440-28-0	68	2	66	2.9	µg/L	0.050	0.10	0.11	0.13	0.11	0.13	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Tin	7440-31-5	36	18	18	50	µg/L	0.10	0.49	0.12	1.5	0.64	0.44	95% KM (t) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Toluene	108-88-3	64	0	64	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	NON-RAD	Tributyl phosphate	126-73-8	106	1	105	0.94	µg/L	0.48	1.0	1.1	1.1	0	1.1	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable tributyl phosphate was not processed.
WMA B-BX-BY Tank Farms	NON-RAD	Trichloroethene	79-01-6	64	0	64	0	µg/L	0.50	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	NON-RAD	Uranium	7440-61-1	573	573	0	100	µg/L	—	—	2.9	5,550	2.3	422	95% Chebyshev (Mean, Sd) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Vanadium	7440-62-2	624	419	205	67	µg/L	0.40	50	5.0	35	0.31	14	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	NON-RAD	Zinc	7440-66-6	622	142	480	23	µg/L	1.6	15	3.4	986	2.1	40	95% KM (Chebyshev) UCL	—
WMA B-BX-BY Tank Farms	RAD	Americium-241	14596-10-2	32	8	24	25	pCi/L	-1.10E-01	0.24	0.071	0.19	0.36	0.10	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA B-BX-BY Tank Farms	RAD	Carbon-14	14762-75-5	32	32	0	100	pCi/L	—	—	9.3	146	0.81	57	95% approximate gamma UCL	—

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	RAD	Cesium-137	10045-97-3	357	0	357	0	pCi/L	-1.20E+01	13	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	RAD	Cobalt-60	10198-40-0	357	144	213	40	pCi/L	-6.80E+00	31	3.9	1,040	1.9	40	97.5% KM (Chebyshev) UCL	—
WMA B-BX-BY Tank Farms	RAD	Europium-154	15585-10-1	357	0	357	0	pCi/L	-3.60E+01	23	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA B-BX-BY Tank Farms	RAD	Iodine-129	15046-84-1	139	131	8	94	pCi/L	0.011	4.5	0.73	6.7	0.31	3.7	95% KM (BCA) UCL	—
WMA B-BX-BY Tank Farms	RAD	Neptunium-237	13994-20-2	32	3	29	9.4	pCi/L	-6.01E-02	0.91	0.48	1.3	0.49	0.56	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an “N/A” value on the output display.
WMA B-BX-BY Tank Farms	RAD	Plutonium-238	13981-16-3	42	0	42	0	pCi/L	-1.90E-01	0.50	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-13. Summary of Groundwater Exposure Point Concentrations for WMA B-BX-BY Tank Farms Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA B-BX-BY Tank Farms	RAD	Plutonium-239/240	PU-239/240	42	3	39	7.1	pCi/L	-2.80E-02	0.11	0.073	0.098	0.15	0.098	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
WMA B-BX-BY Tank Farms	RAD	Strontium-90	10098-97-2	72	8	64	11	pCi/L	-8.00E+00	2.2	1.2	4.6	0.35	2.7	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA B-BX-BY Tank Farms	RAD	Technetium-99	14133-76-7	596	596	0	100	pCi/L	—	—	23	39,000	1.1	11,391	95% Chebyshev (Mean, Sd) UCL	—
WMA B-BX-BY Tank Farms	RAD	Tritium	10028-17-8	577	576	1	99.8	pCi/L	-3.70E+01	-3.70E+01	190	91,000	0.92	11,424	97.5% KM (Chebyshev) UCL	—
WMA B-BX-BY Tank Farms	RAD	Uranium-234	13966-29-5	1	1	0	100	pCi/L	—	—	598	598	0	598	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-234 was not processed.
WMA B-BX-BY Tank Farms	RAD	Uranium-235	15117-96-1	1	1	0	100	pCi/L	—	—	27	27	0	27	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-235 was not processed.
WMA B-BX-BY Tank Farms	RAD	Uranium-238	U-238	1	1	0	100	pCi/L	—	—	585	585	0	585	Maximum detect	Warning: This data set only has one observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-238 was not processed.

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit
WMA = waste management area

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	2-Hexanone	591-78-6	99	1	98	1.0	µg/L	0.22	1.0	2.0	2.0	0	2.0	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable 2-hexanone was not processed.
WMA C Tank Farm	NON-RAD	Acetone	67-64-1	112	3	109	2.7	µg/L	0.34	5.0	0.94	5.6	0.87	1.1	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
WMA C Tank Farm	NON-RAD	Acetophenone	98-86-2	16	0	16	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Aluminum	7429-90-5	9	3	6	33	µg/L	5.0	20	12	26	0.35	26	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
WMA C Tank Farm	NON-RAD	Antimony	7440-36-0	48	8	40	17	µg/L	0.60	4.0	3.6	74	0.45	46	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA C Tank Farm	NON-RAD	Arsenic	7440-38-2	62	61	1	98	µg/L	5.0	5.0	4.1	16	0.32	6.5	95% KM (BCA) UCL	—
WMA C Tank Farm	NON-RAD	Barium	7440-39-3	274	274	0	100	µg/L	—	—	25	98	0.27	56	95% Modified-t UCL	—

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	Benzene	71-43-2	112	0	112	0	µg/L	0.045	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Beryllium	7440-41-7	262	0	262	0	µg/L	0.10	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	29	0	29	0	µg/L	0.75	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Boron	7440-42-8	1	1	0	100	µg/L	—	—	23	23	0	23	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates/ The data set for variable boron was not processed.
WMA C Tank Farm	NON-RAD	Butylbenzylphthalate	85-68-7	16	0	16	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	Cadmium	7440-43-9	274	1	273	0.36	µg/L	0.10	4.1	4.0	4.0	0	4.0	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable cadmium was not processed.
WMA C Tank Farm	NON-RAD	Carbon disulfide	75-15-0	112	3	109	2.7	µg/L	0.050	1.0	0.065	0.12	0.30	0.12	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
WMA C Tank Farm	NON-RAD	Carbon tetrachloride	56-23-5	112	3	109	2.7	µg/L	0.063	1.0	0.22	1.3	0.97	1.3	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
WMA C Tank Farm	NON-RAD	Chloroform	67-66-3	112	20	92	18	µg/L	0.10	1.0	0.11	0.27	0.28	0.14	95% KM (percentile bootstrap) UCL	—
WMA C Tank Farm	NON-RAD	Chromium	7440-47-3	271	143	128	53	µg/L	3.1	14	2.4	106	0.89	11	95% KM (% bootstrap) UCL	—
WMA C Tank Farm	NON-RAD	Cobalt	7440-48-4	268	2	266	0.75	µg/L	0.10	4.1	1.8	4.0	0.54	4.0	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Copper	7440-50-8	274	14	260	5.1	µg/L	0.20	8.0	0.62	1,720	3.6	36	95% KM (Chebyshev) UCL	—
WMA C Tank Farm	NON-RAD	Cyanide	57-12-5	269	89	180	33	µg/L	1.7	4.0	3.3	41	0.66	6.7	95% KM (% bootstrap) UCL	—

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	di-n-Octylphthalate	117-84-0	16	1	15	6.25	µg/L	1	1	3.3	3.3	0	3.3	Maximum Detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable di-n-octylphthalate was not processed.
WMA C Tank Farm	NON-RAD	Fluoride	16984-48-8	280	212	68	76	µg/L	46	300	56	329	0.26	135	95% KM (percentile bootstrap) UCL	—
WMA C Tank Farm	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	271	62	209	23	µg/L	3.1	14	2.4	18	0.40	5.2	95% KM (% bootstrap) UCL	—
WMA C Tank Farm	NON-RAD	Iron	7439-89-6	272	178	94	65	µg/L	9.0	80	18	603	1.0	65	95% KM (BCA) UCL	—
WMA C Tank Farm	NON-RAD	Lead	7439-92-1	24	2	22	8.3	µg/L	0.10	0.20	0.29	0.37	0.18	0.30	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Manganese	7439-96-5	274	30	244	11	µg/L	0.20	6.0	0.80	70	1.3	5.2	95% KM (BCA) UCL	—
WMA C Tank Farm	NON-RAD	Mercury	7439-97-6	29	3	26	10	µg/L	0.050	0.10	0.054	0.20	0.79	0.20	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an “N/A” value on the output display.
WMA C Tank Farm	NON-RAD	Methyl methacrylate	80-62-6	95	1	94	1.1	µg/L	0.26	0.26	1.4	1.4	0	1.4	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable methyl methacrylate was not processed.

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	Methyl methanesulfonate	66-27-3	16	0	16	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Methylene chloride	75-09-2	112	0	112	0	µg/L	0.11	1.8	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Molybdenum	7439-98-7	2	2	0	100	µg/L	—	—	1.2	2.9	0.58	2.9	Maximum detect	Warning: This data set only has two observations Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable molybdenum was not processed.
WMA C Tank Farm	NON-RAD	Nickel	7440-02-0	274	121	153	44	µg/L	1.5	13	0.23	293	1.9	11	95% KM (% bootstrap) UCL	—
WMA C Tank Farm	NON-RAD	Nitrate	14797-55-8	280	280	0	100	µg/L	—	—	8,280	118,000	0.54	44,448	95% Chebyshev (Mean, Sd) UCL	—
WMA C Tank Farm	NON-RAD	Nitrite	14797-65-0	272	46	226	17	µg/L	65	591	125	532	0.37	149	95% KM (t) UCL	—
WMA C Tank Farm	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	28	0	28	0	µg/L	0.50	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	Phenol	108-95-2	43	0	43	0	µg/L	0.47	2.3	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Selenium	7782-49-2	45	45	0	100	µg/L	—	—	3.4	17	0.34	11	95% Student's-t UCL	—
WMA C Tank Farm	NON-RAD	Silver	7440-22-4	272	6	266	2.2	µg/L	0.10	11	4.0	6.8	0.18	5.5	95% KM (percentile bootstrap) UCL	Warning: There are only six detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA C Tank Farm	NON-RAD	Strontium	7440-24-6	274	274	0	100	µg/L	—	—	113	739	0.30	424	95% Modified-t UCL	—
WMA C Tank Farm	NON-RAD	Thallium	7440-28-0	29	2	27	6.9	µg/L	0.050	0.10	0.30	0.32	0.055	0.32	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Tin	7440-31-5	23	4	19	17	µg/L	0.10	0.10	0.14	0.42	0.47	0.39	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
WMA C Tank Farm	NON-RAD	Toluene	108-88-3	112	0	112	0	µg/L	0.062	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	NON-RAD	Tributyl phosphate	126-73-8	28	1	27	3.6	µg/L	0.47	1.0	1.0	1.0	0	1.0	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable tributyl phosphate was not processed.
WMA C Tank Farm	NON-RAD	Trichloroethene	79-01-6	112	0	112	0	µg/L	0.21	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	NON-RAD	Uranium	7440-61-1	239	237	2	99	µg/L	0.10	0.10	0.51	38	0.70	4.3	95% KM (BCA) UCL	—
WMA C Tank Farm	NON-RAD	Vanadium	7440-62-2	273	240	33	88	µg/L	7.0	24	7.6	35	0.22	17	95% KM (BCA) UCL	—
WMA C Tank Farm	NON-RAD	Zinc	7440-66-6	272	52	220	19	µg/L	3.3	25	4.0	53	0.95	5.6	95% KM (% bootstrap) UCL	—
WMA C Tank Farm	RAD	Americium-241	14596-10-2	8	1	7	13	pCi/L	0.0096	0.058	0.14	0.14	0	0.14	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable americium-241 was not processed.
WMA C Tank Farm	RAD	Carbon-14	14762-75-5	8	0	8	0	pCi/L	-2.71E+00	6.7	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	RAD	Cesium-137	10045-97-3	192	0	192	0	pCi/L	-7.90E+00	20	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	RAD	Cobalt-60	10198-40-0	192	0	192	0	pCi/L	-3.90E+00	8.7	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	RAD	Europium-154	15585-10-1	192	0	192	0	pCi/L	-1.80E+01	25	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	RAD	Iodine-129	15046-84-1	92	92	0	100	pCi/L	—	—	1.3	7.5	0.36	4.6	95% Student's-t UCL	—
WMA C Tank Farm	RAD	Neptunium-237	13994-20-2	8	0	8	0	pCi/L	-4.56E-02	0.042	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-14. Summary of Groundwater Exposure Point Concentrations for WMA C Tank Farm Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
WMA C Tank Farm	RAD	Plutonium-238	13981-16-3	8	0	8	0	pCi/L	-5.70E-02	0.087	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	RAD	Plutonium-239/240	PU-239/240	8	2	6	25	pCi/L	0.0091	0.045	0.055	0.11	0.47	0.11	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	RAD	Strontium-90	10098-97-2	8	0	8	0	pCi/L	-6.60E+00	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
WMA C Tank Farm	RAD	Technetium-99	14133-76-7	259	245	14	95	pCi/L	-4.40E+00	4.9	7.0	26,000	1.3	5,981	97.5% KM (Chebyshev) UCL	—
WMA C Tank Farm	RAD	Tritium	10028-17-8	80	78	2	98	pCi/L	210	250	370	2,900	0.34	1,074	95% KM (BCA) UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit
WMA = waste management area

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	NON-RAD	Acetone	67-64-1	4	0	4	0	µg/L	1.0	5.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable acetone was not processed.
B Plant	NON-RAD	Aluminum	7429-90-5	4	0	4	0	µg/L	10	20	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimate. The data set for variable aluminum was not processed.
B Plant	NON-RAD	Antimony	7440-36-0	8	5	3	63	µg/L	0.60	0.60	44	85	0.25	75	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	NON-RAD	Arsenic	7440-38-2	18	18	0	100	µg/L	—	—	1.2	6.7	0.40	4.5	95% Student's-t UCL	—
B Plant	NON-RAD	Barium	7440-39-3	28	28	0	100	µg/L	—	—	47	100	0.20	70	95% Student's-t UCL	—
B Plant	NON-RAD	Benzene	71-43-2	4	0	4	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable benzene was not processed.
B Plant	NON-RAD	Beryllium	7440-41-7	24	0	24	0	µg/L	0.20	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
B Plant	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	4	0	4	0	µg/L	0.90	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable bis(2-ethylhexyl) phthalate was not processed.

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	NON-RAD	Boron	7440-42-8	3	3	0	100	µg/L	—	—	20	53	0.57	53	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable boron was not processed.
B Plant	NON-RAD	Cadmium	7440-43-9	28	1	27	3.6	µg/L	0.10	4.1	5.1	5.1	0	5.1	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the Project Team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable cadmium was not processed.
B Plant	NON-RAD	Carbon disulfide	75-15-0	4	0	4	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon disulfide was not processed.
B Plant	NON-RAD	Carbon tetrachloride	56-23-5	4	0	4	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon tetrachloride was not processed.
B Plant	NON-RAD	Chloroform	67-66-3	4	0	4	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable chloroform was not processed.
B Plant	NON-RAD	Chromium	7440-47-3	28	9	19	32	µg/L	5.0	14	0.83	36	0.96	8.5	95% KM (percentile bootstrap) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	NON-RAD	Cobalt	7440-48-4	28	0	28	0	µg/L	0.10	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
B Plant	NON-RAD	Copper	7440-50-8	28	5	23	18	µg/L	4.0	6.0	0.28	8.3	0.89	3.2	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	NON-RAD	Cyanide	57-12-5	7	4	3	57	µg/L	4.0	4.0	4.2	9.0	0.35	6.9	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	NON-RAD	Fluoride	16984-48-8	57	57	0	100	µg/L	—	—	99	3,270	1.4	892	95% Chebyshev (Mean, Sd) UCL	—
B Plant	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	23	2	21	8.7	µg/L	5.0	14	5.1	5.4	0.040	5.4	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
B Plant	NON-RAD	Iron	7439-89-6	28	21	7	75	µg/L	19	38	38	400	0.83	136	95% KM (percentile bootstrap) UCL	—
B Plant	NON-RAD	Lead	7439-92-1	3	0	3	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable lead was not processed.

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	NON-RAD	Manganese	7439-96-5	28	7	21	25	µg/L	0.20	6.0	0.24	29	0.93	9.3	95% KM (percentile bootstrap) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	NON-RAD	Mercury	7439-97-6	4	0	4	0	µg/L	0.060	0.10	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable mercury was not processed.
B Plant	NON-RAD	Methylene chloride	75-09-2	4	0	4	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methylene chloride was not processed.
B Plant	NON-RAD	Molybdenum	7439-98-7	3	3	0	100	µg/L	—	—	3.6	7.1	0.33	7.1	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable molybdenum was not processed.
B Plant	NON-RAD	Nickel	7440-02-0	28	6	22	21	µg/L	0.20	5.1	0.94	20	0.85	8.5	95% KM (percentile bootstrap) UCL	Warning: There are only six detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	NON-RAD	Nitrate	14797-55-8	57	57	0	100	µg/L	—	—	30,100	420,000	0.73	86,183	95% Modified-t UCL	—
B Plant	NON-RAD	Nitrite	14797-65-0	57	11	46	19	µg/L	65	177	155	279	0.19	207	95% KM (percentile bootstrap) UCL	—
B Plant	NON-RAD	Phenol	108-95-2	4	0	4	0	µg/L	0.90	2.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable phenol was not processed.
B Plant	NON-RAD	Selenium	7782-49-2	3	3	0	100	µg/L	—	—	4.4	8.2	0.31	8.2	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable selenium was not processed.

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	NON-RAD	Silver	7440-22-4	28	1	27	3.6	µg/L	0.10	7.0	8.0	8.0	0	8.0	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable silver was not processed.
B Plant	NON-RAD	Strontium	7440-24-6	28	28	0	100	µg/L	—	—	217	458	0.18	338	95% Student's-t UCL	—
B Plant	NON-RAD	Thallium	7440-28-0	4	0	4	0	µg/L	0.060	0.10	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable thallium was not processed.
B Plant	NON-RAD	Tin	7440-31-5	3	1	2	33	µg/L	0.10	0.10	0.28	0.28	0	0.28	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable tin was not processed.
B Plant	NON-RAD	Toluene	108-88-3	4	0	4	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable toluene was not processed.
B Plant	NON-RAD	Tributyl phosphate	126-73-8	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable tributyl phosphate was not processed.
B Plant	NON-RAD	Trichloroethene	79-01-6	4	0	4	0	µg/L	0.50	1.0	—	—	—	—	—	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable trichloroethene was not processed.
B Plant	NON-RAD	Uranium	7440-61-1	64	64	0	100	µg/L	—	—	2.6	47	0.67	23	95% approximate gamma UCL	—
B Plant	NON-RAD	Vanadium	7440-62-2	28	25	3	89	µg/L	12	17	9.0	26	0.31	18	95% KM (Chebyshev) UCL	—

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	NON-RAD	Zinc	7440-66-6	28	9	19	32	µg/L	4.0	9.0	4.0	793	1.9	369	99% KM (Chebyshev) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	RAD	Americium-241	14596-10-2	16	4	12	25	pCi/L	-3.30E-02	0.11	0.091	0.25	0.50	0.19	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	RAD	Carbon-14	14762-75-5	4	1	3	25	pCi/L	2.7	18	12	12	0	12	Maximum detect	Warning: This data set only has four observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon-14 was not processed.
B Plant	RAD	Cesium-137	10045-97-3	36	16	20	44	pCi/L	-6.00E+00	5.3	35	2,430	1.6	1,390	99% KM (Chebyshev) UCL	—
B Plant	RAD	Cobalt-60	10198-40-0	36	0	36	0	pCi/L	-5.80E+00	14	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
B Plant	RAD	Europium-154	15585-10-1	36	1	35	2.8	pCi/L	-3.20E+01	18	45	45	0	45	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable europium-154 was not processed.
B Plant	RAD	Iodine-129	15046-84-1	41	29	12	71	pCi/L	-2.78E-02	1.9	0.23	3.3	0.58	1.5	95% KM (percentile bootstrap) UCL	—

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	RAD	Neptunium-237	13994-20-2	14	1	13	7.1	pCi/L	-6.37E-02	0.12	0.71	0.71	0	0.71	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable neptunium-237 was not processed.
B Plant	RAD	Plutonium-238	13981-16-3	32	1	31	3.1	pCi/L	-1.70E-01	0.49	0.19	0.19	0	0.19	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable plutonium-238 was not processed.
B Plant	RAD	Plutonium-239/240	PU-239/240	32	19	13	59	pCi/L	-1.80E-02	0.052	0.028	52	1.9	30	99% KM (Chebyshev) UCL	—
B Plant	RAD	Strontium-90	10098-97-2	41	26	15	63	pCi/L	-1.00E+01	1.5	2.8	4,900	1.3	1,127	95% KM (percentile bootstrap) UCL	—
B Plant	RAD	Technetium-99	14133-76-7	23	23	0	100	pCi/L	—	—	24	5,700	3.4	1,415	95% Chebyshev (Mean, Sd) UCL	—
B Plant	RAD	Tritium	10028-17-8	53	53	0	100	pCi/L	—	—	690	12,000	0.58	5,272	95% Student's-t UCL	—
B Plant	RAD	Uranium-233/234	U-233/234	3	3	0	100	pCi/L	—	—	4.6	11	0.40	11	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-233/234 was not processed.
B Plant	RAD	Uranium-234	13966-29-5	7	7	0	100	pCi/L	—	—	3.1	10	0.39	8.3	95% Student's-t UCL	Warning: There are only seven values in this data. It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-15. Summary of Groundwater Exposure Point Concentrations for B Plant Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
B Plant	RAD	Uranium-235	15117-96-1	10	9	1	90	pCi/L	0.088	0.088	0.18	0.72	0.45	0.46	95% KM (t) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
B Plant	RAD	Uranium-238	U-238	10	10	0	100	pCi/L	--	--	2.2	10	0.41	8.4	95% Student's-t UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	NON-RAD	Acetone	67-64-1	1	0	1	0	µg/L	5.0	5.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable acetone was not processed.
Semiworks	NON-RAD	Aluminum	7429-90-5	1	0	1	0	µg/L	20	20	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable aluminum was not processed.
Semiworks	NON-RAD	Antimony	7440-36-0	1	0	1	0	µg/L	0.60	0.60	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable antimony was not processed.
Semiworks	NON-RAD	Arsenic	7440-38-2	2	2	0	100	µg/L	—	—	1.0	4.0	0.85	4.0	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable arsenic was not processed.
Semiworks	NON-RAD	Barium	7440-39-3	2	2	0	100	µg/L	—	—	65	83	0.17	83	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable barium was not processed.
Semiworks	NON-RAD	Benzene	71-43-2	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable benzene was not processed.
Semiworks	NON-RAD	Beryllium	7440-41-7	2	0	2	0	µg/L	0.20	4.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable beryllium was not processed.
Semiworks	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	1	0	1	0	µg/L	0.90	0.90	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable bis(2-ehtylhexyl) phthalate was not processed.

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	NON-RAD	Boron	7440-42-8	1	1	0	100	µg/L	—	—	53	53	0	53	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable boron was not processed.
Semiworks	NON-RAD	Cadmium	7440-43-9	2	0	2	0	µg/L	0.10	4.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable cadmium was not processed.
Semiworks	NON-RAD	Carbon disulfide	75-15-0	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon disulfide was not processed.
Semiworks	NON-RAD	Carbon tetrachloride	56-23-5	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon tetrachloride was not processed.
Semiworks	NON-RAD	Chloroform	67-66-3	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable chloroform was not processed.
Semiworks	NON-RAD	Chromium	7440-47-3	2	2	0	100	µg/L	—	—	2.3	5.2	0.55	5.2	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable chromium was not processed.
Semiworks	NON-RAD	Cobalt	7440-48-4	2	0	2	0	µg/L	0.10	4.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable cobalt was not processed.
Semiworks	NON-RAD	Copper	7440-50-8	2	1	1	50	µg/L	4.0	4.0	1.9	1.9	0	1.9	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable copper was not processed.

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	NON-RAD	Cyanide	57-12-5	1	0	1	0	µg/L	4.0	4.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable cyanide was not processed.
Semiworks	NON-RAD	Fluoride	16984-48-8	3	3	0	100	µg/L	—	—	106	214	0.34	214	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable fluoride was not processed.
Semiworks	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	1	1	0	100	µg/L	—	—	5.4	5.4	0	5.4	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable chromium was not processed.
Semiworks	NON-RAD	Iron	7439-89-6	2	0	2	0	µg/L	19	20	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable iron was not processed.
Semiworks	NON-RAD	Lead	7439-92-1	1	0	1	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable lead was not processed.
Semiworks	NON-RAD	Manganese	7439-96-5	2	0	2	0	µg/L	0.20	4.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable manganese was not processed.
Semiworks	NON-RAD	Mercury	7439-97-6	1	0	1	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable mercury was not processed.
Semiworks	NON-RAD	Methylene chloride	75-09-2	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methylene chloride was not processed.

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	NON-RAD	Molybdenum	7439-98-7	1	1	0	100	µg/L	—	—	3.6	3.6	0	3.6	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable molybdenum was not processed.
Semiworks	NON-RAD	Nickel	7440-02-0	2	1	1	50	µg/L	4.0	4.0	1.2	1.2	0	1.2	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable nickel was not processed.
Semiworks	NON-RAD	Nitrate	14797-55-8	3	3	0	100	µg/L	—	—	27,500	41,300	0.20	41,300	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable nitrate was not processed.
Semiworks	NON-RAD	Nitrite	14797-65-0	3	1	2	33	µg/L	118	131	200	200	0	200	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable nitrite was not processed.
Semiworks	NON-RAD	Phenol	108-95-2	1	0	1	0	µg/L	0.90	0.90	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable phenol was not processed.
Semiworks	NON-RAD	Selenium	7782-49-2	1	1	0	100	µg/L	—	—	5.9	5.9	0	5.9	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable selenium was not processed.
Semiworks	NON-RAD	Silver	7440-22-4	2	0	2	0	µg/L	0.10	4.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable silver was not processed.
Semiworks	NON-RAD	Strontium	7440-24-6	2	2	0	100	µg/L	—	—	298	377	0.17	377	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable strontium was not processed.

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	NON-RAD	Thallium	7440-28-0	1	0	1	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable thallium was not processed.
Semiworks	NON-RAD	Tin	7440-31-5	1	0	1	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable tin was not processed.
Semiworks	NON-RAD	Toluene	108-88-3	1	0	1	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable toluene was not processed.
Semiworks	NON-RAD	Trichloroethene	79-01-6	1	0	1	0	µg/L	0.50	0.50	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable trichloroethene was not processed.
Semiworks	NON-RAD	Uranium	7440-61-1	1	1	0	100	µg/L	—	—	6.1	6.1	0	6.1	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium was not processed.
Semiworks	NON-RAD	Vanadium	7440-62-2	2	2	0	100	µg/L	—	—	12	13	0.023	13	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable vanadium was not processed.
Semiworks	NON-RAD	Zinc	7440-66-6	2	1	1	50	µg/L	5.0	5.0	6.6	6.6	0	6.6	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable zinc was not processed.
Semiworks	RAD	Americium-241	14596-10-2	1	0	1	0	pCi/L	-1.10E-02	-1.10E-02	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable americium-241 was not processed.

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	RAD	Carbon-14	14762-75-5	1	0	1	0	pCi/L	7.6	7.6	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable carbon-14 was not processed.
Semiworks	RAD	Cesium-137	10045-97-3	2	0	2	0	pCi/L	-6.00E+00	0.033	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable cesium-137 was not processed.
Semiworks	RAD	Cobalt-60	10198-40-0	2	0	2	0	pCi/L	0.29	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable cobalt-60 was not processed.
Semiworks	RAD	Europium-154	15585-10-1	2	0	2	0	pCi/L	-9.00E+00	-5.60E-01	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable europium-154 was not processed.
Semiworks	RAD	Iodine-129	15046-84-1	3	3	0	100	pCi/L	—	—	0.69	1.8	0.44	1.8	Maximum detect	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable iodine-129 was not processed.
Semiworks	RAD	Neptunium-237	13994-20-2	1	0	1	0	pCi/L	0.042	0.042	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable neptunium-237 was not processed.
Semiworks	RAD	Plutonium-238	13981-16-3	1	0	1	0	pCi/L	0.013	0.013	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-238 was not processed.

Table G-16. Summary of Groundwater Exposure Point Concentrations for Semiworks Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Semiworks	RAD	Plutonium-239/240	PU-239/240	1	1	0	100	pCi/L	—	—	0.11	0.11	0	0.11	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-239/240 was not processed.
Semiworks	RAD	Strontium-90	10098-97-2	1	1	0	100	pCi/L	—	—	2.8	2.8	0	2.8	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable strontium-90 was not processed.
Semiworks	RAD	Technetium-99	14133-76-7	2	2	0	100	pCi/L	—	—	24	62	0.62	62	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable technetium-99 was not processed.
Semiworks	RAD	Tritium	10028-17-8	2	2	0	100	pCi/L	—	—	5,000	7,500	0.28	7,500	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable tritium was not processed.

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = egression on order statistics
UCL = upper confidence limit

Table G-17. Summary of Groundwater Exposure Point Concentrations for LERF Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LERF	NON-RAD	Acetone	67-64-1	31	0	31	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Antimony	7440-36-0	1	1	0	100	µg/L	—	—	0.32	0.32	0	0.32	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable Antimony was not processed.
LERF	NON-RAD	Arsenic	7440-38-2	32	32	0	100	µg/L	—	—	2.5	5.5	0.19	4.4	95% Student's-t UCL	—
LERF	NON-RAD	Barium	7440-39-3	39	39	0	100	µg/L	—	—	47	89	0.19	66	95% Modified-t UCL	—
LERF	NON-RAD	Benzene	71-43-2	31	0	31	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Beryllium	7440-41-7	34	0	34	0	µg/L	4.0	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	32	0	32	0	µg/L	0.76	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-17. Summary of Groundwater Exposure Point Concentrations for LERF Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LERF	NON-RAD	Cadmium	7440-43-9	39	0	39	0	µg/L	4.0	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Carbon disulfide	75-15-0	31	0	31	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Carbon tetrachloride	56-23-5	31	2	29	6.5	µg/L	1.0	1.0	2.3	2.4	0.030	2.3	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC, BTV).
LERF	NON-RAD	Chloroform	67-66-3	31	0	31	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Chromium	7440-47-3	39	22	17	56	µg/L	4.0	14	5.3	39	0.52	14	95% KM (percentile bootstrap) UCL	—
LERF	NON-RAD	Cobalt	7440-48-4	39	0	39	0	µg/L	4.0	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-17. Summary of Groundwater Exposure Point Concentrations for LERF Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LERF	NON-RAD	Copper	7440-50-8	39	2	37	5.1	µg/L	4.0	9.0	4.0	4.2	0.034	4.0	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC, BTV).
LERF	NON-RAD	Fluoride	16984-48-8	39	36	3	92	µg/L	48	116	100	349	0.26	250	95% KM (t) UCL	—
LERF	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	39	5	34	13	µg/L	4.0	14	5.5	8.0	0.16	6.6	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LERF	NON-RAD	Iron	7439-89-6	39	32	7	82	µg/L	18	38	23	1,090	1.5	230	95% KM (Chebyshev) UCL	—
LERF	NON-RAD	Manganese	7439-96-5	39	12	27	31	µg/L	4.0	6.0	4.1	41	0.74	9.7	95% KM (t) UCL	—
LERF	NON-RAD	Methylene chloride	75-09-2	31	0	31	0	µg/L	1.0	1.8	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Nickel	7440-02-0	39	26	13	67	µg/L	4.0	4.0	5.6	25	0.40	11	95% KM (percentile bootstrap) UCL	—
LERF	NON-RAD	Nitrate	14797-55-8	39	39	0	100	µg/L	—	—	14,600	57,500	0.38	41,898	95% Student's-t UCL	—
LERF	NON-RAD	Nitrite	14797-65-0	39	4	35	10	µg/L	66	576	156	526	0.48	323	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
LERF	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	26	0	26	0	µg/L	0.57	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-17. Summary of Groundwater Exposure Point Concentrations for LERF Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LERF	NON-RAD	Phenol	108-95-2	34	0	34	0	µg/L	0.48	2.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Silver	7440-22-4	38	1	37	2.6	µg/L	4.0	7.0	7.5	7.5	0	7.5	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable silver was not processed.
LERF	NON-RAD	Strontium	7440-24-6	39	39	0	100	µg/L	—	—	297	806	0.27	568	95% Student's-t UCL	—
LERF	NON-RAD	Toluene	108-88-3	31	0	31	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Tributyl phosphate	126-73-8	32	0	32	0	µg/L	0.48	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Trichloroethene	79-01-6	31	0	31	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	NON-RAD	Vanadium	7440-62-2	39	36	3	92	µg/L	12	17	8.2	28	0.35	18	95% KM (t) UCL	—

Table G-17. Summary of Groundwater Exposure Point Concentrations for LERF Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
LERF	NON-RAD	Zinc	7440-66-6	39	14	25	36	µg/L	4.0	9.0	5.0	14	0.30	8.3	95% KM (percentile bootstrap) UCL	—
LERF	RAD	Cesium-137	10045-97-3	33	0	33	0	pCi/L	-8.72E-01	1.9	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	RAD	Cobalt-60	10198-40-0	33	0	33	0	pCi/L	-1.19E+00	2.3	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	RAD	Europium-154	15585-10-1	33	0	33	0	pCi/L	-5.42E+00	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
LERF	RAD	Iodine-129	15046-84-1	35	13	22	37	pCi/L	-3.30E-02	0.63	0.20	0.62	0.36	0.32	95% KM (percentile bootstrap) UCL	—
LERF	RAD	Tritium	10028-17-8	44	14	30	32	pCi/L	-5.70E+01	250	340	1,000	0.25	632	95% KM (percentile bootstrap) UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
LERF = Liquid Effluent Retention Facility
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-18. Summary of Groundwater Exposure Point Concentrations for Gable Mountain Pond Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Gable Mountain Pond	NON-RAD	Antimony	7440-36-0	2	1	1	50	µg/L	4.0	4.0	72	72	0	72	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable antimony was not processed.
Gable Mountain Pond	NON-RAD	Arsenic	7440-38-2	1	1	0	100	µg/L	—	—	4.7	4.7	0	4.7	Maximum detect	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable arsenic was not processed.
Gable Mountain Pond	NON-RAD	Barium	7440-39-3	9	9	0	100	µg/L	—	—	8.1	68	0.58	52	95% Student's-t UCL	Warning: There are only nine values in this data. It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Gable Mountain Pond	NON-RAD	Beryllium	7440-41-7	9	0	9	0	µg/L	0.50	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Gable Mountain Pond	NON-RAD	Cadmium	7440-43-9	9	0	9	0	µg/L	0.45	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Gable Mountain Pond	NON-RAD	Chromium	7440-47-3	9	3	6	33	µg/L	3.1	13	30	42	0.19	34	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.

Table G-18. Summary of Groundwater Exposure Point Concentrations for Gable Mountain Pond Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Gable Mountain Pond	NON-RAD	Cobalt	7440-48-4	8	0	8	0	µg/L	4.0	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Gable Mountain Pond	NON-RAD	Copper	7440-50-8	9	2	7	22	µg/L	4.0	6.0	5.9	6.0	0.012	6.0	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Gable Mountain Pond	NON-RAD	Fluoride	16984-48-8	24	16	8	67	µg/L	46	250	49	153	0.32	102	95% KM (percentile bootstrap) UCL	—
Gable Mountain Pond	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	8	1	7	13	µg/L	3.1	13	5.3	5.3	0	5.3	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable chromium was not processed.
Gable Mountain Pond	NON-RAD	Iron	7439-89-6	9	9	0	100	µg/L	—	—	39	6,250	1.8	3,103	95% approximate gamma UCL	Warning: There are only nine values in this data. It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Gable Mountain Pond	NON-RAD	Manganese	7439-96-5	9	8	1	89	µg/L	4.0	4.0	3.7	142	1.5	91	95% KM (Chebyshev) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Gable Mountain Pond	NON-RAD	Nickel	7440-02-0	9	5	4	56	µg/L	4.0	13	6.6	22	0.52	22	95% KM (% bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-18. Summary of Groundwater Exposure Point Concentrations for Gable Mountain Pond Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Gable Mountain Pond	NON-RAD	Nitrate	14797-55-8	24	24	0	100	µg/L	—	—	6,820	173,000	0.76	94,233	95% approximate gamma UCL	—
Gable Mountain Pond	NON-RAD	Nitrite	14797-65-0	24	5	19	21	µg/L	84	2,500	132	263	0.28	209	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Gable Mountain Pond	NON-RAD	Silver	7440-22-4	9	0	9	0	µg/L	4.0	6.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Gable Mountain Pond	NON-RAD	Strontium	7440-24-6	9	9	0	100	µg/L	—	—	205	1,440	0.72	1,103	95% approximate gamma UCL	Warning: There are only nine values in this data. It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Gable Mountain Pond	NON-RAD	Vanadium	7440-62-2	9	3	6	33	µg/L	5.0	12	5.4	8.1	0.23	8.1	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
Gable Mountain Pond	NON-RAD	Zinc	7440-66-6	9	4	5	44	µg/L	5.0	9.0	5.0	45	0.98	23	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Gable Mountain Pond	RAD	Iodine-129	15046-84-1	9	0	9	0	pCi/L	-3.78E-02	0.18	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Gable Mountain Pond	RAD	Strontium-90	10098-97-2	24	18	6	75	pCi/L	-4.70E+00	1.8	16	522	0.61	214	95% KM (percentile bootstrap) UCL	—

Table G-18. Summary of Groundwater Exposure Point Concentrations for Gable Mountain Pond Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Gable Mountain Pond	RAD	Technetium-99	14133-76-7	4	0	4	0	pCi/L	-9.90E+00	-6.00E-01	—	—	—	—	—	Warning: This data set only has 4 observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable Technetium-99 was not processed.
Gable Mountain Pond	RAD	Tritium	10028-17-8	19	1	18	5.3	pCi/L	-1.80E+02	250	3,200	3,200	0	3,200	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable tritium was not processed.

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	NON-RAD	2-Hexanone	591-78-6	8	0	8	0	µg/L	0.22	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Acetone	67-64-1	22	0	22	0	µg/L	0.34	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Aluminum	7429-90-5	19	11	8	58	µg/L	5.0	10	7.2	7,180	2.1	5,536	99% KM (Chebyshev) UCL	—
200-BP-5 west	NON-RAD	Antimony	7440-36-0	16	2	14	13	µg/L	0.60	4.0	52	59	0.087	59	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC, BTV).
200-BP-5 west	NON-RAD	Arsenic	7440-38-2	30	23	7	77	µg/L	0.80	4.9	3.1	8.1	0.22	6.1	95% KM (percentile bootstrap) UCL	—
200-BP-5 west	NON-RAD	Barium	7440-39-3	60	60	0	100	µg/L	—	—	12	330	1.1	68	95% Chebyshev (Mean, Sd) UCL	—
200-BP-5 west	NON-RAD	Benzene	71-43-2	22	0	22	0	µg/L	0.045	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	NON-RAD	Beryllium	7440-41-7	57	1	56	1.8	µg/L	0.10	4.0	0.12	0.12	0	0.12	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable Beryllium was not processed.
200-BP-5 west	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	11	5	6	45	µg/L	0.70	3.4	2.0	2.9	0.14	2.5	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Boron	7440-42-8	6	0	6	0	µg/L	19	41	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Cadmium	7440-43-9	60	5	55	8.3	µg/L	0.10	4.1	0.20	35	1.3	2.8	95% KM (t) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Carbon disulfide	75-15-0	22	2	20	9.1	µg/L	0.050	1.0	0.056	2.4	1.3	1.6	99% KM (Chebyshev) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Carbon tetrachloride	56-23-5	22	2	20	9.1	µg/L	0.063	1.0	2.0	5.4	0.65	2.5	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	NON-RAD	Chloroform	67-66-3	22	3	19	14	µg/L	0.10	1.0	0.11	0.66	0.78	0.66	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
200-BP-5 west	NON-RAD	Chromium	7440-47-3	60	24	36	40	µg/L	3.1	14	3.2	140	1.4	16	95% KM (% bootstrap) UCL	—
200-BP-5 west	NON-RAD	Cobalt	7440-48-4	59	11	48	19	µg/L	0.10	4.1	0.14	34	1.2	3.4	95% KM (t) UCL	—
200-BP-5 west	NON-RAD	Copper	7440-50-8	59	9	50	15	µg/L	0.20	6.0	0.30	68	1.5	5.0	95% KM (t) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Cyanide	57-12-5	87	74	13	85	µg/L	4.0	4.0	4.0	195	1.1	72	95% KM (Chebyshev) UCL	—
200-BP-5 west	NON-RAD	Fluoride	16984-48-8	100	97	3	97	µg/L	60	105	71	832	0.38	422	95% KM (t) UCL	—
200-BP-5 west	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	62	16	46	26	µg/L	1.0	14	2.0	27	0.85	5.5	95% KM (% bootstrap) UCL	—
200-BP-5 west	NON-RAD	Iron	7439-89-6	60	53	7	88	µg/L	9.0	38	20	18,900	2.8	4,414	97.5% KM (Chebyshev) UCL	—
200-BP-5 west	NON-RAD	Lead	7439-92-1	8	7	1	88	µg/L	0.10	0.10	0.38	8.5	0.79	5.1	95% KM (t) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Lithium	7439-93-2	6	5	1	83	µg/L	4.0	4.0	8.8	15	0.24	13	95% KM (t) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Manganese	7439-96-5	60	27	33	45	µg/L	3.3	6.0	4.0	1,190	2.3	147	95% KM (Chebyshev) UCL	—

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	NON-RAD	Mercury	7439-97-6	17	3	14	18	µg/L	0.050	0.10	0.073	0.64	0.99	0.18	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
200-BP-5 west	NON-RAD	Methyl methacrylate	80-62-6	8	0	8	0	µg/L	0.26	2.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Methylene chloride	75-09-2	22	0	22	0	µg/L	0.11	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Molybdenum	7439-98-7	8	8	0	100	µg/L	—	—	0.19	11	0.94	7.8	95% Student's-t UCL	Warning: There are only eight values in this data. It should be noted that even though bootstrap methods may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Nickel	7440-02-0	60	13	47	22	µg/L	4.0	67	5.8	78	0.99	13	95% KM (t) UCL	—
200-BP-5 west	NON-RAD	Nitrate	14797-55-8	100	96	4	96	µg/L	168	421	248	322,000	1.0	86,692	95% KM (Chebyshev) UCL	—
200-BP-5 west	NON-RAD	Nitrite	14797-65-0	99	21	78	21	µg/L	9.9	2,500	136	555	0.39	191	95% KM (% Bootstrap) UCL	—
200-BP-5 west	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	10	0	10	0	µg/L	0.50	0.90	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	NON-RAD	Phenol	108-95-2	12	0	12	0	µg/L	0.48	2.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Selenium	7782-49-2	8	6	2	75	µg/L	2.0	3.3	1.5	4.2	0.37	3.1	95% KM (t) UCL	Warning: There are only six detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	NON-RAD	Silver	7440-22-4	57	0	57	0	µg/L	0.10	7.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Strontium	7440-24-6	60	60	0	100	µg/L	—	—	33	545	0.39	311	95% approximate gamma UCL	—
200-BP-5 west	NON-RAD	Thallium	7440-28-0	19	0	19	0	µg/L	0.050	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Tin	7440-31-5	8	0	8	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	NON-RAD	Toluene	108-88-3	22	0	22	0	µg/L	0.062	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Tributyl phosphate	126-73-8	12	3	9	25	µg/L	0.48	1.0	0.60	1.7	0.64	1.7	95% KM (percentile bootstrap) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
200-BP-5 west	NON-RAD	Trichloroethene	79-01-6	22	0	22	0	µg/L	0.21	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	NON-RAD	Uranium	7440-61-1	67	66	1	99	µg/L	0.10	0.10	0.27	22	0.84	8.9	95% KM (Chebyshev) UCL	—
200-BP-5 west	NON-RAD	Vanadium	7440-62-2	60	48	12	80	µg/L	12	17	5.0	29	0.25	17	95% KM (t) UCL	—
200-BP-5 west	NON-RAD	Zinc	7440-66-6	60	28	32	47	µg/L	4.0	9.0	4.3	5,450	2.3	1,168	97.5% KM (Chebyshev) UCL	—
200-BP-5 west	RAD	Americium-241	14596-10-2	18	4	14	22	pCi/L	-1.30E-01	0.087	0.092	0.62	0.90	0.31	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	RAD	Carbon-14	14762-75-5	18	0	18	0	pCi/L	-2.35E+00	7.2	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	RAD	Cesium-137	10045-97-3	69	0	69	0	pCi/L	-8.90E+00	4.8	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	RAD	Cobalt-60	10198-40-0	69	6	63	8.7	pCi/L	-7.30E+00	6.9	2.9	9.9	0.35	6.4	95% KM (percentile bootstrap) UCL	Warning: There are only six detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
200-BP-5 west	RAD	Europium-154	15585-10-1	69	0	69	0	pCi/L	-2.30E+01	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	RAD	Iodine-129	15046-84-1	78	28	50	36	pCi/L	-1.12E-01	2.8	0.31	4.0	0.66	1.1	95% KM (t) UCL	—
200-BP-5 west	RAD	Neptunium-237	13994-20-2	12	2	10	17	pCi/L	-5.20E-02	0.076	0.054	0.57	1.2	0.57	Maximum detect	Recommended UCL exceeds maximum concentration. EPC defaulting to maximum concentration since 97.5% and 99% Chebyshev (Mean, Sd) UCLs were not calculated.

Table G-19. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 West Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
200-BP-5 west	RAD	Plutonium-238	13981-16-3	17	0	17	0	pCi/L	-6.20E-02	0.15	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	RAD	Plutonium-239/240	PU-239/240	17	1	16	5.9	pCi/L	-3.90E-02	0.061	0.052	0.052	0	0.052	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable plutonium-239/240 was not processed.
200-BP-5 west	RAD	Strontium-90	10098-97-2	33	2	31	6.1	pCi/L	-7.50E+00	0.72	2.9	180	1.4	83	99% KM (Chebyshev) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
200-BP-5 west	RAD	Technetium-99	14133-76-7	98	84	14	86	pCi/L	-1.30E+01	7.2	8.3	5,800	1.2	1,711	97.5% KM (Chebyshev) UCL	—
200-BP-5 west	RAD	Tritium	10028-17-8	96	76	20	79	pCi/L	-9.90E+01	240	200	20,000	1.2	6,693	97.5% KM (Chebyshev) UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	2-Hexanone	591-78-6	12	0	12	0	µg/L	0.22	0.22	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Acetone	67-64-1	12	0	12	0	µg/L	0.34	0.34	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Aluminum	7429-90-5	12	0	12	0	µg/L	10	10	—	—	—	—	—	Warning: All observations are NDs; therefore all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Antimony	7440-36-0	13	0	13	0	µg/L	0.60	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Arsenic	7440-38-2	14	14	0	100	µg/L	—	—	3.6	15	0.54	13	95% Chebyshev (Mean, Sd) UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Barium	7440-39-3	36	36	0	100	µg/L	—	—	9.5	43	0.45	26	95% Modified-t UCL	—

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	Benzene	71-43-2	12	0	12	0	µg/L	0.045	0.064	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Beryllium	7440-41-7	34	0	34	0	µg/L	0.10	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Boron	7440-42-8	12	1	11	8.3	µg/L	19	41	29	29	0	29	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable boron was not processed.
Far-field area (north of Gable Gap)	NON-RAD	Cadmium	7440-43-9	36	0	36	0	µg/L	0.20	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Carbon disulfide	75-15-0	12	0	12	0	µg/L	0.050	0.051	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	Carbon tetrachloride	56-23-5	12	0	12	0	µg/L	0.063	0.12	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Chloroform	67-66-3	12	0	12	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Chromium	7440-47-3	36	18	18	50	µg/L	1.0	14	1.1	18	0.52	8.7	95% KM (percentile bootstrap) UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Cobalt	7440-48-4	34	0	34	0	µg/L	0.10	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Copper	7440-50-8	36	2	34	5.6	µg/L	0.20	6.0	20	118	1.0	118	Maximum Detect	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	Cyanide	57-12-5	13	0	13	0	µg/L	4.0	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Fluoride	16984-48-8	45	45	0	100	µg/L	—	—	300	789	0.26	599	95% Student's-t UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	36	16	20	44	µg/L	0.50	14	1.7	19	0.36	11	95% KM (percentile bootstrap) UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Iron	7439-89-6	36	29	7	81	µg/L	18	38	40	5,220	2.1	1,316	97.5% KM (Chebyshev) UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Lead	7439-92-1	12	2	10	17	µg/L	0.20	0.20	0.25	0.82	0.75	0.42	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Lithium	7439-93-2	12	8	4	67	µg/L	4.0	4.0	4.0	13	0.39	9.4	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Far-field area (north of Gable Gap)	NON-RAD	Manganese	7439-96-5	36	15	21	42	µg/L	4.0	7.0	6.0	275	1.5	40	95% KM (BCA) UCL	—

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	Mercury	7439-97-6	12	0	12	0	µg/L	0.050	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Methyl methacrylate	80-62-6	12	0	12	0	µg/L	0.26	0.26	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Methylene chloride	75-09-2	12	0	12	0	µg/L	0.11	0.11	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Molybdenum	7439-98-7	12	12	0	100	µg/L	—	—	3.3	5.8	0.14	5.3	95% Student's-t UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Nickel	7440-02-0	36	2	34	5.6	µg/L	4.0	67	5.0	8.0	0.33	5.3	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Nitrate	14797-55-8	45	45	0	100	µg/L	—	—	1,970	30,500	0.51	21,027	95% Chebyshev (Mean, Sd) UCL	—

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	Nitrite	14797-65-0	45	8	37	18	µg/L	9.9	131	170	305	0.18	224	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Far-field area (north of Gable Gap)	NON-RAD	Selenium	7782-49-2	12	9	3	75	µg/L	0.60	0.98	0.76	1.8	0.28	1.2	95% KM (t) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Far-field area (north of Gable Gap)	NON-RAD	Silver	7440-22-4	36	0	36	0	µg/L	0.10	7.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Strontium	7440-24-6	35	35	0	100	µg/L	—	—	111	261	0.19	194	95% Student's-t UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Thallium	7440-28-0	12	0	12	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Tin	7440-31-5	12	0	12	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	NON-RAD	Toluene	108-88-3	12	0	12	0	µg/L	0.062	0.072	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Trichloroethene	79-01-6	12	0	12	0	µg/L	0.21	0.25	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	NON-RAD	Uranium	7440-61-1	11	11	0	100	µg/L	—	—	1.7	6.2	0.45	4.2	95% approximate gamma UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Vanadium	7440-62-2	36	28	8	78	µg/L	12	17	9.9	31	0.29	19	95% KM (t) UCL	—
Far-field area (north of Gable Gap)	NON-RAD	Zinc	7440-66-6	36	23	13	64	µg/L	4.0	9.0	4.0	590	1.5	368	99% KM (Chebyshev) UCL	—
Far-field area (north of Gable Gap)	RAD	Americium-241	14596-10-2	12	1	11	8.3	pCi/L	-2.40E-01	0.084	0.086	0.086	0	0.086	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable Americium-241 was not processed.

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	RAD	Carbon-14	14762-75-5	12	0	12	0	pCi/L	-1.86E+00	5.5	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	RAD	Cesium-137	10045-97-3	22	0	22	0	pCi/L	-3.40E+00	2.4	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	RAD	Cobalt-60	10198-40-0	22	0	22	0	pCi/L	-1.42E+00	6.9	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	RAD	Europium-154	15585-10-1	22	0	22	0	pCi/L	-5.50E+00	16	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	RAD	Iodine-129	15046-84-1	31	15	16	48	pCi/L	-4.19E-03	1.1	0.22	0.80	0.54	0.68	99% KM (Chebyshev) UCL	—

Table G-20. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Far-Field (North of Gable Gap) Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Far-field area (north of Gable Gap)	RAD	Plutonium-238	13981-16-3	3	0	3	0	pCi/L	0.020	0.12	—	—	—	—	—	Warning: This data set only has three observations, Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-238 was not processed.
Far-field area (north of Gable Gap)	RAD	Plutonium-239/240	PU-239/240	3	0	3	0	pCi/L	-4.00E-02	0.049	—	—	—	—	—	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-239/240 was not processed.
Far-field area (north of Gable Gap)	RAD	Strontium-90	10098-97-2	16	0	16	0	pCi/L	-9.40E+00	1.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Far-field area (north of Gable Gap)	RAD	Technetium-99	14133-76-7	32	25	7	78	pCi/L	-1.30E+01	1.6	9.5	150	0.30	150	Maximum detect	Recommended UCL exceeds maximum concentration. EPC defaulting to maximum concentration since 97.5% and 99% Chebyshev (Mean, Sd) UCLs were not calculated.
Far-field area (north of Gable Gap)	RAD	Tritium	10028-17-8	45	38	7	84	pCi/L	-1.10E+02	130	2,500	17,000	0.71	12,770	99% KM (Chebyshev) UCL	—

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	NON-RAD	2-Hexanone	591-78-6	17	0	17	0	µg/L	0.22	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Acetone	67-64-1	17	0	17	0	µg/L	0.34	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Acetophenone	98-86-2	2	0	2	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable acetophenone was not processed.
Near-river area	NON-RAD	Aluminum	7429-90-5	34	7	27	21	µg/L	5.0	20	15	37	0.30	24	95% KM (percentile bootstrap) UCL	Warning: There are only 7 Detected Values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions
Near-river area	NON-RAD	Antimony	7440-36-0	35	0	35	0	µg/L	0.30	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Arsenic	7440-38-2	34	32	2	94	µg/L	0.40	0.80	1.3	4.8	0.30	3.2	95% KM (percentile bootstrap) UCL	—
Near-river area	NON-RAD	Barium	7440-39-3	41	41	0	100	µg/L	--	--	16	36	0.21	29	95% approximate gamma UCL	—
Near-river area	NON-RAD	Benzene	71-43-2	17	0	17	0	µg/L	0.045	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	NON-RAD	Beryllium	7440-41-7	41	0	41	0	µg/L	0.050	4.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	2	0	2	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable bis(2-ethylhexyl) phthalate was not processed.
Near-river area	NON-RAD	Boron	7440-42-8	24	12	12	50	µg/L	19	41	8.0	43	0.47	21	95% KM (t) UCL	—
Near-river area	NON-RAD	Butylbenzylphthalate	85-68-7	2	0	2	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable butylbenzylphthalate was not processed.
Near-river area	NON-RAD	Cadmium	7440-43-9	34	2	32	5.9	µg/L	0.10	0.20	0.10	0.11	0.054	0.10	95% KM (t) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Carbon disulfide	75-15-0	17	0	17	0	µg/L	0.050	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Carbon tetrachloride	56-23-5	17	0	17	0	µg/L	0.063	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	NON-RAD	Chloroform	67-66-3	17	7	10	41	µg/L	0.10	1.0	0.11	0.36	0.52	0.19	95% KM (% bootstrap) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Near-river area	NON-RAD	Chromium	7440-47-3	40	34	6	85	µg/L	3.0	13	0.83	8.7	0.35	6.1	95% KM (t) UCL	—
Near-river area	NON-RAD	Cobalt	7440-48-4	39	2	37	5.1	µg/L	0.050	4.0	0.10	0.14	0.22	0.14	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Copper	7440-50-8	41	9	32	22	µg/L	0.20	6.0	0.22	4.7	1.1	0.94	95% KM (BCA) UCL	Warning: There are only nine detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Near-river area	NON-RAD	Cyanide	57-12-5	3	0	3	0	µg/L	4.0	4.0	—	—	—	—	—	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable cyanide was not processed.
Near-river area	NON-RAD	di-n-Octylphthalate	117-84-0	2	0	2	0	µg/L	1	1	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable di-n-octylphthalate was not processed.
Near-river area	NON-RAD	Fluoride	16984-48-8	50	48	2	96	µg/L	60	250	61	462	0.41	238	95% KM (t) UCL	—
Near-river area	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	40	34	6	85	µg/L	2.8	13	0.68	14	0.46	6.1	95% KM (t) UCL	—
Near-river area	NON-RAD	Iron	7439-89-6	32	25	7	78	µg/L	38	64	20	1,280	1.8	190	95% KM (BCA) UCL	—
Near-river area	NON-RAD	Lead	7439-92-1	34	8	26	24	µg/L	0.10	0.20	0.18	16	2.0	2.3	95% KM (BCA) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Near-river area	NON-RAD	Lithium	7439-93-2	14	11	3	79	µg/L	4.0	15	4.9	19	0.56	10	95% KM (BCA) UCL	—

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	NON-RAD	Manganese	7439-96-5	34	20	14	59	µg/L	4.0	6.0	0.34	70	1.4	14	95% KM (BCA) UCL	—
Near-river area	NON-RAD	Mercury	7439-97-6	23	0	23	0	µg/L	0.050	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Methyl methacrylate	80-62-6	14	0	14	0	µg/L	0.26	0.26	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Methyl methanesulfonate	66-27-3	2	0	2	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methyl methanesulfonate was not processed.
Near-river area	NON-RAD	Methylene chloride	75-09-2	17	0	17	0	µg/L	0.11	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Molybdenum	7439-98-7	31	31	0	100	µg/L	—	—	1.5	7.3	0.39	4.5	95% Student's-t UCL	—
Near-river area	NON-RAD	Nickel	7440-02-0	34	7	27	21	µg/L	0.20	13	0.33	0.97	0.44	0.63	95% KM (percentile bootstrap) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Near-river area	NON-RAD	Nitrate	14797-55-8	49	49	0	100	µg/L	—	—	1,790	28,200	0.48	23,767	95% Chebyshev (Mean, Sd) UCL	—

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	NON-RAD	Nitrite	14797-65-0	49	7	42	14	µg/L	9.9	2,500	30	285	0.43	222	95% KM (percentile bootstrap) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Near-river area	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	2	0	2	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable n-nitrosodi-n-dipropylamine was not processed.
Near-river area	NON-RAD	Phenol	108-95-2	1	0	1	0	µg/L	2.0	2.0	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable phenol was not processed.
Near-river area	NON-RAD	Selenium	7782-49-2	34	20	14	59	µg/L	0.60	4.0	0.65	3.4	0.50	1.7	95% KM (percentile bootstrap) UCL	—
Near-river area	NON-RAD	Silver	7440-22-4	34	0	34	0	µg/L	0.040	0.20	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Strontium	7440-24-6	34	34	0	100	µg/L	—	—	124	308	0.21	205	95% Student's-t UCL	—
Near-river area	NON-RAD	Thallium	7440-28-0	34	1	33	2.9	µg/L	0.050	0.55	1.8	1.8	0	1.8	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable thallium was not processed.
Near-river area	NON-RAD	Tin	7440-31-5	31	3	28	9.7	µg/L	0.10	1.0	0.066	0.17	0.46	0.079	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	NON-RAD	Toluene	108-88-3	17	0	17	0	µg/L	0.062	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	NON-RAD	Tributyl phosphate	126-73-8	2	0	2	0	µg/L	1.0	1.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable tributyl phosphate was not processed.
Near-river area	NON-RAD	Trichloroethene	79-01-6	17	14	3	82	µg/L	0.21	1.0	0.25	3.9	0.79	1.8	95% KM (BCA) UCL	—
Near-river area	NON-RAD	Uranium	7440-61-1	22	22	0	100	µg/L	--	--	0.12	2.9	0.36	2.3	95% Chebyshev (Mean, Sd) UCL	—
Near-river area	NON-RAD	Vanadium	7440-62-2	34	21	13	62	µg/L	7.0	17	0.63	26	0.41	14	95% KM (percentile bootstrap) UCL	—
Near-river area	NON-RAD	Zinc	7440-66-6	34	12	22	35	µg/L	4.0	9.0	2.1	1,270	1.4	164	95% KM (t) UCL	—
Near-river area	RAD	Americium-241	14596-10-2	6	2	4	33	pCi/L	-9.10E-03	0.085	0.090	0.13	0.26	0.13	Maximum detect	Recommended UCL exceeds maximum concentration. EPC defaulting to maximum concentration since 97.5% and 99% Chebyshev (Mean, Sd) UCLs were not calculated.
Near-river area	RAD	Carbon-14	14762-75-5	24	8	16	33	pCi/L	-9.49E+00	5.0	179	436	0.31	293	95% KM (percentile bootstrap) UCL	Warning: There are only eight detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Near-river area	RAD	Cesium-137	10045-97-3	10	0	10	0	pCi/L	-2.86E+00	1.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	RAD	Cobalt-60	10198-40-0	10	0	10	0	pCi/L	-2.86E+00	2.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	RAD	Europium-154	15585-10-1	10	0	10	0	pCi/L	-9.36E+00	3.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	RAD	Iodine-129	15046-84-1	12	2	10	17	pCi/L	-4.12E-02	0.18	0.21	0.25	0.10	0.25	Maximum detect	Recommended UCL exceeds maximum concentration. EPC defaulting to maximum concentration since 97.5% and 99% Chebyshev (Mean, Sd) UCLs were not calculated.
Near-river area	RAD	Plutonium-238	13981-16-3	2	0	2	0	pCi/L	0.0074	0.035	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-238 was not processed.
Near-river area	RAD	Plutonium-239/240	PU-239/240	2	0	2	0	pCi/L	0.0087	0.037	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable plutonium-239/240 was not processed.
Near-river area	RAD	Strontium-90	10098-97-2	25	0	25	0	pCi/L	-1.20E+01	0.83	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Near-river area	RAD	Technetium-99	14133-76-7	34	28	6	82	pCi/L	-1.00E+01	2.4	7.7	120	0.56	61	95% KM (percentile bootstrap) UCL	—
Near-river area	RAD	Tritium	10028-17-8	50	37	13	74	pCi/L	-1.20E+02	240	230	15,000	0.73	12,568	99% KM (Chebyshev) UCL	—
Near-river area	RAD	Uranium-233/234	U-233/234	2	2	0	100	pCi/L	—	—	0.48	0.67	0.23	0.67	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-233/234 was not processed.

Table G-21. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Near-River Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Near-river area	RAD	Uranium-235	15117-96-1	2	1	1	50	pCi/L	0.0097	0.0097	0.048	0.048	0	0.048	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-235 was not processed.
Near-river area	RAD	Uranium-238	U-238	2	2	0	100	pCi/L	—	—	0.41	0.53	0.18	0.53	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-238 was not processed.

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	NON-RAD	2-Hexanone	591-78-6	1	0	1	0	µg/L	0.080	0.080	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable 2-hexanone was not processed.
Confined	NON-RAD	Acetone	67-64-1	21	0	21	0	µg/L	0.56	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Aluminum	7429-90-5	20	11	9	55	µg/L	5.0	20	7.8	71	0.74	24	95% KM (t) UCL	—
Confined	NON-RAD	Antimony	7440-36-0	10	2	8	20	µg/L	0.60	4.0	41	42	0.024	42	95% KM (% bootstrap) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Arsenic	7440-38-2	37	37	0	100	µg/L	—	—	1.1	5.6	0.48	3.0	95% Modified-t UCL	—
Confined	NON-RAD	Barium	7440-39-3	73	73	0	100	µg/L	—	—	34	170	0.26	91	95% approximate gamma UCL	—
Confined	NON-RAD	Benzene	71-43-2	21	1	20	4.8	µg/L	0.032	1.0	2.5	2.5	0	2.5	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable benzene was not processed.
Confined	NON-RAD	Beryllium	7440-41-7	66	0	66	0	µg/L	0.20	5.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Bis(2-ethylhexyl) phthalate	117-81-7	21	5	16	24	µg/L	0.70	1.0	0.97	11	0.99	3.8	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	NON-RAD	Boron	7440-42-8	2	2	0	100	µg/L	—	—	13	18	0.22	18	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable boron was not processed.
Confined	NON-RAD	Cadmium	7440-43-9	73	0	73	0	µg/L	0.10	4.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Carbon disulfide	75-15-0	21	0	21	0	µg/L	0.029	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Carbon tetrachloride	56-23-5	21	1	20	4.8	µg/L	0.042	1.0	2.3	2.3	0	2.3	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable carbon tetrachloride was not processed.
Confined	NON-RAD	Chloroform	67-66-3	21	1	20	4.8	µg/L	0.080	1.0	1.3	1.3	0	1.3	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable chloroform was not processed.
Confined	NON-RAD	Chromium	7440-47-3	73	10	63	14	µg/L	3.1	14	0.24	46	0.91	7.3	95% KM (percentile bootstrap) UCL	—
Confined	NON-RAD	Cobalt	7440-48-4	72	2	70	2.8	µg/L	0.10	4.1	0.12	5.6	1.4	0.86	97.5% KM (Chebyshev) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	NON-RAD	Copper	7440-50-8	73	3	70	4.1	µg/L	4.0	30	0.26	4.4	1.0	1.9	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
Confined	NON-RAD	Cyanide	57-12-5	47	7	40	15	µg/L	2.0	5.0	4.4	31	0.67	9.6	95% KM (percentile bootstrap) UCL	Warning: There are only seven detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Confined	NON-RAD	Fluoride	16984-48-8	80	64	16	80	µg/L	46	250	52	592	0.73	211	95% KM (BCA) UCL	—
Confined	NON-RAD	Hexavalent chromium (Cr-filtered)	18540-29-9	72	5	67	6.9	µg/L	3.1	14	0.20	17	1.0	6.2	95% KM (percentile bootstrap) UCL	Warning: There are only five detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Confined	NON-RAD	Iron	7439-89-6	70	60	10	86	µg/L	19	66	27	14,500	2.6	2,496	97.5% KM (Chebyshev) UCL	—
Confined	NON-RAD	Lead	7439-92-1	3	0	3	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has three observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable lead was not processed.
Confined	NON-RAD	Manganese	7439-96-5	73	60	13	82	µg/L	4.0	6.0	4.1	383	1.1	64	95% KM (BCA) UCL	—
Confined	NON-RAD	Mercury	7439-97-6	20	0	20	0	µg/L	0.050	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Methyl methacrylate	80-62-6	1	0	1	0	µg/L	0.62	0.62	—	—	—	—	—	Warning: This data set only has one observation. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable methyl methacrylate was not processed.

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	NON-RAD	Methylene chloride	75-09-2	21	0	21	0	µg/L	0.091	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Molybdenum	7439-98-7	2	2	0	100	µg/L	—	—	5.1	5.5	0.060	5.5	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable molybdenum was not processed.
Confined	NON-RAD	Nickel	7440-02-0	73	11	62	15	µg/L	4.0	67	0.54	39	0.87	7.8	95% KM (percentile bootstrap) UCL	—
Confined	NON-RAD	Nitrate	14797-55-8	79	74	5	94	µg/L	168	319	103	41,300	1.8	9,270	95% KM (Chebyshev) UCL	—
Confined	NON-RAD	Nitrite	14797-65-0	79	16	63	20	µg/L	9.9	164	126	417	0.38	187	95% KM (percentile bootstrap) UCL	—
Confined	NON-RAD	n-Nitrosodi-n-dipropylamine	621-64-7	18	0	18	0	µg/L	0.50	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Phenol	108-95-2	21	1	20	4.8	µg/L	0.48	4.0	0.91	0.91	0	0.91	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable phenol was not processed.
Confined	NON-RAD	Selenium	7782-49-2	2	0	2	0	µg/L	2.0	2.0	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable selenium was not processed.

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	NON-RAD	Silver	7440-22-4	73	2	71	2.7	µg/L	0.10	7.0	4.0	17	0.88	17	Maximum detect	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Strontium	7440-24-6	71	71	0	100	µg/L	—	—	159	363	0.16	255	95% Student's-t UCL	—
Confined	NON-RAD	Thallium	7440-28-0	21	1	20	4.8	µg/L	0.050	0.10	0.065	0.065	0	0.065	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable thallium was not processed.
Confined	NON-RAD	Tin	7440-31-5	2	0	2	0	µg/L	0.10	0.10	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable tin was not processed.
Confined	NON-RAD	Toluene	108-88-3	21	1	20	4.8	µg/L	0.029	1.0	2.3	2.3	0	2.3	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable toluene was not processed.
Confined	NON-RAD	Tributyl phosphate	126-73-8	19	2	17	11	µg/L	0.48	1.5	1.4	8.4	1.0	8.4	95% KM (BCA) UCL	Warning: Data set has only two distinct detected values. This may not be adequate enough to compute meaningful and reliable test statistics and estimates. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Trichloroethene	79-01-6	21	0	21	0	µg/L	0.11	1.0	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	NON-RAD	Uranium	7440-61-1	63	63	0	100	µg/L	—	—	1.00	5.9	0.31	3.3	95% Modified-t UCL	—
Confined	NON-RAD	Vanadium	7440-62-2	73	36	37	49	µg/L	4.1	50	5.6	29	0.42	11	95% KM (t) UCL	—

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	NON-RAD	Zinc	7440-66-6	73	37	36	51	µg/L	4.0	20	5.0	811	2.7	79	95% KM (Chebyshev) UCL	—
Confined	RAD	Americium-241	14596-10-2	20	4	16	20	pCi/L	-5.70E-02	0.22	0.056	0.11	0.26	0.10	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Confined	RAD	Carbon-14	14762-75-5	20	1	19	5.0	pCi/L	-4.66E+00	6.5	35	35	0	35	Maximum detect	Warning: Only one distinct data value was detected. ProUCL (or any other software) should not be used on such a data set. It is suggested to use alternative site-specific values determined by the project team to estimate environmental parameters (e.g., EPC or BTV). The data set for variable carbon-14 was not processed.
Confined	RAD	Cesium-137	10045-97-3	47	0	47	0	pCi/L	-9.30E+00	6.1	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	RAD	Cobalt-60	10198-40-0	47	0	47	0	pCi/L	-4.60E+00	7.8	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	RAD	Europium-154	15585-10-1	47	0	47	0	pCi/L	-1.82E+01	16	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	RAD	Iodine-129	15046-84-1	61	11	50	18	pCi/L	-2.56E-01	0.49	0.18	3.2	0.94	0.89	97.5% KM (Chebyshev) UCL	—

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	RAD	Neptunium-237	13994-20-2	21	0	21	0	pCi/L	-1.60E-01	0.074	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	RAD	Plutonium-238	13981-16-3	20	0	20	0	pCi/L	-2.30E-01	0.10	—	—	—	—	—	Warning: All observations are NDs; therefore, all statistics and estimates should also be NDs. Specifically, sample mean, UCLs, UPLs, and other statistics are also NDs lying below the largest detection limit. The project team may decide to use alternative site-specific values to estimate environmental parameters (e.g., EPC or BTV).
Confined	RAD	Plutonium-239/240	PU-239/240	20	3	17	15	pCi/L	-1.80E-01	0.073	0.056	0.17	0.65	0.074	95% KM (t) UCL	Warning: There are only three distinct detected values in this data set. The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods. Those methods will return an "N/A" value on the output display.
Confined	RAD	Strontium-90	10098-97-2	36	5	31	14	pCi/L	-7.10E+00	1.2	1.2	4.6	0.61	2.3	95% KM (percentile bootstrap) UCL	Warning: There are only four distinct detected values in this data. It should be noted that even though bootstrap may be performed on this data set, the resulting calculations may not be reliable enough to draw conclusions.
Confined	RAD	Technetium-99	14133-76-7	68	28	40	41	pCi/L	-1.20E+01	8.0	6.7	1,300	1.7	353	97.5% KM (Chebyshev) UCL	—
Confined	RAD	Tritium	10028-17-8	79	14	65	18	pCi/L	-1.70E+02	140	30	7,000	0.92	1,756	97.5% KM (Chebyshev) UCL	—
Confined	RAD	Uranium-234	13966-29-5	2	2	0	100	pCi/L	—	—	1.2	1.3	0.085	1.3	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-234 was not processed.
Confined	RAD	Uranium-235	15117-96-1	2	0	2	0	pCi/L	-7.66E-03	0.15	—	—	—	—	—	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-235 was not processed.

Table G-22. Summary of Groundwater Exposure Point Concentrations for 200-BP-5 Confined Exposure Area

Exposure Area	Analyte Group	Analyte	CAS No.	Total Samples	Total Detects	Total Nondetects	Frequency of Detection (%)	Units	Minimum Detection Limit	Maximum Detection Limit	Minimum Detected Result	Maximum Detected Result	Coefficient of Variation	Exposure Point Concentration	Exposure Point Concentration Basis	Comment
Confined	RAD	Uranium-238	U-238	2	2	0	100	pCi/L	—	—	0.43	1.1	0.60	1.1	Maximum detect	Warning: This data set only has two observations. Data set is too small to compute reliable and meaningful statistics and estimates. The data set for variable uranium-238 was not processed.

BCA = bias-corrected accelerated bootstrap method
BTV = background threshold value
CAS = Chemical Abstracts Service
EPC = exposure point concentration
GOF = goodness of fit
KM = Kaplan-Meier
ND = nondetect
ROS = regression on order statistics
UCL = upper confidence limit

Table G-23. Summary of Exposure Assumptions Used for Tap Water Exposure Scenario

Exposure Factor	Value	Units	Source
Averaging time – carcinogen	70	years	EPA/540/R-92/003
Averaging time – noncarcinogen	26	years	EPA/600/R-090/052F
Adult body weight	80	kg	EPA/600/R-090/052F
Body weight – child	15	kg	EPA/600/R-090/052F
Exposure duration – adult	26	years	EPA/600/R-090/052F
Exposure duration – child	6	year	EPA/540/R-92/003
Exposure frequency	350	year	EPA/540/R-92/003
Exposure time	24	hours/day	OSWER Directive 9200.1-120
Event time – adult	0.71	hours/event	EPA/600/R-090/052F
Event time – child	0.54	hours/event	EPA/600/R-090/052F
Age-adjusted event time	0.671	hours/event	Calculated value
Event frequency	1	event/day	EPA/540/R/99/005
Age-adjusted inhalation rate – radiological	460	m^3-year/day	Calculated value
Inhalation rate – adult	20	m^3/day	OSWER Directive 9285.6-03
Inhalation rate – child	10	m^3/day	EPA/600/P-95/002Fa
Water ingestion rate – adult	2.5	L/day	EPA/600/R-090/052F
Water ingestion rate – child	0.78	L/day	EPA/600/R-090/052F
Age-adjusted water ingestion rate – nonradiological	0.937	L-year/kg-day	Calculated value
Age-adjusted water ingestion rate – radiological	54.68	L-year/day	Calculated value
Age-adjusted skin surface area	7,776	cm^2-year-event/kg-day	Calculated value
Skin surface area – adult	20,900	cm^2	EPA/600/R-090/052F
Skin surface area – child	6,378	cm^2	EPA/600/R-090/052F
Volatilization factor	0.5	L/m^3	EPA/540/R-92/003

Sources:
ECF-Hanford-13-0033, *Exposure Point Concentrations for Baseline Conditions for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*.
EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final*.
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*.
EPA/600/P-95/002Fa, *Exposure Factors Handbook Volume 1: General Factors*.
EPA/600/R-090/052F, *Exposure Factors Handbook: 2011 Edition*.
OSWER Directive 9200.1-120, *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors*.
OSWER Directive 9285.6-03, *Risk Assessment Guidance For Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance*, "Standard Default Exposure Factors," Interim Final.

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Table G-24. Summary of Toxicity Values and Chemical-Specific Information for the 200-BP-5 OU

Analyte Name	Oral Reference Dose[a] (mg/kg-day)	Source	Oral Cancer Slope Factor[a] $(mg/kg\text{-}day)^{-1}$ or Slope Factor Water Ingestion[b] (Risk/pCi)	Source	Inhalation Reference Concentration[a] (mg/m^3)	Source	Inhalation Unit Risk (IUR)[a] $(\mu g/m^3)^{-1}$ or Slope Factor Inhalation[b] (Risk/pCi)	Source	Volatile[a,b]	GIABS[a,b] (unit-less)	Kp[c] (cm/hr)	B[c] (unit-less)	τ[c] (hours/event)	t*[c] (hours)	FA[c] (unit-less)
2-Hexanone	0.005	I	—	—	0.03	I	—	—	Yes	1	0.00355[d]	—	—	—	—
Acetone	0.9	I	—	—	31	A	—	—	Yes	1	0.000512[d]	—	—	—	—
Acetophenone	0.1	I	—	—	—	—	—	—	Yes	1	0.00372[d]	—	—	—	—
Aluminum	1	P	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Antimony	0.0004	I	—	—	—	—	—	—	—	0.15	0.001	—	—	—	—
Arsenic	0.0003	I	1.5	I	—	—	—	—	—	1	0.001	—	—	—	—
Barium	0.2	I	—	—	—	—	—	—	—	0.07	0.001	—	—	—	—
Benzene	0.004	I	0.055	I	0.03	I	0.0000078	I	Yes	1	0.015	0.1	0.29	0.7	1
Beryllium	0.002	I	—	—	—	—	—	—	—	0.007	0.001	—	—	—	—
Bis(2-ethylhexyl) phthalate	0.02	I	0.014	I	—	—	—	—	—	1	0.025	0.2	16.64	39.93	0.8
Boron	0.2	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Butylbenzylphthalate	0.2	I	0.0019	P	—	—	—	—	—	1	0.0385[d]	—	—	—	—
Cadmium	0.0005	I	—	—	—	—	—	—	—	0.05	0.001	0.1	—	—	—
Carbon disulfide	0.1	I	—	—	0.7	I	—	—	Yes	1	0.017	0.1	0.3	0.72	1
Carbon tetrachloride	0.004	I	0.07	I	0.1	I	0.000006	I	Yes	1	0.016	0	0.78	1.86	1
Chloroform	0.01	I	0.031	C	0.098	A	0.000023	I	Yes	1	0.0068	—	0.5	1.19	1
Chromium	1.5	I	—	—	—	—	—	—	—	0.013	0.001	—	—	—	—
Cobalt	0.0003	P	—	—	—	—	—	—	—	1	0.0004	—	—	—	—
Copper	0.04	H	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Cyanide	0.0006	I	—	—	0.0008	S	—	—	Yes	1	0.001	—	—	—	—
di-n-Octylphthalate	0.01	P	—	—	—	—	—	—	—	1	2.43[d]	—	—	—	—
Fluoride	0.06	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Hexavalent chromium	0.003	I	—	—	—	—	—	—	—	0.025	0.002	—	—	—	—
Iron	0.7	P	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Lead	—	—	—	—	—	—	—	—	—	1	0.0001	—	—	—	—
Lithium	0.002	P	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Manganese	0.024	S	—	—	—	—	—	—	—	0.04	0.001	—	—	—	—

Table G-24. Summary of Toxicity Values and Chemical-Specific Information for the 200-BP-5 OU

Analyte Name	Oral Reference Dose[a] (mg/kg-day)	Source	Oral Cancer Slope Factor[a] $(mg/kg\text{-}day)^{-1}$ or Slope Factor Water Ingestion[b] (Risk/pCi)	Source	Inhalation Reference Concentration[a] (mg/m^3)	Source	Inhalation Unit Risk (IUR)[a] $(\mu g/m^3)^{-1}$ or Slope Factor Inhalation[b] (Risk/pCi)	Source	Volatile[a,b]	GIABS[a,b] (unit-less)	Kp[c] (cm/hr)	B[c] (unit-less)	τ[c] (hours/event)	t*[c] (hours)	FA[c] (unit-less)
Mercury	0.0003	I	—	—	—	—	—	—	—	0.07	0.001	—	—	—	—
Methyl methacrylate	1.4	I	—	—	0.7	I	—	—	Yes	1	0.00355[d]	—	—	—	—
Methyl methanesulfonate	—	—	0.099	C	—	—	—	—	—	1	0.000138[d]	—	—	—	—
Methylene chloride	0.006	I	0.002	I	0.6	I	0.00000001	I	Yes	1	0.0035	0	0.32	0.76	1
Molybdenum	0.005	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Nickel	0.02	I	—	—	—	—	—	—	—	0.04	0.0002	—	—	—	—
Nitrate	7.1	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Nitrite	0.3	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
n-Nitrosodi-n-dipropylamine	—	—	7	I	—	—	—	—	—	1	0.0023	0	0.57	1.37	1
Octachlorodibenzofuran	0.00000233	WAC	39	WAC	—	—	—	—	—	0.03	0.81	5.6	6.82	30.09	0.5
Phenol	0.3	I	—	—	—	—	—	—	—	1	0.0043	0	0.36	0.86	1
Selenium	0.005	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Silver	0.005	I	—	—	—	—	—	—	—	0.04	0.0006	—	—	—	—
Strontium	0.6	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Thallium	0.00001	X	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Tin	0.6	H	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Toluene	0.08	I	—	—	5	I	—	—	Yes	1	0.031	0.1	0.35	0.84	1
Tributyl phosphate	0.01	P	0.009	P	—	—	—	—	—	1	0.0228[d]	—	—	—	—
Trichloroethene	0.0005	I	0.046	I	0.002	I	0.0000041	I	Yes	1	0.012	0.1	0.58	1.39	1
Uranium	0.003	I	—	—	—	—	—	—	—	1	0.001	—	—	—	—
Vanadium	0.005	S	—	—	—	—	—	—	—	0.026	0.001	—	—	—	—
Zinc	0.3	I	—	—	—	—	—	—	—	1	0.0006	—	—	—	—
Americium-241	—	—	1.04E-10	H	—	—	—	—	—	0.0005	—	—	—	—	—
Carbon-14	—	—	1.55E-12	H	—	—	—	—	—	1	—	—	—	—	—
Cesium-137	—	—	3.04E-11	H	—	—	—	—	—	1	—	—	—	—	—
Cobalt-60	—	—	1.57E-11	H	—	—	—	—	—	0.1	—	—	—	—	—
Europium-154	—	—	1.03E-11	H	—	—	—	—	—	0.0005	—	—	—	—	—

Table G-24. Summary of Toxicity Values and Chemical-Specific Information for the 200-BP-5 OU

Analyte Name	Oral Reference Dose[a] (mg/kg-day)	Source	Oral Cancer Slope Factor[a] $(mg/kg\text{-}day)^{-1}$ or Slope Factor Water Ingestion[b] (Risk/pCi)	Source	Inhalation Reference Concentration[a] (mg/m^3)	Source	Inhalation Unit Risk (IUR)[a] $(\mu g/m^3)^{-1}$ or Slope Factor Inhalation[b] (Risk/pCi)	Source	Volatile[a,b]	GIABS[a,b] (unit-less)	Kp[c] (cm/hr)	B[c] (unit-less)	τ[c] (hours/event)	t*[c] (hours)	FA[c] (unit-less)
Iodine-129	—	—	1.48E-10	H	—	—	—	—	—	1	—	—	—	—	—
Neptunium-237	—	—	6.18E-11	H	—	—	—	—	—	0.0005	—	—	—	—	—
Plutonium-238	—	—	1.31E-10	H	—	—	—	—	—	0.0005	—	—	—	—	—
Plutonium-239/240	—	—	1.35E-10	H	—	—	—	—	—	0.0005	—	—	—	—	—
Strontium-90	—	—	5.59E-11	H	—	—	—	—	—	0.3	—	—	—	—	—
Technetium-99	—	—	2.75E-12	H	—	—	—	—	—	0.5	—	—	—	—	—
Tritium	—	—	5.07E-14	H	—	—	5.62E-14	H	Yes	1	—	—	—	—	—
Uranium-233/234	—	—	7.18E-11	H	—	—	—	—	—	0.02	—	—	—	—	—
Uranium-234	—	—	7.07E-11	H	—	—	—	—	—	0.02	—	—	—	—	—
Uranium-235	—	—	6.96E-11	H	—	—	—	—	—	0.02	—	—	—	—	—
Uranium-238	—	—	6.4E-11	H	—	—	—	—	—	0.02	—	—	—	—	—

a. U.S. Environmental Protection Agency (EPA) web site "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).
Reference key for sources listed:
A = Agency for Toxic Substances and Disease Registry
C = California Environmental Protection Agency (CalEPA)
E = Environmental Criteria and Assessment Office
H = Health Effects Assessment Summary Tables (HEAST)
I = EPA's Integrated Risk Information System (IRIS)
P = Provisional Peer Reviewed Toxicity Values (PPRTV)
S = special case chemical (basis for value discussed on EPA Regional Screening Levels website)
b. EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."
c. EPA/540/R/99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* (Part E, Supplemental Guidance for Dermal Risk Assessment).
d. The Kp value was taken from Oak Ridge National Laboratory's Risk Assessment Information System (ORNL, 2013).
GIABS = gastrointestinal absorption factor
H = HEAST
I = IRIS
Kp = dermal permeability constant
t* = time to reach steady-state
τ = lag time

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Table G-25. LLWMA-1 Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Acetone	67-64-1	0.0010	Yes	—	—	—	0.00E+00	0
Aluminum	7429-90-5	0.047	—	—	—	—	0.00E+00	0
Antimony	7440-36-0	0.047	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0048	—	9.29E-05	5.17E-07	--	9.34E-05	30
Barium	7440-39-3	0.072	—	—	—	—	0.00E+00	0
Cadmium	7440-43-9	0.00040	—	—	—	—	0.00E+00	0
Chloroform	67-66-3	0.00013	Yes	5.17E-08	4.67E-09	5.32E-07	5.89E-07	0.19
Chromium	7440-47-3	0.014	—	—	—	—	0.00E+00	0
Cobalt	7440-48-4	0.00037	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.00088	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.14	Yes	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.33	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0077	—	—	—	—	0.00E+00	0
Iron	7439-89-6	0.082	—	—	—	—	0.00E+00	0
Lead	7439-92-1	0.00024	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.0016	—	—	—	—	0.00E+00	0
Mercury	7439-97-6	0.00018	—	—	—	—	0.00E+00	0

Table G-25. LLWMA-1 Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Molybdenum	7439-98-7	0.0066	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.0056	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	181	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.16	—	—	—	—	0.00E+00	0
Octachlorodibenzofuran	39001-02-0	1.43E-09	—	7.14E-10	1.42E-08	—	1.49E-08	0.0047
Selenium	7782-49-2	0.0067	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.0068	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.39	—	—	—	—	0.00E+00	0
Thallium	7440-28-0	0.00024	—	—	—	—	0.00E+00	0
Tin	7440-31-5	0.00023	—	—	—	—	0.00E+00	0
Uranium	7440-61-1	0.022	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.017	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.0055	—	—	—	—	0.00E+00	0
Cobalt-60	10198-40-0	25.9	—	7.80E-06	—	—	7.80E-06	2.5
Iodine-129	15046-84-1	2.4	—	6.74E-06	—	—	6.74E-06	2.1

Table G-25. LLWMA-1 Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Technetium-99	14133-76-7	3,168	—	1.67E-04	—	—	1.67E-04	53
Tritium	10028-17-8	7,417	Yes	7.20E-06	—	3.36E-05	4.08E-05	13
Total cumulative ELCR				**2.81E-04**	**5.36E-07**	**3.41E-05**	**3.16E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-26. LLWMA1 Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Acetone	67-64-1	0.0010	Yes	3.33E-05	—	1.55E-05	4.88E-05	5.07E-05
Aluminum	7429-90-5	0.047	—	0.0014	8.31E-06	—	0.0014	0.0015
Antimony	7440-36-0	0.047	—	3.5	0.14	—	3.6	3.8
Arsenic	7440-38-2	0.0048	—	0.48	0.0029	—	0.48	0.50
Barium	7440-39-3	0.072	—	0.011	9.18E-04	—	0.012	0.012
Cadmium	7440-43-9	0.00040	—	0.024	0.0029	—	0.027	0.028
Chloroform	67-66-3	0.00013	Yes	3.90E-04	3.65E-05	6.36E-04	0.0011	0.0011
Chromium	7440-47-3	0.014	—	2.74E-04	1.25E-04	—	3.98E-04	4.14E-04
Cobalt	7440-48-4	0.00037	—	0.037	8.88E-05	—	0.037	0.039
Copper	7440-50-8	0.00088	—	6.62E-04	3.93E-06	—	6.66E-04	6.92E-04
Cyanide	57-12-5	0.14	Yes	7.0	0.041	83	90	94
Fluoride	16984-48-8	0.33	—	0.17	9.89E-04	—	0.17	0.17
Hexavalent chromium	18540-29-9	0.0077	—	0.077	0.036	—	0.11	0.12
Iron	7439-89-6	0.082	—	0.0035	2.08E-05	—	0.0035	0.0037
Lead	7439-92-1	0.00024	—	—	—	—	0	0
Manganese	7439-96-5	0.0016	—	0.0019	2.88E-04	—	0.0022	0.0023
Mercury	7439-97-6	0.00018	—	0.018	0.0015	—	0.020	0.020
Molybdenum	7439-98-7	0.0066	—	0.039	2.34E-04	—	0.040	0.041

Table G-26. LLWMA1 Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Nickel	7440-02-0	0.0056	—	0.0084	2.50E-04	—	0.0087	0.0090
Nitrate	14797-55-8	181	—	0.76	0.0045	—	0.77	0.80
Nitrite	14797-65-0	0.16	—	0.016	9.24E-05	—	0.016	0.016
Octachlorodibenzofuran	39001-02-0	1.43E-09	—	1.84E-05	3.78E-04	—	3.96E-04	4.12E-04
Selenium	7782-49-2	0.0067	—	0.040	2.39E-04	—	0.041	0.042
Silver	7440-22-4	0.0068	—	0.041	0.0036	—	0.044	0.046
Strontium	7440-24-6	0.39	—	0.020	1.16E-04	—	0.020	0.020
Thallium	7440-28-0	0.00024	—	—	—	—	0	0
Tin	7440-31-5	0.00023	—	1.17E-05	6.94E-08	—	1.18E-05	1.22E-05
Uranium	7440-61-1	0.022	—	0.22	0.0013	—	0.22	0.23
Vanadium	7440-62-2	0.017	—	0.100	0.023	—	0.12	0.13
Zinc	7440-66-6	0.0055	—	5.50E-04	1.96E-06	—	5.52E-04	5.73E-04
			Total HI	**13**	**0.26**	**83**	**96**	**100**

a. Volatile analytes as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile analytes are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-27. LLWMA-2 and 216-B-63 Trench Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Antimony	7440-36-0	0.065	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0085	—	1.64E-04	9.11E-07	—	1.65E-04	77
Barium	7440-39-3	0.055	—	—	—	—	0.00E+00	0
Chromium	7440-47-3	0.016	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0050	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.057	Yes	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.23	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0089	—	—	—	—	0.00E+00	0
Iron	7439-89-6	0.090	—	—	—	—	0.00E+00	0
Lead	7439-92-1	0.00023	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.0051	—	—	—	—	0.00E+00	0
Mercury	7439-97-6	6.30E-05	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.017	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	53.9	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.16	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.0046	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.34	—	—	—	—	0.00E+00	0
Uranium	7440-61-1	0.0038	—	—	—	—	0.00E+00	0

Table G-27. LLWMA-2 and 216-B-63 Trench Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Vanadium	7440-62-2	0.021	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.0057	—	—	—	—	0.00E+00	0
Iodine-129	15046-84-1	1.4	—	3.92E-06	—	—	3.92E-06	1.8
Technetium-99	14133-76-7	801	—	4.22E-05	—	—	4.22E-05	20
Tritium	10028-17-8	572	Yes	5.55E-07	—	2.59E-06	3.14E-06	1.5
Total cumulative ELCR				**2.10E-04**	**9.11E-07**	**2.59E-06**	**2.14E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-28. LLWMA-2 and 216-B-63 Trench Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Antimony	7440-36-0	0.065	—	4.9	0.19	—	5.1	12
Arsenic	7440-38-2	0.0085	—	0.85	0.0050	—	0.85	1.9
Barium	7440-39-3	0.055	—	0.0082	6.94E-04	—	0.0089	0.020
Chromium	7440-47-3	0.016	—	3.20E-04	1.46E-04	—	4.65E-04	0.0011
Copper	7440-50-8	0.0050	—	0.0038	2.24E-05	—	0.0038	0.0086
Cyanide	57-12-5	0.057	Yes	2.9	0.017	34	37	85
Fluoride	16984-48-8	0.23	—	0.11	6.77E-04	—	0.11	0.26
Hexavalent chromium	18540-29-9	0.0089	—	0.089	0.042	—	0.13	0.30
Iron	7439-89-6	0.090	—	0.0039	2.29E-05	—	0.0039	0.0088
Lead	7439-92-1	0.00023	—	—	—	—	0	0
Manganese	7439-96-5	0.0051	—	0.0063	9.38E-04	—	0.0073	0.017
Mercury	7439-97-6	6.30E-05	—	0.0063	5.34E-04	—	0.0068	0.016
Nickel	7440-02-0	0.017	—	0.026	7.62E-04	—	0.026	0.060
Nitrate	14797-55-8	53.9	—	0.23	0.0014	—	0.23	0.52
Nitrite	14797-65-0	0.16	—	0.016	9.40E-05	—	0.016	0.036
Silver	7440-22-4	0.0046	—	0.027	0.0024	—	0.030	0.068
Strontium	7440-24-6	0.34	—	0.017	1.01E-04	—	0.017	0.039

Table G-28. LLWMA-2 and 216-B-63 Trench Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Uranium	7440-61-1	0.0038	—	0.038	2.25E-04	—	0.038	0.087
Vanadium	7440-62-2	0.021	—	0.13	0.029	—	0.15	0.35
Zinc	7440-66-6	0.0057	—	5.74E-04	2.04E-06	—	5.76E-04	0.0013
			Total HI	**9.3**	**0.29**	**34**	**44**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-29. WMA B-BX-BY Tank Farms Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Acetophenone	98-86-2	0.0017	Yes	—	—	—	0.00E+00	0
Aluminum	7429-90-5	0.014	—	—	—	—	0.00E+00	0
Antimony	7440-36-0	0.044	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0089	—	1.72E-04	9.57E-07	—	1.73E-04	5.4
Barium	7440-39-3	0.12	—	—	—	—	0.00E+00	0
Bis(2-ethylhexyl) phthalate	117-81-7	0.0017	—	3.02E-07	4.63E-07	—	7.65E-07	0.024
Butylbenzylphthalate	85-68-7	0.0028	—	6.83E-08	—	—	6.83E-08	0.0021
Cadmium	7440-43-9	0.0047	—	—	—	—	0.00E+00	0
Carbon tetrachloride	56-23-5	0.0035	Yes	3.13E-06	8.30E-07	3.72E-06	7.67E-06	0.24
Chloroform	67-66-3	0.0014	Yes	5.59E-07	5.05E-08	5.76E-06	6.37E-06	0.20
Chromium	7440-47-3	0.036	—	—	—	—	0.00E+00	0
Cobalt	7440-48-4	0.0047	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0064	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.32	Yes	—	—	—	0.00E+00	0
di-n-Octylphthalate	117-84-0	0.0055	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.25	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.027	—	—	—	—	0.00E+00	0
Iron	7439-89-6	0.35	—	—	—	—	0.00E+00	0
Lead	7439-92-1	0.00055	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.018	—	—	—	—	0.00E+00	0

Table G-29. WMA B-BX-BY Tank Farms Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Mercury	7439-97-6	0.00032	—	—	—	—	0.00E+00	0
Methyl methanesulfonate	66-27-3	0.34	—	4.32E-04	—	—	4.32E-04	14
Methylene chloride	75-09-2	0.0018	Yes	4.62E-08	1.72E-09	3.21E-09	5.11E-08	0.0016
Molybdenum	7439-98-7	0.0045	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.051	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	598	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.19	—	—	—	—	0.00E+00	0
n-Nitrosodi-n-dipropylamine	621-64-7	0.0035	—	3.14E-04	1.03E-05	—	3.25E-04	10
Phenol	108-95-2	0.0011	—	—	—	—	0.00E+00	0
Selenium	7782-49-2	0.011	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.0051	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.85	—	—	—	—	0.00E+00	0
Thallium	7440-28-0	0.00013	—	—	—	—	0.00E+00	0
Tin	7440-31-5	0.00044	—	—	—	—	0.00E+00	0
Tributyl phosphate	126-73-8	0.0011	—	1.27E-07	—	—	1.27E-07	0.0040
Uranium	7440-61-1	0.42	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.014	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.040	—	—	—	—	0.00E+00	0
Americium-241	14596-10-2	0.10	—	2.09E-07	—	—	2.09E-07	0.0065
Carbon-14	14762-75-5	56.7	—	1.68E-06	—	—	1.68E-06	0.053

Table G-29. WMA B-BX-BY Tank Farms Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Cobalt-60	10198-40-0	40.1	—	1.21E-05	—	—	1.21E-05	0.38
Iodine-129	15046-84-1	3.7	—	1.04E-05	—	—	1.04E-05	0.33
Neptunium-237	13994-20-2	0.56	—	6.68E-07	—	—	6.68E-07	0.021
Plutonium-239/240	PU-239/240	0.10	—	2.53E-07	—	—	2.53E-07	0.0079
Strontium-90	10098-97-2	2.7	—	2.84E-06	—	—	2.84E-06	0.089
Technetium-99	14133-76-7	11,391	—	5.99E-04	—	—	5.99E-04	19
Tritium	10028-17-8	11,424	Yes	1.11E-05	—	5.17E-05	6.28E-05	2.0
Uranium-234	13966-29-5	598	—	8.09E-04	—	—	8.09E-04	25
Uranium-235	15117-96-1	26.9	—	3.58E-05	—	—	3.58E-05	1.1
Uranium-238	U-238	585	—	7.17E-04	—	—	7.17E-04	22
Total cumulative ELCR				**3.12E-03**	**1.26E-05**	**6.12E-05**	**3.20E-03**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-30. WMA B-BX-BY Tank Farms Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Acetophenone	98-86-2	0.0017	Yes	5.09E-04	—	—	5.09E-04	2.31E-04
Aluminum	7429-90-5	0.014	—	4.10E-04	2.43E-06	—	4.13E-04	1.87E-04
Antimony	7440-36-0	0.044	—	3.3	0.13	—	3.5	1.6
Arsenic	7440-38-2	0.0089	—	0.89	0.0053	—	0.90	0.41
Barium	7440-39-3	0.12	—	0.018	0.0015	—	0.020	0.0088
Bis(2-ethylhexyl) phthalate	117-81-7	0.0017	—	0.0025	0.0040	—	0.0065	0.0030
Butylbenzylphthalate	85-68-7	0.0028	—	4.20E-04	—	—	4.20E-04	1.90E-04
Cadmium	7440-43-9	0.0047	—	0.28	0.033	—	0.32	0.14
Carbon tetrachloride	56-23-5	0.0035	Yes	0.026	0.0072	0.017	0.050	0.023
Chloroform	67-66-3	0.0014	Yes	0.0042	3.94E-04	0.0069	0.011	0.0052
Chromium	7440-47-3	0.036	—	7.09E-04	3.24E-04	—	0.0010	4.68E-04
Cobalt	7440-48-4	0.0047	—	0.47	0.0011	—	0.47	0.21
Copper	7440-50-8	0.0064	—	0.0048	2.83E-05	—	0.0048	0.0022
Cyanide	57-12-5	0.32	Yes	16	0.095	192	208	94
di-n-Octylphthalate	117-84-0	0.0055	—	0.016	—	—	0.016	0.0075
Fluoride	16984-48-8	0.25	—	0.12	7.34E-04	—	0.12	0.056
Hexavalent chromium	18540-29-9	0.027	—	0.27	0.13	—	0.40	0.18
Iron	7439-89-6	0.35	—	0.015	8.92E-05	—	0.015	0.0069

Table G-30. WMA B-BX-BY Tank Farms Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Lead	7439-92-1	0.00055	—	—	—	—	0	0
Manganese	7439-96-5	0.018	—	0.022	0.0033	—	0.025	0.012
Mercury	7439-97-6	0.00032	—	0.032	0.0027	—	0.034	0.016
Methyl methanesulfonate	66-27-3	0.34	—	—	—	—	0	0
Methylene chloride	75-09-2	0.0018	Yes	0.0090	3.47E-04	0.0014	0.011	0.0049
Molybdenum	7439-98-7	0.0045	—	0.027	1.60E-04	—	0.027	0.012
Nickel	7440-02-0	0.051	—	0.077	0.0023	—	0.079	0.036
Nitrate	14797-55-8	598	—	2.5	0.015	—	2.5	1.2
Nitrite	14797-65-0	0.19	—	0.019	1.13E-04	—	0.019	0.0087
n-Nitrosodi-n-dipropylamine	621-64-7	0.0035	—	—	—	—	0	0
Phenol	108-95-2	0.0011	—	1.10E-04	5.52E-06	—	1.15E-04	5.23E-05
Selenium	7782-49-2	0.011	—	0.067	3.98E-04	—	0.067	0.031
Silver	7440-22-4	0.0051	—	0.031	0.0027	—	0.034	0.015
Strontium	7440-24-6	0.85	—	0.043	2.53E-04	—	0.043	0.019
Thallium	7440-28-0	0.00013	—	—	—	—	0	0
Tin	7440-31-5	0.00044	—	2.20E-05	1.30E-07	—	2.21E-05	1.00E-05
Tributyl phosphate	126-73-8	0.0011	—	0.0033	—	—	0.0033	0.0015
Uranium	7440-61-1	0.42	—	4.2	0.025	—	4.2	1.9

Table G-30. WMA B-BX-BY Tank Farms Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Vanadium	7440-62-2	0.014	—	0.081	0.018	—	0.099	0.045
Zinc	7440-66-6	0.040	—	0.0040	1.43E-05	—	0.0040	0.0018
			Total HI	**29**	**0.48**	**192**	**221**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-31. WMA C Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
2-Hexanone	591-78-6	0.0020	Yes	—	—	—	0.00E+00	0
Acetone	67-64-1	0.0011	Yes	—	—	—	0.00E+00	0
Aluminum	7429-90-5	0.026	—	—	—	—	0.00E+00	0
Antimony	7440-36-0	0.046	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0065	—	1.26E-04	7.02E-07	—	1.27E-04	27
Barium	7440-39-3	0.056	—	—	—	—	0.00E+00	0
Boron	7440-42-8	0.023	—	—	—	—	0.00E+00	0
Cadmium	7440-43-9	0.0040	—	—	—	—	0.00E+00	0
Carbon disulfide	75-15-0	0.00012	Yes	—	—	—	0.00E+00	0
Carbon tetrachloride	56-23-5	0.0013	Yes	1.17E-06	3.10E-07	1.39E-06	2.87E-06	0.62
Chloroform	67-66-3	0.00014	Yes	5.44E-08	4.92E-09	5.60E-07	6.20E-07	0.13
Chromium	7440-47-3	0.011	—	—	—	—	0.00E+00	0
Cobalt	7440-48-4	0.0040	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.036	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.0067	Yes	—	—	—	0.00E+00	0
di-n-Octylphthalate	117-84-0	0.0033	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.13	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0052	—	—	—	—	0.00E+00	0

Table G-31. WMA C Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Iron	7439-89-6	0.065	—	—	—	—	0.00E+00	0
Lead	7439-92-1	0.00030	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.0052	—	—	—	—	0.00E+00	0
Mercury	7439-97-6	0.00020	—	—	—	—	0.00E+00	0
Methyl methacrylate	80-62-6	0.0014	Yes	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0029	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.011	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	44.4	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.15	—	—	—	—	0.00E+00	0
Selenium	7782-49-2	0.011	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.0055	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.42	—	—	—	—	0.00E+00	0
Thallium	7440-28-0	0.00032	—	—	—	—	0.00E+00	0
Tin	7440-31-5	0.00039	—	—	—	—	0.00E+00	0
Tributyl phosphate	126-73-8	0.0010	—	1.16E-07	—	—	1.16E-07	0.025
Uranium	7440-61-1	0.0043	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.017	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.0056	—	—	—	—	0.00E+00	0

Table G-31. WMA C Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Americium-241	14596-10-2	0.14	—	2.79E-07	—	—	2.79E-07	0.060
Iodine-129	15046-84-1	4.6	—	1.30E-05	—	—	1.30E-05	2.8
Plutonium-239/240	PU-239/240	0.11	—	2.84E-07	—	—	2.84E-07	0.061
Technetium-99	14133-76-7	5,981	—	3.15E-04	—	—	3.15E-04	68
Tritium	10028-17-8	1,074	Yes	1.04E-06	—	4.86E-06	5.90E-06	1.3
Total cumulative ELCR				**4.57E-04**	**1.02E-06**	**6.81E-06**	**4.65E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-32. WMA C Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
2-Hexanone	591-78-6	0.0020	Yes	0.012	—	0.032	0.044	0.43
Acetone	67-64-1	0.0011	Yes	3.58E-05	—	1.66E-05	5.25E-05	5.17E-04
Aluminum	7429-90-5	0.026	—	7.67E-04	4.55E-06	—	7.72E-04	0.0076
Antimony	7440-36-0	0.046	—	3.5	0.14	—	3.6	36
Arsenic	7440-38-2	0.0065	—	0.65	0.0039	—	0.66	6.5
Barium	7440-39-3	0.056	—	0.0083	7.07E-04	—	0.0090	0.089
Boron	7440-42-8	0.023	—	0.0035	2.07E-05	—	0.0035	0.035
Cadmium	7440-43-9	0.0040	—	0.24	0.028	—	0.27	2.6
Carbon disulfide	75-15-0	0.00012	Yes	3.60E-05	6.52E-06	8.22E-05	1.25E-04	0.0012
Carbon tetrachloride	56-23-5	0.0013	Yes	0.0097	0.0027	0.0062	0.019	0.18
Chloroform	67-66-3	0.00014	Yes	4.10E-04	3.84E-05	6.69E-04	0.0011	0.011
Chromium	7440-47-3	0.011	—	2.18E-04	9.96E-05	—	3.18E-04	0.0031
Cobalt	7440-48-4	0.0040	—	0.40	9.49E-04	—	0.40	3.9
Copper	7440-50-8	0.036	—	0.027	1.61E-04	—	0.027	0.27
Cyanide	57-12-5	0.0067	Yes	0.34	0.0020	4.0	4.4	43
di-n-Octylphthalate	117-84-0	0.0033	—	0.0099	—	—	0.0099	0.097

Table G-32. WMA C Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Fluoride	16984-48-8	0.13	—	0.067	3.99E-04	—	0.068	0.67
Hexavalent chromium	18540-29-9	0.0052	—	0.052	0.025	—	0.077	0.76
Iron	7439-89-6	0.065	—	0.0028	1.66E-05	—	0.0028	0.028
Lead	7439-92-1	0.00030	—	—	—	—	0	0
Manganese	7439-96-5	0.0052	—	0.0064	9.57E-04	—	0.0074	0.073
Mercury	7439-97-6	0.00020	—	0.020	0.0017	—	0.022	0.21
Methyl methacrylate	80-62-6	0.0014	Yes	3.00E-05	—	9.59E-04	9.89E-04	0.0097
Molybdenum	7439-98-7	0.0029	—	0.017	1.02E-04	—	0.017	0.17
Nickel	7440-02-0	0.011	—	0.016	4.75E-04	—	0.016	0.16
Nitrate	14797-55-8	44.4	—	0.19	0.0011	—	0.19	1.9
Nitrite	14797-65-0	0.15	—	0.015	8.83E-05	—	0.015	0.15
Selenium	7782-49-2	0.011	—	0.065	3.85E-04	—	0.065	0.64
Silver	7440-22-4	0.0055	—	0.033	0.0029	—	0.036	0.36
Strontium	7440-24-6	0.42	—	0.021	1.26E-04	—	0.021	0.21
Thallium	7440-28-0	0.00032	—	—	—	—	0	0
Tin	7440-31-5	0.00039	—	1.94E-05	1.15E-07	—	1.95E-05	1.92E-04
Tributyl phosphate	126-73-8	0.0010	—	0.0030	--	—	0.0030	0.030

Table G-32. WMA C Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Uranium	7440-61-1	0.0043	—	0.043	2.54E-04	—	0.043	0.43
Vanadium	7440-62-2	0.017	—	0.10	0.023	—	0.13	1.2
Zinc	7440-66-6	0.0056	—	5.58E-04	1.99E-06	—	5.60E-04	0.0055
			Total HI	**5.8**	**0.23**	**4.1**	**10**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-33. B Plant Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Antimony	7440-36-0	0.075	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0045	—	8.74E-05	4.86E-07	—	8.79E-05	3.8
Barium	7440-39-3	0.070	—	—	—	—	0.00E+00	0
Boron	7440-42-8	0.053	—	—	—	—	0.00E+00	0
Cadmium	7440-43-9	0.0051	—	—	—	—	0.00E+00	0
Chromium	7440-47-3	0.0085	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0032	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.0069	Yes	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.89	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0054	—	—	—	—	0.00E+00	0
Iron	7439-89-6	0.14	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.0093	—	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0071	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.0085	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	86.2	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.21	—	—	—	—	0.00E+00	0

Table G-33. B Plant Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Selenium	7782-49-2	0.0082	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.0080	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.34	—	—	—	—	0.00E+00	0
Tin	7440-31-5	0.00028	—	—	—	—	0.00E+00	0
Uranium	7440-61-1	0.023	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.018	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.37	—	—	—	—	0.00E+00	0
Americium-241	14596-10-2	0.19	—	3.76E-07	—	—	3.76E-07	0.016
Carbon-14	14762-75-5	12.3	—	3.65E-07	—	—	3.65E-07	0.016
Cesium-137	10045-97-3	1,390	—	8.09E-04	—	—	8.09E-04	35
Europium-154	15585-10-1	45.0	—	8.87E-06	—	—	8.87E-06	0.38
Iodine-129	15046-84-1	1.5	—	4.34E-06	—	—	4.34E-06	0.19
Neptunium-237	13994-20-2	0.71	—	8.40E-07	—	—	8.40E-07	0.036
Plutonium-238	13981-16-3	0.19	—	4.76E-07	—	—	4.76E-07	0.020
Plutonium-239/240	PU-239/240	30.3	—	7.84E-05	—	—	7.84E-05	3.4
Strontium-90	10098-97-2	1,127	—	1.21E-03	—	—	1.21E-03	52
Technetium-99	14133-76-7	1,415	—	7.45E-05	—	—	7.45E-05	3.2

Table G-33. B Plant Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Tritium	10028-17-8	5,272	Yes	5.12E-06	—	2.39E-05	2.90E-05	1.2
Uranium-233/234	U-233/234	11.0	—	1.49E-05	—	—	1.49E-05	0.64
Uranium-235	15117-96-1	0.46	—	6.11E-07	—	—	6.11E-07	0.026
Uranium-238	U-238	8.4	—	1.02E-05	—	—	1.02E-05	0.44
Total cumulative ELCR				**2.30E-03**	**4.86E-07**	**2.39E-05**	**2.33E-03**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-34. B Plant Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Antimony	7440-36-0	0.075	—	5.6	0.22	—	5.9	46
Arsenic	7440-38-2	0.0045	—	0.45	0.0027	—	0.46	3.6
Barium	7440-39-3	0.070	—	0.011	8.95E-04	—	0.011	0.090
Boron	7440-42-8	0.053	—	0.0080	4.72E-05	—	0.0080	0.063
Cadmium	7440-43-9	0.0051	—	0.31	0.036	—	0.34	2.7
Chromium	7440-47-3	0.0085	—	1.71E-04	7.79E-05	—	2.48E-04	0.0020
Copper	7440-50-8	0.0032	—	0.0024	1.40E-05	—	0.0024	0.019
Cyanide	57-12-5	0.0069	Yes	0.34	0.0020	4.1	4.5	35
Fluoride	16984-48-8	0.89	—	0.45	0.0026	—	0.45	3.5
Hexavalent chromium	18540-29-9	0.0054	—	0.054	0.026	—	0.080	0.63
Iron	7439-89-6	0.14	—	0.0058	3.45E-05	—	0.0058	0.046
Manganese	7439-96-5	0.0093	—	0.012	0.0017	—	0.013	0.10
Molybdenum	7439-98-7	0.0071	—	0.042	2.52E-04	—	0.043	0.34
Nickel	7440-02-0	0.0085	—	0.013	3.76E-04	—	0.013	0.10
Nitrate	14797-55-8	86.2	—	0.36	0.0022	—	0.37	2.9
Nitrite	14797-65-0	0.21	—	0.021	1.22E-04	—	0.021	0.16
Selenium	7782-49-2	0.0082	—	0.049	2.90E-04	—	0.049	0.39
Silver	7440-22-4	0.0080	—	0.048	0.0043	—	0.052	0.41

Table G-34. B Plant Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Strontium	7440-24-6	0.34	—	0.017	1.00E-04	—	0.017	0.13
Tin	7440-31-5	0.00028	—	1.41E-05	8.36E-08	—	1.42E-05	1.12E-04
Uranium	7440-61-1	0.023	—	0.23	0.0014	—	0.23	1.8
Vanadium	7440-62-2	0.018	—	0.11	0.025	—	0.13	1.0
Zinc	7440-66-6	0.37	—	0.037	1.31E-04	—	0.037	0.29
			Total HI	**8.2**	**0.33**	**4.1**	**13**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-35. Semiworks Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Arsenic	7440-38-2	0.0040	—	7.70E-05	4.29E-07	—	7.74E-05	59
Barium	7440-39-3	0.083	—	—	—	—	0.00E+00	0
Boron	7440-42-8	0.053	—	—	—	—	0.00E+00	0
Chromium	7440-47-3	0.0052	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0019	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.21	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0054	—	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0036	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.0012	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	41.3	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.20	—	—	—	—	0.00E+00	0
Selenium	7782-49-2	0.0059	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.38	—	—	—	—	0.00E+00	0
Uranium	7440-61-1	0.0061	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.013	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.0066	—	—	—	—	0.00E+00	0
Iodine-129	15046-84-1	1.8	—	5.18E-06	—	—	5.18E-06	4.0
Plutonium-239/240	PU-239/240	0.11	—	2.84E-07	—	—	2.84E-07	0.22

Table G-35. Semiworks Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Strontium-90	10098-97-2	2.8	—	3.00E-06	—	—	3.00E-06	2.3
Technetium-99	14133-76-7	62.0	—	3.26E-06	—	—	3.26E-06	2.5
Tritium	10028-17-8	7,500	Yes	7.28E-06	—	3.39E-05	4.12E-05	32
Total cumulative ELCR				**9.60E-05**	**4.29E-07**	**3.39E-05**	**1.30E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

CAS = Chemical Abstracts Service

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

ELCR = excess lifetime cancer risk

Table G-36. Semiworks Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Arsenic	7440-38-2	0.0040	—	0.40	0.0024	—	0.40	39
Barium	7440-39-3	0.083	—	0.012	0.0011	—	0.013	1.3
Boron	7440-42-8	0.053	—	0.0080	4.72E-05	—	0.0080	0.77
Chromium	7440-47-3	0.0052	—	1.04E-04	4.74E-05	—	1.51E-04	0.015
Copper	7440-50-8	0.0019	—	0.0014	8.40E-06	—	0.0014	0.14
Fluoride	16984-48-8	0.21	—	0.11	6.34E-04	—	0.11	10
Hexavalent chromium	18540-29-9	0.0054	—	0.054	0.026	—	0.080	7.6
Molybdenum	7439-98-7	0.0036	—	0.022	1.29E-04	—	0.022	2.1
Nickel	7440-02-0	0.0012	—	0.0018	5.29E-05	—	0.0018	0.18
Nitrate	14797-55-8	41.3	—	0.17	0.0010	—	0.18	17
Nitrite	14797-65-0	0.20	—	0.020	1.19E-04	—	0.020	1.9
Selenium	7782-49-2	0.0059	—	0.035	2.09E-04	—	0.035	3.4
Strontium	7440-24-6	0.38	—	0.019	1.12E-04	—	0.019	1.8
Uranium	7440-61-1	0.0061	—	0.061	3.62E-04	—	0.061	5.9
Vanadium	7440-62-2	0.013	—	0.076	0.017	—	0.093	8.9

Table G-36. Semiworks Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Zinc	7440-66-6	0.0066	—	6.62E-04	2.36E-06	—	6.65E-04	0.064
			Total HI	**0.99**	**0.049**	**0**	**1.0**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-37. LERF Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS #	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Antimony	7440-36-0	0.00032	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0044	—	8.55E-05	4.76E-07	—	8.60E-05	90
Barium	7440-39-3	0.066	—	—	—	—	0.00E+00	0
Carbon tetrachloride	56-23-5	0.0023	Yes	2.08E-06	5.51E-07	2.47E-06	5.10E-06	5.3
Chromium	7440-47-3	0.014	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0040	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.25	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0066	—	—	—	—	0.00E+00	0
Iron	7439-89-6	0.23	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.010	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.011	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	41.9	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.32	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.0075	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.57	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.018	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.0083	—	—	—	—	0.00E+00	0

Table G-37. LERF Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS #	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Iodine-129	15046-84-1	0.32	—	8.95E-07	—	—	8.95E-07	0.94
Tritium	10028-17-8	632	Yes	6.13E-07	—	2.86E-06	3.47E-06	3.6
Total cumulative ELCR				**8.91E-05**	**1.03E-06**	**5.33E-06**	**9.54E-05**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-38. LERF Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Antimony	7440-36-0	0.00032	—	0.024	9.49E-04	—	0.025	2.1
Arsenic	7440-38-2	0.0044	—	0.44	0.0026	—	0.45	37
Barium	7440-39-3	0.066	—	0.0099	8.38E-04	—	0.011	0.89
Carbon tetrachloride	56-23-5	0.0023	Yes	0.017	0.0048	0.011	0.033	2.8
Chromium	7440-47-3	0.014	—	2.81E-04	1.28E-04	—	4.09E-04	0.034
Copper	7440-50-8	0.0040	—	0.0030	1.79E-05	—	0.0030	0.25
Fluoride	16984-48-8	0.25	—	0.12	7.41E-04	—	0.13	10
Hexavalent chromium	18540-29-9	0.0066	—	0.066	0.031	—	0.097	8.1
Iron	7439-89-6	0.23	—	0.0098	5.84E-05	—	0.0099	0.82
Manganese	7439-96-5	0.010	—	0.012	0.0018	—	0.014	1.2
Nickel	7440-02-0	0.011	—	0.016	4.80E-04	—	0.017	1.4
Nitrate	14797-55-8	41.9	—	0.18	0.0010	—	0.18	15
Nitrite	14797-65-0	0.32	—	0.032	1.91E-04	—	0.032	2.7
Silver	7440-22-4	0.0075	—	0.045	0.0040	—	0.049	4.1
Strontium	7440-24-6	0.57	—	0.028	1.68E-04	—	0.029	2.4
Vanadium	7440-62-2	0.018	—	0.11	0.024	—	0.13	11

Table G-38. LERF Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Zinc	7440-66-6	0.0083	—	8.31E-04	2.96E-06	—	8.34E-04	0.069
			Total HI	**1.1**	**0.074**	**0.011**	**1.2**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-39. Gable Mountain Pond Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Antimony	7440-36-0	0.072	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0047	—	8.97E-05	4.99E-07	--	9.02E-05	27
Barium	7440-39-3	0.052	—	—	—	—	0.00E+00	0
Chromium	7440-47-3	0.034	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0060	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.10	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0053	—	—	—	—	0.00E+00	0
Iron	7439-89-6	3.1	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.091	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.022	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	94.2	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.21	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	1.1	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.0081	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.023	—	—	—	—	0.00E+00	0
Strontium-90	10098-97-2	214	—	2.28E-04	—	—	2.28E-04	68

Table G-39. Gable Mountain Pond Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Tritium	10028-17-8	3,200	Yes	3.10E-06	—	1.45E-05	1.76E-05	5.2
Total cumulative ELCR				**3.21E-04**	**4.99E-07**	**1.45E-05**	**3.36E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-40. Gable Mountain Pond Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Antimony	7440-36-0	0.072	—	5.4	0.21	—	5.6	79
Arsenic	7440-38-2	0.0047	—	0.47	0.0028	—	0.47	6.7
Barium	7440-39-3	0.052	—	0.0078	6.65E-04	—	0.0085	0.12
Chromium	7440-47-3	0.034	—	6.80E-04	3.11E-04	—	9.91E-04	0.014
Copper	7440-50-8	0.0060	—	0.0045	2.67E-05	—	0.0045	0.064
Fluoride	16984-48-8	0.10	—	0.051	3.04E-04	—	0.051	0.73
Hexavalent chromium	18540-29-9	0.0053	—	0.053	0.025	—	0.078	1.1
Iron	7439-89-6	3.1	—	0.13	7.88E-04	—	0.13	1.9
Manganese	7439-96-5	0.091	—	0.11	0.017	—	0.13	1.9
Nickel	7440-02-0	0.022	—	0.032	9.63E-04	—	0.033	0.48
Nitrate	14797-55-8	94.2	—	0.40	0.0024	—	0.40	5.7
Nitrite	14797-65-0	0.21	—	0.021	1.24E-04	—	0.021	0.30
Strontium	7440-24-6	1.1	—	0.055	3.27E-04	—	0.055	0.79
Vanadium	7440-62-2	0.0081	—	0.049	0.011	—	0.060	0.85

Table G-40. Gable Mountain Pond Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Zinc	7440-66-6	0.023	—	0.0023	8.17E-06	—	0.0023	0.033
			Total HI	**6.8**	**0.27**	**0**	**7.0**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-41. 200-BP-5 West Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Aluminum	7429-90-5	5.5	—	—	—	—	0.00E+00	0
Antimony	7440-36-0	0.059	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0061	—	1.17E-04	6.51E-07	—	1.18E-04	34
Barium	7440-39-3	0.068	—	—	—	—	0.00E+00	0
Beryllium	7440-41-7	0.00012	—	—	—	—	0.00E+00	0
Bis(2-ethylhexyl) phthalate	117-81-7	0.0025	—	4.46E-07	6.84E-07	—	1.13E-06	0.32
Cadmium	7440-43-9	0.0028	—	—	—	—	0.00E+00	0
Carbon disulfide	75-15-0	0.0016	Yes	—	—	—	0.00E+00	0
Carbon tetrachloride	56-23-5	0.0025	Yes	2.27E-06	6.02E-07	2.69E-06	5.56E-06	1.6
Chloroform	67-66-3	0.00066	Yes	2.63E-07	2.37E-08	2.70E-06	2.99E-06	0.86
Chromium	7440-47-3	0.016	—	—	—	—	0.00E+00	0
Cobalt	7440-48-4	0.0034	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0050	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.072	Yes	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.42	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0055	—	—	—	—	0.00E+00	0
Iron	7439-89-6	4.4	—	—	—	—	0.00E+00	0

Table G-41. 200-BP-5 West Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Lead	7439-92-1	0.0051	—	—	—	—	0.00E+00	0
Lithium	7439-93-2	0.013	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.15	—	—	—	—	0.00E+00	0
Mercury	7439-97-6	0.00018	—	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0078	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.013	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	86.7	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.19	—	—	—	—	0.00E+00	0
Selenium	7782-49-2	0.0031	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.31	—	—	—	—	0.00E+00	0
Tributyl phosphate	126-73-8	0.0017	—	1.96E-07	—	—	1.96E-07	0.056
Uranium	7440-61-1	0.0089	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.017	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	1.2	—	—	—	—	0.00E+00	0
Americium-241	14596-10-2	0.31	—	6.15E-07	—	—	6.15E-07	0.18
Cobalt-60	10198-40-0	6.4	—	1.91E-06	—	—	1.91E-06	0.55
Iodine-129	15046-84-1	1.1	—	2.98E-06	—	—	2.98E-06	0.85
Neptunium-237	13994-20-2	0.57	—	6.69E-07	—	—	6.69E-07	0.19

Table G-41. 200-BP-5 West Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Plutonium-239/240	PU-239/240	0.052	—	1.34E-07	—	—	1.34E-07	0.038
Strontium-90	10098-97-2	82.6	—	8.84E-05	—	—	8.84E-05	25
Technetium-99	14133-76-7	1,711	—	9.00E-05	—	—	9.00E-05	26
Tritium	10028-17-8	6,693	Yes	6.49E-06	—	3.03E-05	3.68E-05	11
Total cumulative ELCR				**3.11E-04**	**1.96E-06**	**3.57E-05**	**3.49E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-42. 200-BP-5 West Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Aluminum	7429-90-5	5.5	—	0.17	9.85E-04	—	0.17	0.31
Antimony	7440-36-0	0.059	—	4.4	0.17	—	4.6	8.5
Arsenic	7440-38-2	0.0061	—	0.61	0.0036	—	0.61	1.1
Barium	7440-39-3	0.068	—	0.010	8.61E-04	—	0.011	0.020
Beryllium	7440-41-7	0.00012	—	0.0018	0.0015	—	0.0032	0.0060
Bis(2-ethylhexyl) phthalate	117-81-7	0.0025	—	0.0037	0.0059	—	0.0096	0.018
Cadmium	7440-43-9	0.0028	—	0.17	0.020	—	0.19	0.34
Carbon disulfide	75-15-0	0.0016	Yes	4.88E-04	8.84E-05	0.0011	0.0017	0.0031
Carbon tetrachloride	56-23-5	0.0025	Yes	0.019	0.0052	0.012	0.036	0.067
Chloroform	67-66-3	0.00066	Yes	0.0020	1.85E-04	0.0032	0.0054	0.0100
Chromium	7440-47-3	0.016	—	3.19E-04	1.46E-04	—	4.65E-04	8.58E-04
Cobalt	7440-48-4	0.0034	—	0.34	8.06E-04	—	0.34	0.63
Copper	7440-50-8	0.0050	—	0.0038	2.23E-05	—	0.0038	0.0070
Cyanide	57-12-5	0.072	Yes	3.6	0.021	43	46	86
Fluoride	16984-48-8	0.42	—	0.21	0.0013	—	0.21	0.39
Hexavalent chromium	18540-29-9	0.0055	—	0.055	0.026	—	0.081	0.15
Iron	7439-89-6	4.4	—	0.19	0.0011	—	0.19	0.35
Lead	7439-92-1	0.0051	—	—	—	—	0	0
Lithium	7439-93-2	0.013	—	0.19	0.0012	—	0.20	0.36
Manganese	7439-96-5	0.15	—	0.18	0.027	—	0.21	0.39

Table G-42. 200-BP-5 West Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Mercury	7439-97-6	0.00018	—	0.018	0.0016	—	0.020	0.037
Molybdenum	7439-98-7	0.0078	—	0.047	2.77E-04	—	0.047	0.087
Nickel	7440-02-0	0.013	—	0.019	5.63E-04	—	0.020	0.036
Nitrate	14797-55-8	86.7	—	0.37	0.0022	—	0.37	0.68
Nitrite	14797-65-0	0.19	—	0.019	1.13E-04	—	0.019	0.035
Selenium	7782-49-2	0.0031	—	0.018	1.09E-04	—	0.018	0.034
Strontium	7440-24-6	0.31	—	0.016	9.22E-05	—	0.016	0.029
Tributyl phosphate	126-73-8	0.0017	—	0.0051	—	—	0.0051	0.0094
Uranium	7440-61-1	0.0089	—	0.089	5.29E-04	—	0.090	0.17
Vanadium	7440-62-2	0.017	—	0.10	0.023	—	0.12	0.23
Zinc	7440-66-6	1.2	—	0.12	4.16E-04	—	0.12	0.22
			Total HI	**11**	**0.32**	**43**	**54**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure rout

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-43. 200-BP-5 Confined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Aluminum	7429-90-5	0.024	—	—	—	—	0.00E+00	0
Antimony	7440-36-0	0.042	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0030	—	5.86E-05	3.26E-07	—	5.89E-05	51
Barium	7440-39-3	0.091	—	—	—	—	0.00E+00	0
Benzene	71-43-2	0.0025	Yes	1.76E-06	2.68E-07	3.47E-06	5.51E-06	4.8
Bis(2-ethylhexyl) phthalate	117-81-7	0.0038	—	6.80E-07	1.04E-06	—	1.72E-06	1.5
Boron	7440-42-8	0.018	—	—	—	—	0.00E+00	0
Carbon tetrachloride	56-23-5	0.0023	Yes	2.07E-06	5.49E-07	2.46E-06	5.07E-06	4.4
Chloroform	67-66-3	0.0013	Yes	5.17E-07	4.67E-08	5.32E-06	5.89E-06	5.1
Chromium	7440-47-3	0.0073	—	—	—	—	0.00E+00	0
Cobalt	7440-48-4	0.00086	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.0019	—	—	—	—	0.00E+00	0
Cyanide	57-12-5	0.010	Yes	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.21	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0062	—	—	—	—	0.00E+00	0
Iron	7439-89-6	2.5	—	—	—	—	0.00E+00	0

Table G-43. 200-BP-5 Confined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Manganese	7439-96-5	0.064	—	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0055	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.0078	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	9.3	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.19	—	—	—	—	0.00E+00	0
Phenol	108-95-2	0.00091	—	—	—	—	0.00E+00	0
Silver	7440-22-4	0.017	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.26	—	—	—	—	0.00E+00	0
Thallium	7440-28-0	6.47E-05	—	—	—	—	0.00E+00	0
Toluene	108-88-3	0.0023	Yes	—	—	—	0.00E+00	0
Tributyl phosphate	126-73-8	0.0084	—	9.70E-07	—	—	9.70E-07	0.84
Uranium	7440-61-1	0.0033	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.011	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.079	—	—	—	—	0.00E+00	0
Americium-241	14596-10-2	0.10	—	2.01E-07	—	—	2.01E-07	0.17
Carbon-14	14762-75-5	34.7	—	1.03E-06	—	—	1.03E-06	0.89
Iodine-129	15046-84-1	0.89	—	2.51E-06	—	—	2.51E-06	2.2
Plutonium-239/240	PU-239/240	0.074	—	1.91E-07	—	—	1.91E-07	0.17

Table G-43. 200-BP-5 Confined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Strontium-90	10098-97-2	2.3	—	2.46E-06	—	—	2.46E-06	2.1
Technetium-99	14133-76-7	353	—	1.86E-05	—	—	1.86E-05	16
Tritium	10028-17-8	1,756	Yes	1.70E-06	—	7.95E-06	9.65E-06	8.3
Uranium-234	13966-29-5	1.3	—	1.80E-06	—	—	1.80E-06	1.6
Uranium-238	U-238	1.1	—	1.30E-06	—	—	1.30E-06	1.1
Total cumulative ELCR				**9.44E-05**	**2.23E-06**	**1.92E-05**	**1.16E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-44. 200-BP-5 Confined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Aluminum	7429-90-5	0.024	—	7.30E-04	4.33E-06	—	7.34E-04	0.0068
Antimony	7440-36-0	0.042	—	3.1	0.12	—	3.3	30
Arsenic	7440-38-2	0.0030	—	0.30	0.0018	—	0.31	2.8
Barium	7440-39-3	0.091	—	0.014	0.0012	—	0.015	0.14
Benzene	71-43-2	0.0025	Yes	0.019	0.0029	0.040	0.062	0.57
Bis(2-ethylhexyl) phthalate	117-81-7	0.0038	—	0.0057	0.0090	—	0.015	0.14
Boron	7440-42-8	0.018	—	0.0027	1.59E-05	—	0.0027	0.025
Carbon tetrachloride	56-23-5	0.0023	Yes	0.017	0.0047	0.011	0.033	0.31
Chloroform	67-66-3	0.0013	Yes	0.0039	3.65E-04	0.0064	0.011	0.098
Chromium	7440-47-3	0.0073	—	1.46E-04	6.68E-05	—	2.13E-04	0.0020
Cobalt	7440-48-4	0.00086	—	0.086	2.05E-04	—	0.086	0.80
Copper	7440-50-8	0.0019	—	0.0014	8.31E-06	—	0.0014	0.013
Cyanide	57-12-5	0.010	Yes	0.48	0.0028	5.7	6.2	58
Fluoride	16984-48-8	0.21	—	0.11	6.26E-04	—	0.11	0.98
Hexavalent chromium	18540-29-9	0.0062	—	0.061	0.029	—	0.091	0.84
Iron	7439-89-6	2.5	—	0.11	6.34E-04	—	0.11	1.00
Manganese	7439-96-5	0.064	—	0.080	0.012	—	0.092	0.86
Molybdenum	7439-98-7	0.0055	—	0.033	1.96E-04	—	0.033	0.31

Table G-44. 200-BP-5 Confined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Nickel	7440-02-0	0.0078	—	0.012	3.46E-04	—	0.012	0.11
Nitrate	14797-55-8	9.3	—	0.039	2.32E-04	—	0.039	0.36
Nitrite	14797-65-0	0.19	—	0.019	1.11E-04	—	0.019	0.17
Phenol	108-95-2	0.00091	—	9.09E-05	4.57E-06	—	9.55E-05	8.84E-04
Silver	7440-22-4	0.017	—	0.10	0.0091	—	0.11	1.0
Strontium	7440-24-6	0.26	—	0.013	7.56E-05	—	0.013	0.12
Thallium	7440-28-0	6.47E-05	—	—	—	—	0	0
Toluene	108-88-3	0.0023	Yes	8.62E-04	3.08E-04	2.21E-04	0.0014	0.013
Tributyl phosphate	126-73-8	0.0084	—	0.025	—	—	0.025	0.23
Uranium	7440-61-1	0.0033	—	0.033	1.95E-04	—	0.033	0.31
Vanadium	7440-62-2	0.011	—	0.067	0.015	—	0.082	0.76
Zinc	7440-66-6	0.079	—	0.0079	2.81E-05	—	0.0079	0.073
			Total HI	**4.8**	**0.22**	**5.8**	**11**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-45. 200-BP-5 Far-Field (North of Gable Gap) Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Arsenic	7440-38-2	0.013	—	2.44E-04	1.36E-06	—	2.45E-04	75
Barium	7440-39-3	0.026	—	—	—	—	0.00E+00	0
Boron	7440-42-8	0.029	—	—	—	—	0.00E+00	0
Chromium	7440-47-3	0.0087	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.12	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.60	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.011	—	—	—	—	0.00E+00	0
Iron	7439-89-6	1.3	—	—	—	—	0.00E+00	0
Lead	7439-92-1	0.00042	—	—	—	—	0.00E+00	0
Lithium	7439-93-2	0.0094	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.040	—	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0053	—	—	—	—	0.00E+00	0
Nickel	7440-02-0	0.0053	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	21.0	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.22	—	—	—	—	0.00E+00	0
Selenium	7782-49-2	0.0012	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.19	—	—	—	—	0.00E+00	0
Uranium	7440-61-1	0.0042	—	—	—	—	0.00E+00	0

Table G-45. 200-BP-5 Far-Field (North of Gable Gap) Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Vanadium	7440-62-2	0.019	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.37	—	—	—	—	0.00E+00	0
Americium-241	14596-10-2	0.086	—	1.71E-07	—	—	1.71E-07	0.053
Iodine-129	15046-84-1	0.68	—	1.91E-06	—	—	1.91E-06	0.59
Technetium-99	14133-76-7	150	—	7.89E-06	—	—	7.89E-06	2.4
Tritium	10028-17-8	12,770	Yes	1.24E-05	—	5.78E-05	7.02E-05	22
Total cumulative ELCR				**2.66E-04**	**1.36E-06**	**5.78E-05**	**3.25E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-46. 200-BP-5 Far-Field (North of Gable Gap) Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Arsenic	7440-38-2	0.013	—	1.3	0.0075	—	1.3	51
Barium	7440-39-3	0.026	—	0.0039	3.30E-04	—	0.0042	0.17
Boron	7440-42-8	0.029	—	0.0044	2.61E-05	—	0.0044	0.18
Chromium	7440-47-3	0.0087	—	1.74E-04	7.96E-05	—	2.54E-04	0.010
Copper	7440-50-8	0.12	—	0.088	5.25E-04	—	0.089	3.6
Fluoride	16984-48-8	0.60	—	0.30	0.0018	—	0.30	12
Hexavalent chromium	18540-29-9	0.011	—	0.11	0.054	—	0.17	6.8
Iron	7439-89-6	1.3	—	0.056	3.34E-04	—	0.057	2.3
Lead	7439-92-1	0.00042	—	—	—	—	0	0
Lithium	7439-93-2	0.0094	—	0.14	8.37E-04	—	0.14	5.7
Manganese	7439-96-5	0.040	—	0.050	0.0074	—	0.058	2.3
Molybdenum	7439-98-7	0.0053	—	0.032	1.89E-04	—	0.032	1.3
Nickel	7440-02-0	0.0053	—	0.0079	2.35E-04	—	0.0082	0.33
Nitrate	14797-55-8	21.0	—	0.089	5.27E-04	—	0.089	3.6
Nitrite	14797-65-0	0.22	—	0.022	1.33E-04	—	0.022	0.91
Selenium	7782-49-2	0.0012	—	0.0074	4.37E-05	—	0.0074	0.30

Table G-46. 200-BP-5 Far-Field (North of Gable Gap) Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Strontium	7440-24-6	0.19	—	0.0097	5.74E-05	—	0.0097	0.39
Uranium	7440-61-1	0.0042	—	0.042	2.51E-04	—	0.042	1.7
Vanadium	7440-62-2	0.019	—	0.11	0.026	—	0.14	5.7
Zinc	7440-66-6	0.37	—	0.037	1.31E-04	—	0.037	1.5
			Total HI	**2.4**	**0.10**	**0**	**2.5**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

Table G-47. 200-BP-5 Near-River Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Aluminum	7429-90-5	0.024	—	—	—	—	0.00E+00	0
Arsenic	7440-38-2	0.0032	—	6.07E-05	3.38E-07	—	6.10E-05	41
Barium	7440-39-3	0.029	—	—	—	—	0.00E+00	0
Boron	7440-42-8	0.021	—	—	—	—	0.00E+00	0
Cadmium	7440-43-9	0.00010	—	—	—	—	0.00E+00	0
Chloroform	67-66-3	0.00019	Yes	7.59E-08	6.86E-09	7.81E-07	8.64E-07	0.58
Chromium	7440-47-3	0.0061	—	—	—	—	0.00E+00	0
Cobalt	7440-48-4	0.00014	—	—	—	—	0.00E+00	0
Copper	7440-50-8	0.00094	—	—	—	—	0.00E+00	0
Fluoride	16984-48-8	0.24	—	—	—	—	0.00E+00	0
Hexavalent chromium	18540-29-9	0.0061	—	—	—	—	0.00E+00	0
Iron	7439-89-6	0.19	—	—	—	—	0.00E+00	0
Lead	7439-92-1	0.0023	—	—	—	—	0.00E+00	0
Lithium	7439-93-2	0.010	—	—	—	—	0.00E+00	0
Manganese	7439-96-5	0.014	—	—	—	—	0.00E+00	0
Molybdenum	7439-98-7	0.0045	—	—	—	—	0.00E+00	0

Table G-47. 200-BP-5 Near-River Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Nickel	7440-02-0	0.00063	—	—	—	—	0.00E+00	0
Nitrate	14797-55-8	23.8	—	—	—	—	0.00E+00	0
Nitrite	14797-65-0	0.22	—	—	—	—	0.00E+00	0
Selenium	7782-49-2	0.0017	—	—	—	—	0.00E+00	0
Strontium	7440-24-6	0.21	—	—	—	—	0.00E+00	0
Thallium	7440-28-0	0.0018	—	—	—	—	0.00E+00	0
Tin	7440-31-5	7.88E-05	—	—	—	—	0.00E+00	0
Trichloroethene	79-01-6	0.0018	Yes	1.08E-06	1.85E-07	1.33E-06	2.59E-06	1.8
Uranium	7440-61-1	0.0023	—	—	—	—	0.00E+00	0
Vanadium	7440-62-2	0.014	—	—	—	—	0.00E+00	0
Zinc	7440-66-6	0.16	—	—	—	—	0.00E+00	0
Americium-241	14596-10-2	0.13	—	2.59E-07	—	—	2.59E-07	0.17
Carbon-14	14762-75-5	293	—	8.68E-06	—	—	8.68E-06	5.9
Iodine-129	15046-84-1	0.25	—	6.97E-07	—	—	6.97E-07	0.47
Technetium-99	14133-76-7	61.2	—	3.22E-06	—	—	3.22E-06	2.2
Tritium	10028-17-8	12,568	Yes	1.22E-05	—	5.69E-05	6.91E-05	47
Uranium-233/234	U-233/234	0.67	—	9.07E-07	—	—	9.07E-07	0.61

Table G-47. 200-BP-5 Near-River Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Cancer Risk Results for Radioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L or pCi/L)	Volatile[a,b]	Risk (Ingestion)	Risk (Dermal)	Risk (Inhalation)	Total Risk	% Contribution
Uranium-235	15117-96-1	0.048	—	6.39E-08	—	—	6.39E-08	0.043
Uranium-238	U-238	0.53	—	6.49E-07	—	—	6.49E-07	0.44
Total cumulative ELCR				**8.85E-05**	**5.30E-07**	**5.90E-05**	**1.48E-04**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013); or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001, Update: Radionuclide Toxicity," "Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors."

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route

CAS = Chemical Abstracts Service

ELCR = excess lifetime cancer risk

Table G-48. 200-BP-5 Near-River Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Aluminum	7429-90-5	0.024	—	7.30E-04	4.33E-06	—	7.34E-04	0.045
Arsenic	7440-38-2	0.0032	—	0.31	0.0019	—	0.32	20
Barium	7440-39-3	0.029	—	0.0043	3.63E-04	—	0.0046	0.29
Boron	7440-42-8	0.021	—	0.0031	1.86E-05	—	0.0031	0.19
Cadmium	7440-43-9	0.00010	—	0.0061	7.24E-04	—	0.0068	0.42
Chloroform	67-66-3	0.00019	Yes	5.72E-04	5.35E-05	9.33E-04	0.0016	0.096
Chromium	7440-47-3	0.0061	—	1.23E-04	5.60E-05	—	1.79E-04	0.011
Cobalt	7440-48-4	0.00014	—	0.014	3.27E-05	—	0.014	0.85
Copper	7440-50-8	0.00094	—	7.02E-04	4.16E-06	—	7.06E-04	0.043
Fluoride	16984-48-8	0.24	—	0.12	7.07E-04	—	0.12	7.4
Hexavalent chromium	18540-29-9	0.0061	—	0.061	0.029	—	0.090	5.5
Iron	7439-89-6	0.19	—	0.0081	4.82E-05	—	0.0082	0.50
Lead	7439-92-1	0.0023	—	—	—	—	0	0
Lithium	7439-93-2	0.010	—	0.15	9.05E-04	—	0.15	9.4
Manganese	7439-96-5	0.014	—	0.018	0.0027	—	0.021	1.3
Molybdenum	7439-98-7	0.0045	—	0.027	1.59E-04	—	0.027	1.7
Nickel	7440-02-0	0.00063	—	9.39E-04	2.79E-05	—	9.67E-04	0.060
Nitrate	14797-55-8	23.8	—	0.10	5.95E-04	—	0.10	6.2

Table G-48. 200-BP-5 Near-River Unconfined Exposure Area Tap Water Risk Assessment – Summary of Tap Water Exposure Pathway Noncancer Hazard Results for Nonradioactive Analytes in Groundwater

Analyte Name	CAS No.	Exposure Point Concentration in Groundwater Cw (mg/L)	Volatile[a,b]	HQ (Ingestion)	HQ (Dermal)	HQ (Inhalation)	Total HQ	% Contribution
Nitrite	14797-65-0	0.22	—	0.022	1.32E-04	—	0.022	1.4
Selenium	7782-49-2	0.0017	—	0.010	6.09E-05	—	0.010	0.64
Strontium	7440-24-6	0.21	—	0.010	6.09E-05	—	0.010	0.64
Thallium	7440-28-0	0.0018	—	—	—	—	0	0
Tin	7440-31-5	7.88E-05	—	3.93E-06	2.34E-08	—	3.96E-06	2.44E-04
Trichloroethene	79-01-6	0.0018	Yes	0.11	0.019	0.44	0.57	35
Uranium	7440-61-1	0.0023	—	0.023	1.39E-04	—	0.024	1.5
Vanadium	7440-62-2	0.014	—	0.086	0.020	—	0.11	6.5
Zinc	7440-66-6	0.16	—	0.016	5.85E-05	—	0.016	1.0
			Total HI	**1.1**	**0.077**	**0.44**	**1.6**	**100**

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2013).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

— = indicates toxicity criteria not available to quantify contaminant's noncancer hazard via this exposure route

CAS = Chemical Abstracts Service

HI = hazard index

HQ = hazard quotient

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Appendix H

COPC Identification Using a Well-Specific Evaluation Process

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Terms

BEHP	bis(2-ethylhexyl) phthalate
CAS	Chemical Abstracts Service
COPC	contaminant of potential concern
Cr(VI)	hexavalent chromium
DWS	drinking water standard
Ecology	Washington State Department of Ecology
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
LLWMA	low-level waste management area
MTCA	"Model Toxics Control Act—Cleanup" (WAC 173-340)
OU	operable unit
RfD	reference dose
RI	remedial investigation
TCE	trichloroethene
WMA	waste management area

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H1 Introduction

This appendix summarizes the risk estimates for monitoring wells selected for well-specific risk evaluation. Risk estimates were calculated for analytes detected in each monitoring wells using the U.S. Environmental Protection Agency (EPA) tap water (residential) scenario. The methods and assumptions used to calculate the groundwater cleanup levels are described in ECF-HANFORD-13-0035, *Tap Water Risk Assessment for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*. In total, 44 of 161 monitoring wells within the 200-BP-5 Groundwater Operable Unit (OU) were selected by the Washington State Department of Ecology (Ecology) to confirm that the contaminants of potential concern (COPCs) identified in Chapter 4 (Section 4.5) and Chapter 6 (Section 6.4) of the main text of this remedial investigation (RI) report are consistent with those that are identified in the select wells.

H2 Identification of Monitoring Wells

A total of 44 monitoring wells were selected by Ecology for the purpose of calculating well-specific cancer risk and noncancer hazards. Table H-1 lists the 44 wells and associated exposure areas within the 200-BP-5 OU that were included in the well-specific evaluation.

H3 Groundwater Data Used for Analysis

Groundwater data collected over the last 6 years of measurement (January 2008 through December 2013) were used. The groundwater data sets were processed and reduced using the same methods as those described in Chapter 6, Section 6.1.1.2 in the main text. Data processing and reduction steps included the following:

- 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

Similarly, the exclusion criteria applied to this data set are the same as those described in Chapter 6 (Section 6.1.2.1) in the main text. Exclusion criteria included the following:

- Analytes that were not detected at least once
- Naturally occurring radionuclides associated with background radiation
- Radionuclides with half-lives of less than 3 years and are not significant daughter products
- Essential nutrients (minerals)
- Analytes without known toxicity information

The exposure point concentrations (EPCs) for each analyte that does not meet the exclusion criteria in each monitoring well are listed in Tables H-2 through H-5.

H4 Well-Specific Data Evaluation

The results of the well-specific risk evaluation are presented in Tables H-6 through H-13. Each table lists the well name, the total cumulative cancer risk, the major risk contributors, the hazard index (HI), and the major noncancer hazard contributors.

Table H-1. Summary of Monitoring Wells Included in the 200-BP-5 OU Well-Specific Evaluation

LLWMA-1	LLWMA-2 and 216-B-63 Trench	WMA B-BX-BY Tank Farms		WMA C Tank Farm	B Plant	200-BP-5 West	200-BP-5 Far-Field Area	200-BP-5 Near-River Area
299-E28-28	299-E33-33	299-E33-1A	299-E33-48	299-E27-7	299-E28-23	699-49-57A	699-62-43F	699-70-68
299-E33-34		299-E33-4	299-E33-205	299-E27-14	299-E28-24	699-50-56	699-65-50	
299-E33-265		299-E33-15	299-E33-334	299-E27-15	299-E28-25	699-50-59		
299-E33-266		299-E33-16	299-E33-337	299-E27-155		699-52-55		
		299-E33-17	299-E33-338			699-53-55B		
		299-E33-18	299-E33-339			699-53-55C		
		299-E33-20	299-E33-341			699-54-45A		
		299-E33-38	299-E33-342			699-55-57		
		299-E33-42	299-E33-343					
		299-E33-44	299-E33-345					
		299-E33-47						

Note: None of the wells listed in this table were identified by Ecology for well-specific analyses within the following exposure areas: Semiworks, Liquid Effluent Retention Facility, Gable Mountain Pond, and 200-BP-5 confined.

Ecology = Washington State Department of Ecology

LLWMA = low-level waste management area

WMA = waste management area

Table H-2. Summary of Analytes and EPCs for Wells Associated with LLWMA-1, LLWMA-2 and 216-B-63 Trench, and WMA C Tank Farm, and B Plant Exposure Areas in the 200-BP-5 OU

Analyte Name	CAS No.	Units	LLWMA-1				LLWMA-2 and 216-B-63 Trench	WMA C Tank Farm				B Plant		
			299-E28-28	299-E33-34	299-E33-265	299-E33-266	299-E33-33	299-E27-7	299-E27-14	299-E27-15	299-E27-155	299-E28-23	299-E28-24	299-E28-25
2-Hexanone	591-78-6	µg/L	—	—	—	—	—	—	—	—	2.0	—	—	—
Acetone	67-64-1	µg/L	—	—	—	1.0	—	—	—	—	5.6	—	—	—
Aluminum	7429-90-5	µg/L	—	—	—	—	—	—	—	—	26	—	—	—
Antimony	7440-36-0	µg/L	46	—	—	—	—	—	—	62	—	—	—	44
Arsenic	7440-38-2	µg/L	4.0	6.3	4.9	4.7	9.0	4.9	16	12	4.9	2.8	1.2	3.9
Barium	7440-39-3	µg/L	63	167	56	60	58	59	88	45	61	--	--	63
Benzene	71-43-2	µg/L	—	—	—	—	—	—	—	—	—	--	--	—
Beryllium	7440-41-7	µg/L	—	—	—	—	—	—	—	—	—	--	--	—
Bis(2-ethylhexyl) Phthalate	117-81-7	µg/L	—	—	—	—	—	—	—	—	—	--	--	—
Boron	7440-42-8	µg/L	—	—	—	—	—	—	—	—	23	—	—	—
Butylbenzylphthalate	85-68-7	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Cadmium	7440-43-9	µg/L	—	—	—	—	—	—	—	—	--	—	—	—
Carbon Disulfide	75-15-0	µg/L	—	—	—	—	—	—	—	—	0.12	—	—	—
Carbon Tetrachloride	56-23-5	µg/L	—	—	—	—	—	—	—	—	1.3	—	—	—
Chloroform	67-66-3	µg/L	—	—	0.13	—	—	—	—	0.11	0.20	—	—	—
Chromium	7440-47-3	µg/L	10	28	5.2	5.1	26	9.9	12	18	7.8	—	—	—
Chromium (Dissolved)	7440-47-3-D	µg/L	3.7	26	5.8	3.1	18	6.4	7.2	15	7.2	—	—	—
Cobalt	7440-48-4	µg/L	—	0.57	—	—	—	—	—	—	—	—	—	—
Copper	7440-50-8	µg/L	0.62	4.9	2.3	—	—	5.0	981	5.9	0.62	—	—	—
Cyanide	57-12-5	µg/L	6.7	450	42	26	20	21	15	—	6.9	—	—	—
Di-n-octylphthalate	117-84-0	µg/L	—	—	—	—	—	—	—	3.3	—	—	—	—
Fluoride	16984-48-8	µg/L	430	327	348	376	289	110	136	153	136	399	3,270	402
Hexavalent Chromium	18540-29-9	µg/L	—	14	—	—	—	—	—	—	—	—	—	—
Iron	7439-89-6	µg/L	41	282	22	39	81	192	113	67	43	—	—	201
Lead	7439-92-1	µg/L	—	—	0.41	0.56	—	—	—	—	—	—	—	—
Lithium	7439-93-2	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Manganese	7439-96-5	µg/L	1.2	0.65	0.36	0.21	—	5.8	1.3	5.2	25	—	—	—
Mercury	7439-97-6	µg/L	—	0.18	—	—	—	—	—	—	0.060	—	—	—
Methyl Methacrylate	80-62-6	µg/L	—	—	—	—	—	—	—	—	1.4	—	—	—
Methyl Methanesulfonate	66-27-3	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Methylene Chloride	75-09-2	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Molybdenum	7439-98-7	µg/L	6.5	4.5	6.3	6.5	—	—	—	—	1.2	—	—	—

Table H-2. Summary of Analytes and EPCs for Wells Associated with LLWMA-1, LLWMA-2 and 216-B-63 Trench, and WMA C Tank Farm, and B Plant Exposure Areas in the 200-BP-5 OU

Analyte Name	CAS No.	Units	LLWMA-1				LLWMA-2 and 216-B-63 Trench	WMA C Tank Farm				B Plant		
			299-E28-28	299-E33-34	299-E33-265	299-E33-266	299-E33-33	299-E27-7	299-E27-14	299-E27-15	299-E27-155	299-E28-23	299-E28-24	299-E28-25
Nickel	7440-02-0	µg/L	5.1	3.7	2.5	0.59	13	6.6	9.5	29	0.23	—	—	—
Nitrate	14797-55-8	µg/L	47,893	813,045	99,478	83,394	86,069	37,882	92,014	19,572	50,829	56,200	420,000	71,931
Nitrite	14797-65-0	µg/L	230	—	189	219	223	150	—	195	290	—	155	203
n-Nitrosodi-n-dipropylamine	621-64-7	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Octachlorodibenzofuran	39001-02-0	µg/L	—	—	—	1.70E-06	—	—	—	—	—	—	—	—
Phenol	108-95-2	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Selenium	7782-49-2	µg/L	4.9	8.4	6.5	6.0	—	13	17	17	13	—	—	—
Silver	7440-22-4	µg/L	—	0.14	6.7	—	—	4.7	—	—	6.1	—	—	—
Strontium	7440-24-6	µg/L	246	1,091	359	355	309	533	621	318	470	—	—	332
Thallium	7440-28-0	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Tin	7440-31-5	µg/L	—	—	—	—	—	—	—	0.21	—	—	—	—
Toluene	108-88-3	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Tributyl Phosphate	126-73-8	µg/L	—	—	—	—	—	—	1.0	—	—	—	—	—
Trichloroethene	79-01-6	µg/L	—	—	—	—	—	—	—	—	—	—	—	—
Uranium	7440-61-1	µg/L	5.6	120	18	20	4.0	3.9	7.2	12	6.1	29	26	28
Vanadium	7440-62-2	µg/L	21	15	16	17	25	16	18	18	18	—	—	9.8
Zinc	7440-66-6	µg/L	—	—	6.0	8.0	—	6.6	6.9	10	6.5	—	—	394
Americium-241	14596-10-2	pCi/L	—	—	—	—	—	—	—	—	0.14	0.25	—	0.094
Carbon-14	14762-75-5	pCi/L	—	—	—	—	—	—	—	—	—	—	—	—
Cesium-137	10045-97-3	pCi/L	—	—	—	—	—	—	—	—	—	2,430	89	41
Cobalt-60	10198-40-0	pCi/L	—	36	—	—	—	—	—	—	—	—	—	—
Iodine-129	15046-84-1	pCi/L	—	4.0	2.4	1.5	2.5	6.1	4.5	5.7	4.4	1.8	1.5	1.9
Neptunium-237	13994-20-2	pCi/L	—	—	—	—	—	—	—	—	—	—	—	—
Plutonium-238	13981-16-3	pCi/L	—	—	—	—	—	—	—	—	—	0.19	—	—
Plutonium-239/240	PU-239/240	pCi/L	—	—	—	—	—	—	—	—	0.11	52	1.1	1.3
Strontium-90	10098-97-2	pCi/L	—	—	—	—	—	—	—	—	—	4,900	685	2,199
Technetium-99	14133-76-7	pCi/L	42	16,966	970	333	497	81	5,396	80	8,100	—	5,700	—
Tritium	10028-17-8	pCi/L	711	20,191	6,600	5,267	511	829	946	1,200	1,581	6,600	7,611	6,398
Uranium-233/234	U-233/234	pCi/L	—	—	—	—	—	—	—	—	—	—	9.0	11
Uranium-234	13966-29-5	pCi/L	—	—	—	—	—	—	—	—	—	10	7.2	6.0
Uranium-235	15117-96-1	pCi/L	—	—	—	—	—	—	—	—	—	0.39	0.52	0.72
Uranium-238	U-238	pCi/L	—	—	—	—	—	—	—	—	—	9.6	8.9	10

CAS = Chemical Abstracts Service

Table H-2. Summary of Analytes and EPCs for Wells Associated with LLWMA-1, LLWMA-2 and 216-B-63 Trench, and WMA C Tank Farm, and B Plant Exposure Areas in the 200-BP-5 OU

Analyte Name	CAS No.	Units	LLWMA-1				LLWMA-2 and 216-B-63 Trench	WMA C Tank Farm				B Plant		
			299-E28-28	299-E33-34	299-E33-265	299-E33-266	299-E33-33	299-E27-7	299-E27-14	299-E27-15	299-E27-155	299-E28-23	299-E28-24	299-E28-25

LLWMA = low-level waste management area
WMA = waste management area

Table H-3. Summary of Analytes and EPCs for Wells Associated with WMA B-BX-BY Tank Farms Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	WMA B-BX-BY Tank Farms										
			299-E33-1A	299-E33-4	299-E33-15	299-E33-16	299-E33-17	299-E33-20	299-E33-38	299-E33-42	299-E33-44	299-E33-47	299-E33-48
2-Hexanone	591-78-6	µg/L	—	—	—	—	—	—	—	—	—	—	—
Acetone	67-64-1	µg/L	—	—	—	—	—	—	—	—	—	—	—
Aluminum	7429-90-5	µg/L	—	—	—	—	—	—	—	—	—	—	—
Antimony	7440-36-0	µg/L	—	—	—	211	—	—	175	101	150	118	48
Arsenic	7440-38-2	µg/L	—	—	7.1	82	6.1	4.7	6.9	5.0	7.8	6.4	6.6
Barium	7440-39-3	µg/L	225	—	200	176	166	244	190	153	96	225	74
Benzene	71-43-2	µg/L	—	—	—	—	—	—	—	—	—	—	—
Beryllium	7440-41-7	µg/L	—	—	—	—	—	—	—	—	—	—	—
Bis(2-ethylhexyl) Phthalate	117-81-7	µg/L	—	—	—	—	—	—	—	—	8.0	—	—
Boron	7440-42-8	µg/L	—	—	—	—	—	—	—	—	—	—	—
Butylbenzylphthalate	85-68-7	µg/L	—	—	—	—	—	—	—	—	2.8	—	—
Cadmium	7440-43-9	µg/L	—	—	—	—	—	—	1.7	—	—	—	—
Carbon Disulfide	75-15-0	µg/L	—	—	—	—	—	—	—	—	—	—	—
Carbon Tetrachloride	56-23-5	µg/L	—	—	—	—	—	—	—	—	—	—	—
Chloroform	67-66-3	µg/L	—	—	—	—	—	—	—	—	—	—	—
Chromium	7440-47-3	µg/L	69	—	65	100	61	53	39	21	53	46	16
Chromium (Dissolved)	7440-47-3-D	µg/L	49	—	61	81	58	52	37	17	51	47	8.6
Cobalt	7440-48-4	µg/L	4.8	—	5.3	—	—	—	4.4	—	8.2	4.5	--
Copper	7440-50-8	µg/L	—	—	—	—	4.4	—	—	—	4.2	—	7.4
Cyanide	57-12-5	µg/L	791	—	835	874	1,020	143	952	85	553	505	45
Di-n-octylphthalate	117-84-0	µg/L	—	—	—	—	—	—	—	2.3	5.5	1.6	—
Fluoride	16984-48-8	µg/L	522	—	572	85	293	353	267	178	168	209	231
Hexavalent Chromium	18540-29-9	µg/L	—	—	—	80	—	—	—	—	—	69	—
Iron	7439-89-6	µg/L	640	—	464	706	325	220	467	107	393	424	63
Lead	7439-92-1	µg/L	—	—	—	—	—	2.4	0.67	0.49	0.44	0.34	0.60
Lithium	7439-93-2	µg/L	—	—	—	—	—	—	—	—	—	—	—

Table H-3. Summary of Analytes and EPCs for Wells Associated with WMA B-BX-BY Tank Farms Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	WMA B-BX-BY Tank Farms										
			299-E33-1A	299-E33-4	299-E33-15	299-E33-16	299-E33-17	299-E33-20	299-E33-38	299-E33-42	299-E33-44	299-E33-47	299-E33-48
Manganese	7439-96-5	µg/L	29	—	42	16	15	82	1.2	—	—	—	35
Mercury	7439-97-6	µg/L	—	—	—	—	—	—	0.51	0.099	0.33	1.7	—
Methyl Methacrylate	80-62-6	µg/L	—	—	—	—	—	—	—	—	—	—	—
Methyl Methanesulfonate	66-27-3	µg/L	—	—	—	—	—	—	—	—	—	340	—
Methylene Chloride	75-09-2	µg/L	—	—	—	—	—	—	—	—	—	—	—
Molybdenum	7439-98-7	µg/L	—	—	—	—	—	—	—	—	0.58	—	—
Nickel	7440-02-0	µg/L	17	—	—	16	—	—	6.2	6.6	6.6	6.7	28
Nitrate	14797-55-8	µg/L	1.28E+06	—	1.09E+06	1.09E+06	1.16E+06	891,124	1.21E+06	506,111	954,455	1.17E+06	216,068
Nitrite	14797-65-0	µg/L	—	—	154	407	—	125	247	195	339	299	205
n-Nitrosodi-n-dipropylamine	621-64-7	µg/L	—	—	—	—	—	—	—	2.6	—	—	—
Octachlorodibenzofuran	39001-02-0	µg/L	—	—	—	—	—	—	—	—	—	—	—
Phenol	108-95-2	µg/L	—	—	—	—	—	—	—	—	—	—	—
Selenium	7782-49-2	µg/L	—	—	—	—	—	12	12	11	16	16	7.9
Silver	7440-22-4	µg/L	—	—	—	4.5	—	4.0	20	99	4.0	5.0	31
Strontium	7440-24-6	µg/L	1,534	—	1,251	1,035	1,035	1,091	1,504	837	1,298	1,369	376
Thallium	7440-28-0	µg/L	—	—	—	—	—	—	—	—	—	—	—
Tin	7440-31-5	µg/L	—	—	—	—	—	0.92	0.95	0.36	0.35	0.61	1.5
Toluene	108-88-3	µg/L	—	—	—	—	—	—	—	—	—	—	—
Tributyl Phosphate	126-73-8	µg/L	—	—	—	—	—	—	—	—	—	—	—
Trichloroethene	79-01-6	µg/L	—	—	—	—	—	—	—	—	—	—	—
Uranium	7440-61-1	µg/L	164	—	59	500	5.8	19	541	262	370	24	41
Vanadium	7440-62-2	µg/L	15	—	19	25	14	9.9	13	13	8.8	16	17
Zinc	7440-66-6	µg/L	—	—	351	58	253	632	9.2	4.9	4.1	9.9	7.6
Americium-241	14596-10-2	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Carbon-14	14762-75-5	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Cesium-137	10045-97-3	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Cobalt-60	10198-40-0	pCi/L	43	1,040	19	43	30	—	55	—	35	56	—
Iodine-129	15046-84-1	pCi/L	3.9	—	2.3	4.7	4.0	3.6	4.9	4.3	3.9	4.5	3.7
Neptunium-237	13994-20-2	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Plutonium-238	13981-16-3	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Plutonium-239/240	PU-239/240	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Strontium-90	10098-97-2	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Technetium-99	14133-76-7	pCi/L	23,167	—	15,364	21,243	16,987	5,881	30,677	6,027	17,420	26,061	1,492
Tritium	10028-17-8	pCi/L	19,068	—	14,139	14,136	11,401	3,457	16,047	5,797	13,587	7,942	9,410
Uranium-233/234	U-233/234	pCi/L	—	—	—	—	—	—	—	—	—	—	—

Table H-3. Summary of Analytes and EPCs for Wells Associated with WMA B-BX-BY Tank Farms Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	WMA B-BX-BY Tank Farms										
			299-E33-1A	299-E33-4	299-E33-15	299-E33-16	299-E33-17	299-E33-20	299-E33-38	299-E33-42	299-E33-44	299-E33-47	299-E33-48
Uranium-234	13966-29-5	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Uranium-235	15117-96-1	pCi/L	—	—	—	—	—	—	—	—	—	—	—
Uranium-238	U-238	pCi/L	—	—	—	—	—	—	—	—	—	—	—

CAS = Chemical Abstracts Service
WMA = waste management area

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Table H-4. Summary of Analytes and EPCs for Wells Associated with WMA B-BX-BY Tank Farms Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	WMA B-BX-BY Tank Farms								
			299-E33-205	299-E33-334	299-E33-337	299-E33-338	299-E33-339	299-E33-341	299-E33-342	299-E33-343	299-E33-345
2-Hexanone	591-78-6	µg/L	—	—	—	—	—	—	—	—	—
Acetone	67-64-1	µg/L	—	—	—	—	—	—	—	—	—
Aluminum	7429-90-5	µg/L	—	—	—	—	—	10	—	6.2	23
Antimony	7440-36-0	µg/L	—	43	78	62	92	147	213	—	—
Arsenic	7440-38-2	µg/L	4.6	6.1	5.7	6.7	5.9	6.2	6.4	6.0	4.3
Barium	7440-39-3	µg/L	117	78	90	76	98	180	154	112	89
Benzene	71-43-2	µg/L	—	—	—	—	—	—	—	—	—
Beryllium	7440-41-7	µg/L	—	—	—	—	—	—	—	—	—
Bis(2-ethylhexyl) Phthalate	117-81-7	µg/L	—	—	—	—	—	2.1	1.5	2.6	1.7
Boron	7440-42-8	µg/L	—	—	—	—	—	—	—	—	—
Butylbenzylphthalate	85-68-7	µg/L	—	—	—	—	—	—	—	—	—
Cadmium	7440-43-9	µg/L	—	—	—	—	—	—	—	—	—
Carbon Disulfide	75-15-0	µg/L	—	—	—	—	—	—	—	—	—
Carbon Tetrachloride	56-23-5	µg/L	—	—	—	—	—	3.4	5.9	2.0	—
Chloroform	67-66-3	µg/L	—	—	—	—	—	—	1.4	1.5	—
Chromium	7440-47-3	µg/L	25	13	187	24	79	45	37	33	66
Chromium (Dissolved)	7440-47-3-D	µg/L	26	7.8	31	13	15	46	38	31	73
Cobalt	7440-48-4	µg/L	—	—	22	4.0	13	—	—	—	—
Copper	7440-50-8	µg/L	—	—	65	6.2	10	—	5.0	9.2	—
Cyanide	57-12-5	µg/L	51	43	163	87	69	1,093	849	7.5	2.2
Di-n-octylphthalate	117-84-0	µg/L	—	—	—	—	—	—	—	—	—
Fluoride	16984-48-8	µg/L	150	237	211	213	209	458	247	206	256
Hexavalent Chromium	18540-29-9	µg/L	—	—	12	—	11	—	—	26	—
Iron	7439-89-6	µg/L	—	64	652	88	477	476	373	35	53

Table H-4. Summary of Analytes and EPCs for Wells Associated with WMA B-BX-BY Tank Farms Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	WMA B-BX-BY Tank Farms								
			299-E33-205	299-E33-334	299-E33-337	299-E33-338	299-E33-339	299-E33-341	299-E33-342	299-E33-343	299-E33-345
Lead	7439-92-1	µg/L	—	0.43	0.73	—	0.36	—	—	—	0.20
Lithium	7439-93-2	µg/L	—	—	—	—	—	—	—	—	—
Manganese	7439-96-5	µg/L	8.9	5.4	147	4.3	21	22	14	5.6	94
Mercury	7439-97-6	µg/L	—	—	0.14	—	0.22	1.3	0.26	—	—
Methyl Methacrylate	80-62-6	µg/L	—	—	—	—	—	—	—	—	—
Methyl Methanesulfonate	66-27-3	µg/L	—	—	—	—	—	—	—	—	—
Methylene Chloride	75-09-2	µg/L	—	—	—	—	—	—	—	1.8	—
Molybdenum	7439-98-7	µg/L	—	—	—	—	—	—	—	—	—
Nickel	7440-02-0	µg/L	—	6.4	1,728	9.2	148	—	—	—	4.9
Nitrate	14797-55-8	µg/L	401,000	114,057	319,054	210,101	204,707	1.38E+06	1.22E+06	303,021	345,056
Nitrite	14797-65-0	µg/L	165	232	182	213	223	884	3,639	162	4,481
n-Nitrosodi-n-dipropylamine	621-64-7	µg/L	—	3.5	—	—	—	—	—	—	—
Octachlorodibenzofuran	39001-02-0	µg/L	—	—	—	—	—	—	—	—	—
Phenol	108-95-2	µg/L	—	—	—	—	—	1.1	—	—	1.1
Selenium	7782-49-2	µg/L	—	7.4	11	7.5	9.7	—	—	—	—
Silver	7440-22-4	µg/L	—	—	—	7.3	--	8.0	5.4	12	51
Strontium	7440-24-6	µg/L	844	362	557	392	503	1,562	1,391	684	694
Thallium	7440-28-0	µg/L	—	—	0.11	—	—	—	—	—	0.13
Tin	7440-31-5	µg/L	—	1.1	—	—	0.41	—	—	—	—
Toluene	108-88-3	µg/L	—	—	—	—	—	—	—	—	—
Tributyl Phosphate	126-73-8	µg/L	—	—	—	—	—	—	—	—	1.1
Trichloroethene	79-01-6	µg/L	—	—	—	—	—	—	—	—	—
Uranium	7440-61-1	µg/L	794	32	64	46	194	115	608	3,730	360
Vanadium	7440-62-2	µg/L	14	16	17	16	16	15	18	14	12
Zinc	7440-66-6	µg/L	136	6.7	7.4	6.0	12	—	7.6	20	5.0
Americium-241	14596-10-2	pCi/L	0.12	—	—	—	—	0.19	0.16	0.097	0.10
Carbon-14	14762-75-5	pCi/L	14	—	—	—	—	126	54	49	15
Cesium-137	10045-97-3	pCi/L	—	—	—	—	—	—	—	—	—
Cobalt-60	10198-40-0	pCi/L	3.9	—	—	—	—	54	45	—	—
Iodine-129	15046-84-1	pCi/L	4.4	3.8	2.7	4.7	4.0	3.4	4.9	4.9	5.4
Neptunium-237	13994-20-2	pCi/L	0.48	—	—	—	—	—	—	1.3	—
Plutonium-238	13981-16-3	pCi/L	—	—	—	—	—	—	—	—	—
Plutonium-239/240	PU-239/240	pCi/L	—	—	—	—	—	0.073	0.090	—	0.098
Strontium-90	10098-97-2	pCi/L	—	—	—	4.6	—	2.6	3.5	2.7	2.3
Technetium-99	14133-76-7	pCi/L	8,300	1,103	3,614	2,832	2,975	26,849	24,473	15,471	18,739

Table H-4. Summary of Analytes and EPCs for Wells Associated with WMA B-BX-BY Tank Farms Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	WMA B-BX-BY Tank Farms								
			299-E33-205	299-E33-334	299-E33-337	299-E33-338	299-E33-339	299-E33-341	299-E33-342	299-E33-343	299-E33-345
Tritium	10028-17-8	pCi/L	4,900	9,314	9,128	4,477	8,744	13,716	—	—	—
Uranium-233/234	U-233/234	pCi/L	—	—	—	v	—	—	—	—	—
Uranium-234	13966-29-5	pCi/L	—	—	—	--	—	—	—	598	—
Uranium-235	15117-96-1	pCi/L	—	—	—	--	—	—	—	27	—
Uranium-238	U-238	pCi/L	—	—	—	--	—	—	—	585	—

CAS = Chemical Abstracts Service
WMA = waste management area

Table H-5. Summary of Analytes and EPCs for Wells Associated with 200-BP-5 West Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	200-BP-5 West							
			699-49-57A	699-50-56	699-50-59	699-52-55	699-53-55B	699-53-55C	699-54-45A	699-55-57
2-Hexanone	591-78-6	µg/L	—	—	—	—	—	—	—	—
Acetone	67-64-1	µg/L	—	—	—	—	—	—	—	—
Aluminum	7429-90-5	µg/L	--	7.2	—	7,180	—	--	274	—
Antimony	7440-36-0	µg/L	59	—	—	—	—	52	—	—
Arsenic	7440-38-2	µg/L	5.4	7.9	—	5.1	—	—	—	5.9
Barium	7440-39-3	µg/L	76	34	70	330	44	44	29	29
Benzene	71-43-2	µg/L	—	—	—	—	--	—	--	--
Beryllium	7440-41-7	µg/L	—	—	—	—	--	—	0.12	—
Bis(2-ethylhexyl) Phthalate	117-81-7	µg/L	—	2.9	—	2.3	--	—	—	—
Boron	7440-42-8	µg/L	—	—	—	—	--	—	—	—
Butylbenzylphthalate	85-68-7	µg/L	—	—	—	—	--	—	—	—
Cadmium	7440-43-9	µg/L	—	—	—	35	--	—	0.55	—
Carbon Disulfide	75-15-0	µg/L	—	—	—	—	--	—	2.4	—
Carbon Tetrachloride	56-23-5	µg/L	—	—	—	2.0	--	—	5.4	—
Chloroform	67-66-3	µg/L	—	—	—	—	--	—	0.66	—
Chromium	7440-47-3	µg/L	8.2	7.1	—	69	33	—	43	140
Chromium (Dissolved)	7440-47-3-D	µg/L	10	7.8	—	—	—	5.2	—	4.7
Cobalt	7440-48-4	µg/L	—	15	—	34	—	—	9.1	—
Copper	7440-50-8	µg/L	—	—	—	68	—	—	11	5.9
Cyanide	57-12-5	µg/L	152	55	52	18	170	172	—	64
Di-n-octylphthalate	117-84-0	µg/L	—	—	—	—	—	—	—	—
Fluoride	16984-48-8	µg/L	434	500	322	684	320	293	175	336
Hexavalent Chromium	18540-29-9	µg/L	2.9	—	—	—	—	—	—	—
Iron	7439-89-6	µg/L	151	55	36	15,800	1,660	197	18,900	2,690
Lead	7439-92-1	µg/L	—	—	—	—	—	—	8.5	—
Lithium	7439-93-2	µg/L	—	—	—	—	—	—	13	—
Manganese	7439-96-5	µg/L	9.0	—	—	1,190	52	5.7	213	146
Mercury	7439-97-6	µg/L	—	—	—	0.64	—	—	—	—
Methyl Methacrylate	80-62-6	µg/L	—	—	—	—	—	—	—	—
Methyl Methanesulfonate	66-27-3	µg/L	—	—	—	—	—	—	—	—
Methylene Chloride	75-09-2	µg/L	—	—	—	—	—	—	—	—
Molybdenum	7439-98-7	µg/L	—	—	—	—	—	—	0.50	—
Nickel	7440-02-0	µg/L	—	11	—	63	15	—	21	78
Nitrate	14797-55-8	µg/L	285,966	55,116	112,209	6,570	153,000	149,068	1,560	84,177

Table H-5. Summary of Analytes and EPCs for Wells Associated with 200-BP-5 West Exposure Area in the 200-BP-5 OU

Analyte Name	CAS No.	Units	200-BP-5 West							
			699-49-57A	699-50-56	699-50-59	699-52-55	699-53-55B	699-53-55C	699-54-45A	699-55-57
Nitrite	14797-65-0	µg/L	196	193	256	255	181	224	160	246
n-Nitrosodi-n-dipropylamine	621-64-7	µg/L	—	—	—	—	—	—	—	—
Octachlorodibenzofuran	39001-02-0	µg/L	—	—	—	—	—	—	—	—
Phenol	108-95-2	µg/L	—	—	—	—	—	—	—	—
Selenium	7782-49-2	µg/L	—	—	—	—	—	—	4.2	—
Silver	7440-22-4	µg/L	—	—	—	—	—	—	—	—
Strontium	7440-24-6	µg/L	545	329	443	363	465	516	146	354
Thallium	7440-28-0	µg/L	—	—	—	—	—	—	—	—
Tin	7440-31-5	µg/L	—	—	—	—	—	—	—	—
Toluene	108-88-3	µg/L	—	—	—	—	—	—	—	—
Tributyl Phosphate	126-73-8	µg/L	—	0.63	—	1.7	—	—	—	—
Trichloroethene	79-01-6	µg/L	—	—	—	—	—	—	—	—
Uranium	7440-61-1	µg/L	21	5.0	13	5.3	4.6	4.9	—	6.8
Vanadium	7440-62-2	µg/L	22	19	15	29	15	18	—	12
Zinc	7440-66-6	µg/L	22	14	—	2,680	—	9.0	5,450	—
Americium-241	14596-10-2	pCi/L	—	0.27	—	0.092	—	—	—	—
Carbon-14	14762-75-5	pCi/L	—	—	—	—	—	—	—	—
Cesium-137	10045-97-3	pCi/L	—	—	—	—	—	—	—	—
Cobalt-60	10198-40-0	pCi/L	8.0	—	—	—	6.7	9.9	—	—
Iodine-129	15046-84-1	pCi/L	3.3	—	4.0	—	—	—	—	—
Neptunium-237	13994-20-2	pCi/L	—	—	—	0.57	—	—	—	—
Plutonium-238	13981-16-3	pCi/L	—	—	—	—	—	—	—	—
Plutonium-239/240	PU-239/240	pCi/L	—	0.052	—	—	—	—	—	—
Strontium-90	10098-97-2	pCi/L	2.9	180	—	—	—	—	—	—
Technetium-99	14133-76-7	pCi/L	5,308	1,088	1,560	129	2,641	3,075	—	1,616
Tritium	10028-17-8	pCi/L	11,906	866	7,909	300	755	619	—	1,894
Uranium-233/234	U-233/234	pCi/L	—	—	—	—	—	—	—	—
Uranium-234	13966-29-5	pCi/L	—	—	—	—	—	—	—	—
Uranium-235	15117-96-1	pCi/L	—	—	—	—	—	—	—	—
Uranium-238	U-238	pCi/L	—	—	—	—	—	—	—	—

CAS = Chemical Abstracts Service

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Table H-6. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the LLWMA-1 Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E28-28	6.1×10^{-6}	Technetium-99 (2.2×10^{-6}, 36%) Tritium (3.9×10^{-6}, 64%)	5.2	Cyanide (HQ = 4.4, 84%) Fluoride (HQ = 0.22, 4.2%) Cr(VI) (HQ = 0.05; 1.1%) Nitrate (HQ = 0.20, 3.9%) Uranium (HQ = 0.06; 1.1%) Vanadium (HQ = 0.16, 3.0%)
299-E33-34	1.0×10^{-3}	Cobalt-60 (1.1×10^{-5}, 1.1%) Iodine-129 (1.1×10^{-5}, 1.1%) Technetium-99 (8.9×10^{-4}, 87%) Tritium (1.1×10^{-4}, 11%)	298	Cyanide (HQ = 292, 98%) Nitrate (HQ = 3.4, 1.2%)
299-E33-265	9.4×10^{-5}	Iodine-129 (6.8×10^{-6}, 7.2%) Technetium-99 (5.1×10^{-5}, 54%) Tritium (3.6×10^{-5}, 39%)	29	Cyanide (HQ = 28, 96%) Nitrate (HQ = 0.42, 1.5%)
299-E33-266	5.1×10^{-5}	Iodine-129 (4.3×10^{-6}, 8.6%) Technetium-99 (1.8×10^{-5}, 34%) Tritium (2.9×10^{-5}, 57%)	18	Cyanide (HQ = 17, 94%) Nitrate (HQ = 0.35, 1.9%) Uranium (HQ = 0.20, 1.1%)

Cr(VI) = hexavalent chromium
HI = hazard index
HQ = hazard quotient

Table H-7. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the LLWMA-2 and 216-B-63 Trench Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E33-33	3.6×10^{-5}	Iodine-129 (7.2×10^{-6}, 20%) Technetium-99 (2.6×10^{-5}, 72%) Tritium (2.8×10^{-6}, 7.8%)	14	Cyanide (HQ = 13, 93%) Cr(VI) (HQ = 0.26; 1.8%) Nitrate (HQ = 0.37, 2.6%) Vanadium HQ = 0.18, 1.3%)

Cr(VI) = hexavalent chromium
HI = hazard index
HQ = hazard quotient

1

Table H-8. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the WMA B-BX-BY Tank Farms Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E33-1A	1.3×10^{-3}	Technetium99 (1.2×10^{-3}, 90%) Tritium (1.0×10^{-4}, 7.8%)	523	Cyanide (HQ = 514, 99%) Nitrate (HQ = 5.4, 1.0%)
299-E33-4	3.1×10^{-4}	Cobalt-60 (3.1×10^{-4}, 100%)	—	None
299-E33-15	9.0×10^{-4}	Technetium-99 (8.1×10^{-4}, 90%) Tritium (7.8×10^{-5}, 8.6%)	550	Cyanide (HQ = 542, 99%)
299-E33-16	2.8×10^{-3}	Arsenic (1.6×10^{-3}, 57%) Technetium-99 (1.1×10^{-3}, 40%) Tritium (7.8×10^{-5}, 2.8%)	588	Arsenic (HQ = 8.3, 1.4%) Cyanide (HQ = 568, 97%)
299-E33-17	9.8×10^{-4}	Iodine-129 (1.1×10^{-5}, 1.2%) Technetium-99 (8.9×10^{-4}, 92%) Tritium (6.3×10^{-5}, 6.4%)	669	Cyanide (HQ = 663, 99%)
299-E33-18	1.3×10^{-3}	Technetium-99 (-1.2×10^{-3}, 92%) Tritium (9.6×10^{-5}, 7.1%)	65	Cyanide (HQ = 35, 53%) Cr(VI) (HQ = 0.93, 1.4%) Nitrate (HQ = 2.5, 3.8%) Uranium (HQ = 27, 41%)
299-E33-20	3.4×10^{-4}	Iodine-129 (1.0×10^{-5}, 3.0%) Technetium-99 (3.1×10^{-4}, 91%) Tritium (1.9×10^{-5}, 5.6%)	96	Cyanide (HQ = 90, 94%) Nitrate (HQ = 3.8, 4.0%)

Table H-8. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the WMA B-BX-BY Tank Farms Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E33-38	1.7×10^{-3}	Technetium-99 (1.6×10^{-3}, 93%) Tritium (8.8×10^{-5}, 5.1%)	631	Cyanide (HQ = 619, 98%)
299-E33-42	6.0×10^{-4}	n-Nitrosodi-n-propylamine (2.4×10^{-4}, 40%) Iodine-129 (1.2×10^{-5}, 2.0%) Technetium-99 (3.2×10^{-4}, 53%) Tritium (3.2×10^{-5}, 5.3%)	61	Cyanide (HQ = 55, 90%) Nitrate (HQ = 2.1, 3.5%) Silver (HQ = 0.64, 1.1%) Uranium (HQ = 2.6, 4.3%)
299-E33-44	1.2×10^{-3}	Arsenic (1.5×10^{-4}, 13%) Technetium-99 (9.2×10^{-4}, 79%) Tritium (7.5×10^{-5}, 6.4%)	370	Cyanide (HQ = 359, 97%) Nitrate (HQ = 4.1, 1.1%) Uranium (HQ = 3.7, 1.0%)
299-E33-47	1.9×10^{-3}	Methyl methanesulfonate (4.3×10^{-4}, 23%) Technetium-99 (1.4×10^{-3}, 73%) Tritium (4.4×10^{-5}, 2.3%)	335	Cyanide (HQ = 328, 98%) Nitrate (HQ = 5.0, 1.5%)
299-E33-48	1.4×10^{-4}	Iodine-129 (1.1×10^{-5}, 7.4%) Technetium-99 (7.9×10^{-5}, 56%) Tritium 5.2×10^{-5}, 37%)	31	Cyanide (HQ = 29, 93%) Nitrate (HQ = 0.92, 3.0%) Uranium (HQ = 0.41, 1.3%)
299-E33-205	4.8×10^{-4}	Iodine-129 (1.2×10^{-5}, 2.6%) Technetium-99 (4.4×10^{-4}, 91%) Tritium (2.7×10^{-5}, 5.6%)	43	Cyanide (HQ = 33, 76%) Nitrate (HQ = 1.7, 3.9%) Uranium (HQ = 8.0, 18%)
299-E33-334	4.4×10^{-4}	n-Nitrosodi-n-propylamine (3.2×10^{-4}, 73%) Iodine-129 (1.1×10^{-5}, 2.4%) Technetium-99 (5.8×10^{-5}, 13%) Tritium (5.1×10^{-5}, 12%)	27	Cyanide (HQ = 25, 95%) Nitrate (HQ = 0.48, 1.8%) Uranium (HQ = 0.32, 1.2%)
299-E33-337	2.5×10^{-4}	Iodine-129 (7.5×10^{-6}, 3.0%) Technetium-99 (1.9×10^{-4}, 77%) Tritium (5.0×10^{-5}, 20%)	114	Cobalt (HQ = 2.2, 1.9%) Cyanide (HQ = 106, 93%) Nickel (HQ = 2.7, 2.3%) Nitrate (HQ = 1.4, 1.2%)
299-E33-338	1.9×10^{-4}	Iodine-129 (1.3×10^{-5}, 7.0%) Strontium-90 (4.9×10^{-6}, 2.6%) Technetium-99 (1.5×10^{-4}, 78%) Tritium (2.5×10^{-5}, 13%)	59	Cyanide (HQ = 57, 96%) Nitrate (HQ = 0.89, 1.5%)

Table H-8. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the WMA B-BX-BY Tank Farms Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E33-339	2.2×10^{-4}	Iodine-129 (1.2×10^{-5}, 5.3%) Technetium-99 (1.6×10^{-4}, 72%) Tritium (4.8×10^{-5}, 22%)	50	Cobalt (HQ = 1.3, 2.6%) Cyanide (HQ = 45, 90%) Nitrate (HQ = 0.87, 1.7%) Uranium (HQ = 2.0, 3.9%)
299-E33-341	1.5×10^{-3}	Cobalt-60 (1.6×10^{-5}, 1.1%) Technetium-99 (1.4×10^{-3}, 92%) Tritium (7.5×10^{-5}, 4.9%)	719	Cyanide (HQ = 710, 99%)
299-E33-342	1.5×10^{-3}	Technetium-99 (1.3×10^{-3}, 88%) Tritium (1.2×10^{-4}, 8.3%)	564	Cyanide (HQ = 551, 98%) Uranium (HQ = 6.1, 1.1%)
299-E33-343	2.5×10^{-3}	Technetium-99 (8.1×10^{-4}, 33%) Tritium (5.8×10^{-5}, 2.4%) Uranium-234 (8.1×10^{-4}, 33%) Uranium-235 (3.6×10^{-5}, 1.5%) Uranium-238 (7.2×10^{-4}, 29%)	45	Cyanide (HQ = 4.9, 11%) Nitrate (HQ = 1.3, 2.9%) Uranium (HQ = 38, 84%)
299-E33-345	1.1×10^{-3}	Iodine-129 (1.5×10^{-5}, 1.4%) Technetium-99 (9.9×10^{-4}, 92%) Tritium (6.2×10^{-5}, 5.8%)	8.8	Cyanide (HQ = 1.4, 16%) Fluoride (HQ = 0.13, 1.5%) Cr(VI) (HQ = 1.1, 12%) Manganese (HQ = 0.14, 1.5%) Nitrate (HQ = 1.5, 17%) Nitrite (HQ = 0.45, 5.1%) Silver (HQ = 0.33, 3.8%) Uranium (HQ = 3.6, 41%)

Cr(VI) = hexavalent chromium
HI = hazard index
HQ = hazard quotient

Table H-9. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the WMA C Tank Farm Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E27-7	2.6×10^{-5}	Iodine-129 (1.7×10^{-5}, 66%) Technetium-99 (4.3×10^{-6}, 16%) Tritium (4.6×10^{-6}, 17%)	14	Cyanide (HQ = 14, 95%) Nitrate (HQ = 0.16, 1.1%)
299-E27-14	6.2×10^{-4}	Arsenic (3.2×10^{-4}, 51%) Iodine-129 (1.3×10^{-5}, 2.1%) Technetium-99 (2.8×10^{-4}, 46%)	13	Arsenic (HQ = 1.6, 13%) Copper (HQ = 0.74, 5.7%) Cyanide (HQ = 9.6, 74%) Nitrate (HQ = 0.39, 3.0%)
299-E27-15	2.5×10^{-4}	Arsenic (2.3×10^{-4}, 89%) Iodine-129 (1.6×10^{-5}, 6.3%) Technetium-99 (4.2×10^{-6}, 1.7%) Tritium (6.6×10^{-6}, 2.6%)	1.9	Arsenic (HQ = 1.2, 62%) Fluoride (HQ = 0.08, 4.1%) Cr(VI) (HQ = 0.09, 4.9%) Nickel (HQ = 0.05, 2.4%) Nitrate (HQ = 0.08, 4.4%) Selenium (HQ = 0.10, 5.3%) Uranium (HQ = 0.12, 6.1%) Vanadium (HQ = 0.13, 6.8%)
299-E27-155	4.5×10^{-4}	Iodine-129 (1.2×10^{-5}, 2.7%) Technetium-99 (4.3×10^{-4}, 94%) Tritium (8.7×10^{-6}, 1.9%)	5.4	Cyanide (HQ = 4.5, 83%) Fluoride (HQ = 0.07, 1.3%) Cr(VI) (HQ = 0.11, 2.0%) Nitrate (HQ = 0.22, 4.0%) Selenium (HQ = 0.08, 1.5%) Uranium (HQ = 0.06, 1.1%) Vanadium (HQ = 0.13, 2.4%)

Cr(VI) = hexavalent chromium
HI = hazard index
HQ = hazard quotient

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Table H-10. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the B Plant Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
299-E28-23	6.9×10^{-3}	Cesium-137 (1.4×10^{-3}, 21%) Plutonium-239/240 (1.3×10^{-4}, 2.0%) Strontium-90 (5.2×10^{-3}, 76%)	0.73	None
299-E28-24	1.2×10^{-3}	Cesium-137 (5.2×10^{-5}, 4.4%) Strontium-90 (7.3×10^{-4}, 63%) Technetium-99 (3.0×10^{-4}, 26%) Tritium (4.2×10^{-5}, 3.6%)	3.7	Fluoride (HQ = 1.6, 44%) Nitrate (HQ = 1.8, 48%) Uranium (HQ = 0.26, 6.9%)
299-E28-25	2.5×10^{-3}	Strontium-90 (2.4×10^{-3}, 96%) Tritium (3.5×10^{-5}, 1.4%)	0.96	None

HI = hazard index
HQ = hazard quotient

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Table H-11. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the 200-BP-5 West Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
699-49-57A	3.6×10^{-4}	Iodine-129 (9.5×10^{-6}, 2.6%) Technetium-99 (2.8×10^{-4}, 78%) Tritium (6.5×10^{-5}, 18%)	101	Cyanide (HQ = 99, 98%) Nitrate (HQ = 1.2, 1.2%)
699-50-56	2.6×10^{-4}	Strontium-90 (1.9×10^{-4}, 75%) Technetium-99 (5.7×10^{-5}, 22%) Tritium (4.8×10^{-6}, 1.9%)	37	Cobalt (HQ = 1.1, 2.9%) Cyanide (HQ = 35, 95%)
699-50-59	1.4×10^{-4}	Iodine-129 (1.1×10^{-5}, 8.3%) Technetium-99 (8.2×10^{-5}, 60%) Tritium (4.4×10^{-5}, 32%)	35	Cyanide (HQ = 34, 97%) Nitrate (HQ = 0.48, 1.4%)

Table H-11. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the 200-BP-5 West Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
699-52-55	1.5×10^{-5}	Bis(2-ethylhexyl) phthalate (1.1×10^{-6}, 7.0%) Carbon tetrachloride (4.4×10^{-6}, 30%) Technetium-99 (6.8×10^{-6}, 45%) Tritium (1.7×10^{-6}, 11%)	21	Cadmium (HQ = 2.3, 11%) Cobalt (HQ = 3.4, 16%) Cyanide (HQ = 11, 54%) Fluoride (HQ = 0.34, 1.6%) Iron (HQ = 0.68, 3.2%) Manganese (HQ = 1.7, 8.1%) Zinc (HQ = 0.27, 1.3%)
699-53-55B	1.5×10^{-4}	Cobalt-60 (2.0×10^{-6}, 1.4%) Technetium-99 (1.4×10^{-4}, 96%) Tritium (4.2×10^{-6}, 2.9%)	111	Cyanide (HQ = 110, 99%)
699-53-55C	1.7×10^{-4}	Cobalt-60 (3.0×10^{-6}, 1.8%) Technetium-99 (1.6×10^{-4}, 96%) Tritium (3.4×10^{-6}, 2.0%)	113	Cyanide (HQ = 112, 99%)
699-54-45A	1.5×10^{-5}	Carbon tetrachloride (1.2×10^{-5}, 80%) Chloroform (3.0×10^{-6}, 20%)	3.1	Cadmium (HQ = 0.04, 1.2%) Carbon tetrachloride (HQ = 0.08, 2.5%) Cobalt (HQ = 0.92, 29%) Fluoride (HQ = 0.09, 2.8%) Iron (HQ = 0.81, 26%) Lithium (HQ = 0.20, 6.3%) Manganese (HQ = 0.31, 9.8%) Zinc (HQ = 0.55, 18%)
699-55-57	9.6×10^{-5}	Technetium-99 (8.5×10^{-5}, 89%) Tritium (1.0×10^{-5}, 11%)	43	Cyanide (HQ = 42, 97%)

HI = hazard index
HQ = hazard quotient

Table H-12. Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the 200-BP-5 Far-Field Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
699-62-43F	3.1×10^{-4}	Arsenic (2.9×10^{-4}, 92%) Technetium-99 (6.3×10^{-6}, 2.0%) Tritium (1.8×10^{-5}, 5.6%)	2.7	Arsenic (HQ = 1.5, 56%) Fluoride (HQ = 0.38, 14%) Cr(VI) (HQ = 0.24, 9.0%) Lithium (HQ = 0.18; 6.8%) Molybdenum (HQ = 0.03; 1.3%) Nitrate (HQ = 0.06, 2.4%) Vanadium (HQ = 0.20; 7.6%)
699-65-50	2.3×10^{-4}	Arsenic (2.1×10^{-4}, 89%) Technetium-99 (6.1×10^{-6}, 2.7%) Tritium (1.8×10^{-5}, 7.9%)	2.1	Arsenic (HQ = 1.1, 50%) Fluoride (HQ = 0.38, 18%) Cr(VI) (HQ = 0.18, 8.2%) Lithium (HQ = 0.18; 8.4%) Molybdenum (HQ = 0.03; 1.6%) Nitrate (HQ = 0.06, 2.9%) Nitrite (HQ = 0.02, 1.1%) Vanadium (HQ = 0.20; 9.3%)

Cr(VI) = hexavalent chromium
HI = hazard index
HQ = hazard quotient

In addition to the well-specific evaluation, analyses were performed to provide better understanding of the primary contributors to cancer risk and noncancer hazards. The following subsections provide information on the evaluation of results for arsenic and antimony, as well as cumulative noncancer effects.

Table H-13. Summary of Summary of Well-Specific Cancer Risks, Noncancer Hazards, and Major Contributors for Monitoring Wells in the 200-BP-5 Near-River Exposure Area

Well Name	Total Cumulative Cancer Risk	Major Risk Contributors	HI	Major Noncancer Hazard Contributors
699-70-68	6.9×10^{-5}	TCE (2.4×10^{-6}, 3.5%) Technetium-99 (5.4×10^{-6}, 7.9%) Tritium (6.0×10^{-5}, 87%)	1.3	Fluoride (HQ = 0.15, 12%) Cr(VI) (HQ = 0.07, 5.8%) Lithium (HQ = 0.10; 8.2%) Molybdenum (HQ = 0.04; 3.5%) Nitrate (HQ = 0.11, 8.9%) Nitrite (HQ = 0.02; 1.9%) Selenium (HQ = 0.02; 1.5%) TCE (HQ = 0.53; 42%) Uranium (HQ = 0.02; 2.0%) Vanadium (HQ = 0.15; 12%)

Cr(VI) = hexavalent chromium
HI = hazard index
HQ = hazard quotient
TCE = trichloroethene

H4.1 Evaluation of Arsenic Results

A total of 10 of 161 wells within the 200-BP-5 OU reported at least one measurement greater than the drinking water standard (DWS) of 10 µg/L. Of these 10 wells, 6 wells (299-E33-16, 299-E33-44, 299-E27-14, 299-E27-15, 699-62-43F, and 699-65-50) were selected for the well-specific evaluation. Arsenic concentrations in the remaining 151 wells within the OU reported concentrations within naturally occurring levels. Minimum, maximum, and 90th percentile concentrations for (filtered) background concentrations of arsenic are 0.5 µg/L, 8.8 µg/L, and 7.85 µg/L, respectively.

Unfiltered arsenic concentrations are plotted on time-series charts (Figures H-1 through H-12) for all of the wells within each exposure area. Additionally, a time-series chart is provided for the 10 monitoring wells that report at least one measurement greater than the DWS; these charts show both unfiltered and filtered arsenic concentrations. The times-series charts represent measurements that have been collected over the past 10 years.

For the purpose of this evaluation, monitoring wells with arsenic concentrations greater than the DWS are included in the cancer risk and noncancer hazard estimates and are included in the figures showing primary cancer risk and noncancer hazard contributors. Monitoring wells with arsenic concentrations within the range of naturally occurring levels are not included in the cancer risk and noncancer hazard calculations or figures.

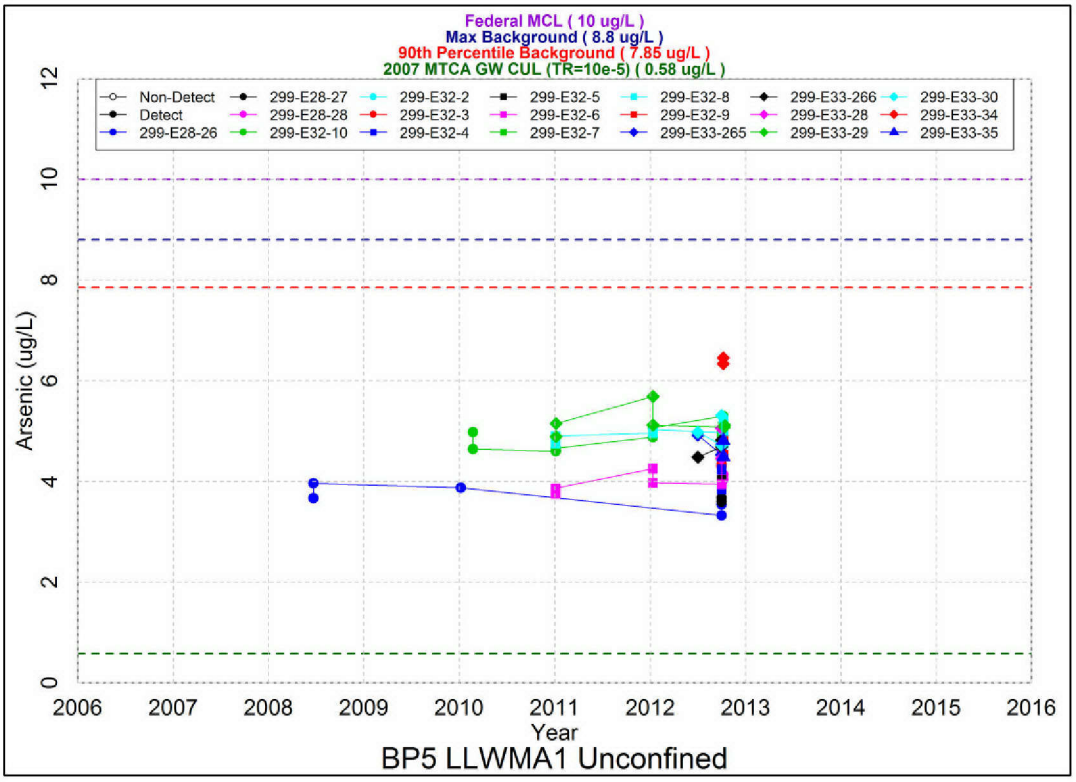

Figure H-1. Unfiltered Arsenic Concentrations for Wells within the LLWMA-1 Exposure Area

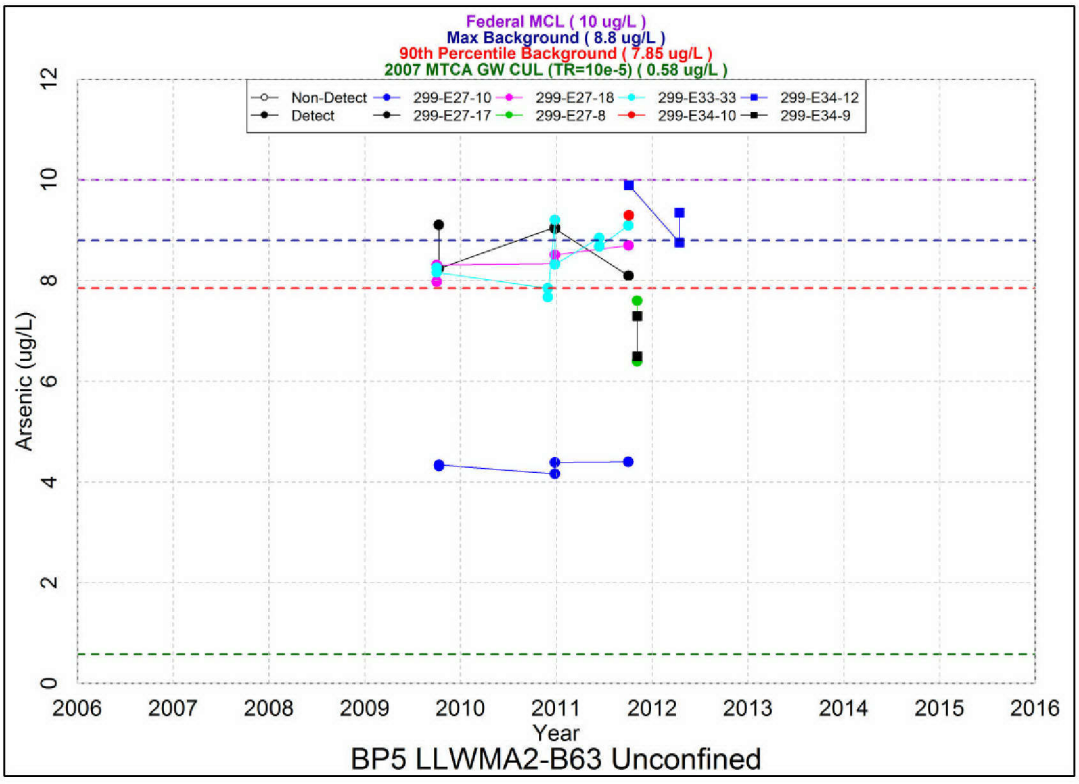

Figure H-2. Unfiltered Arsenic Concentrations for Wells within the LLWMA-2 and 216-B-63 Trench Exposure Area

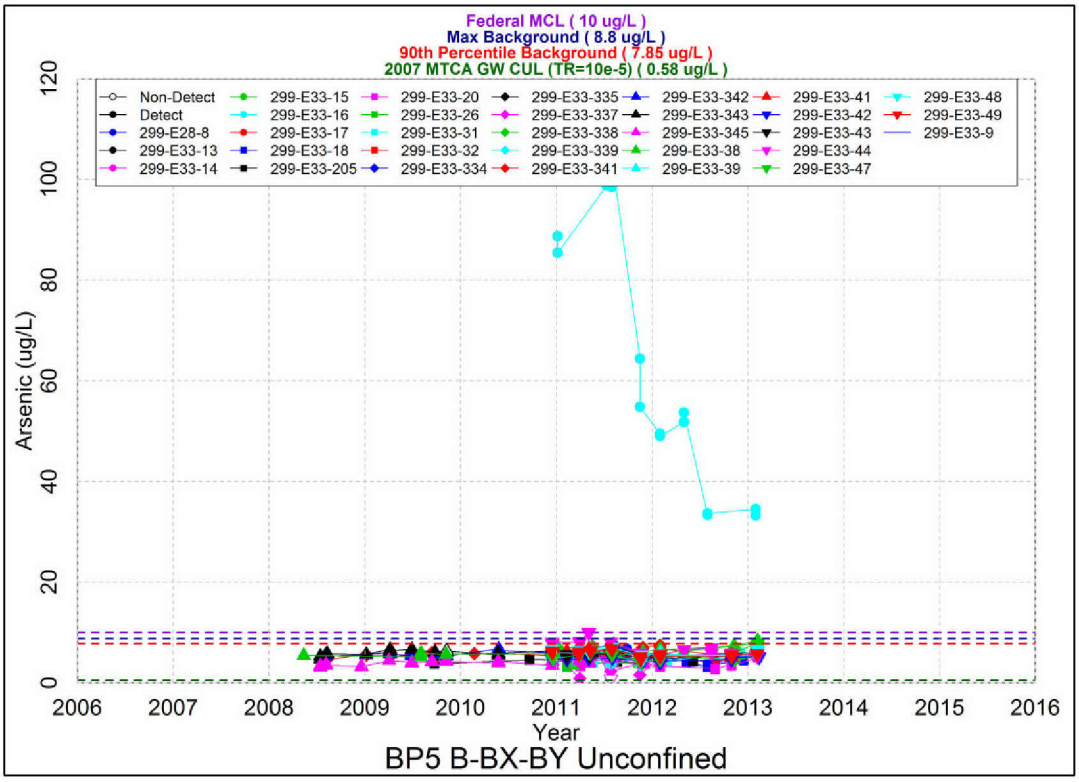

Figure H-3. Unfiltered Arsenic Concentrations for Wells within the WMA B-BX-BY Tank Farms Exposure Area

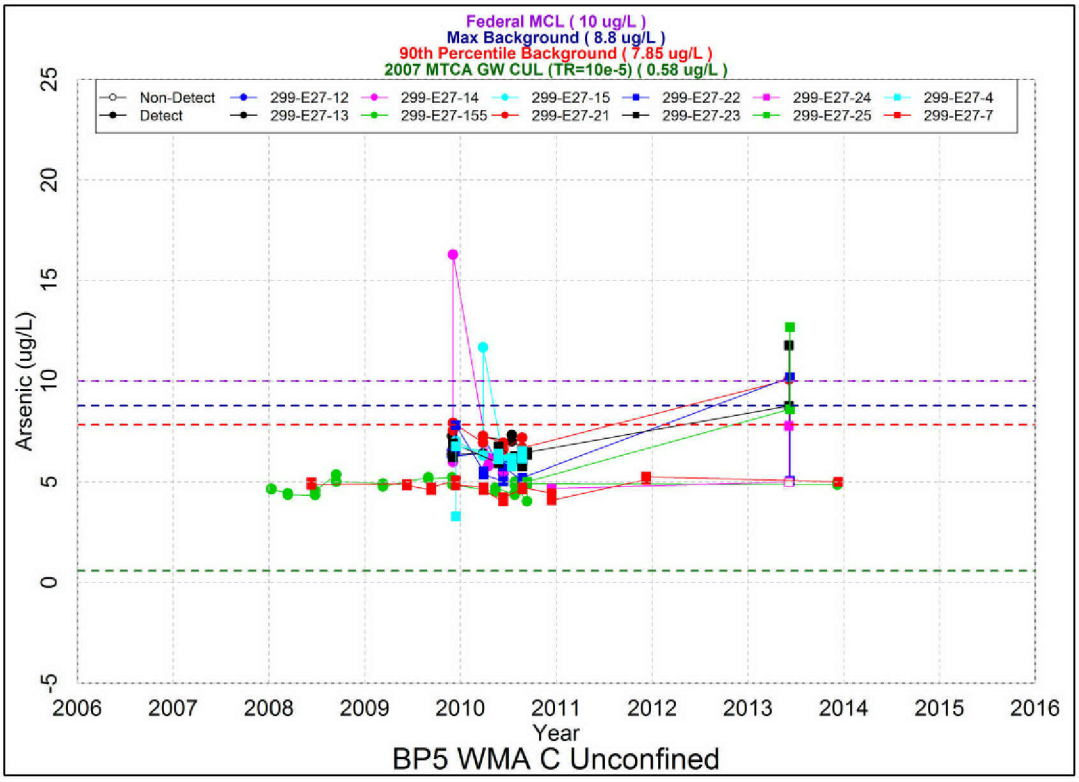

Figure H-4. Unfiltered Arsenic Concentrations for Wells within the WMA C Exposure Area

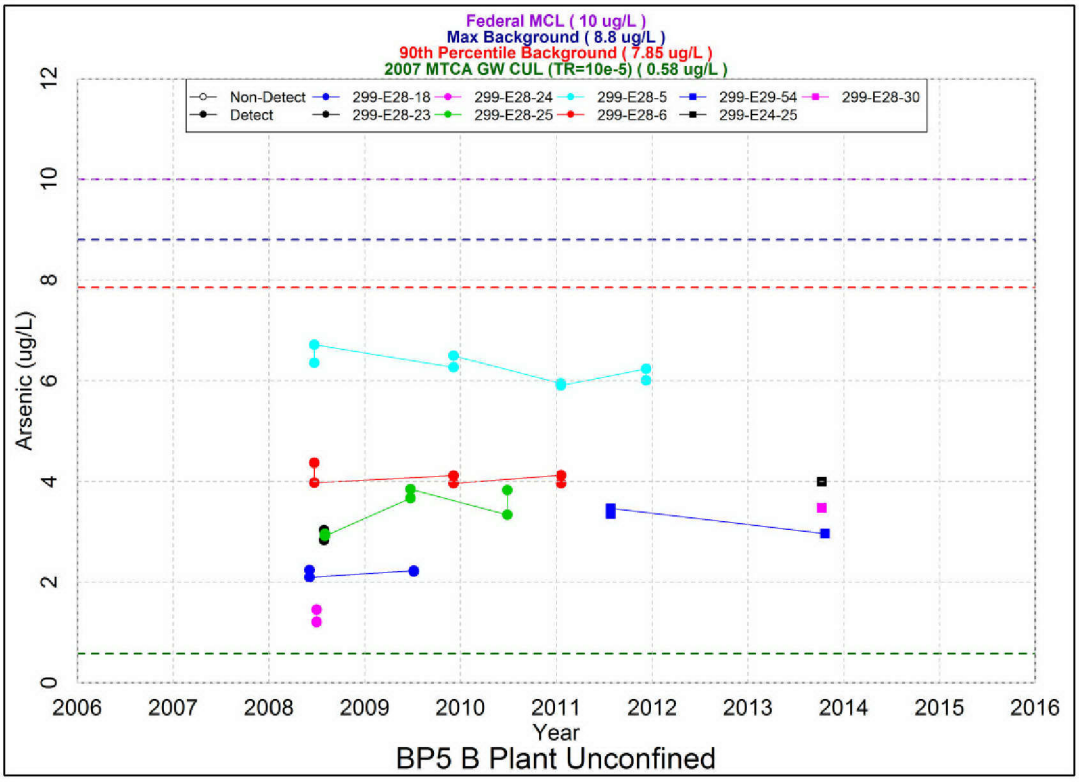

Figure H-5. Unfiltered Arsenic Concentrations for Wells within the B Plant Exposure Area

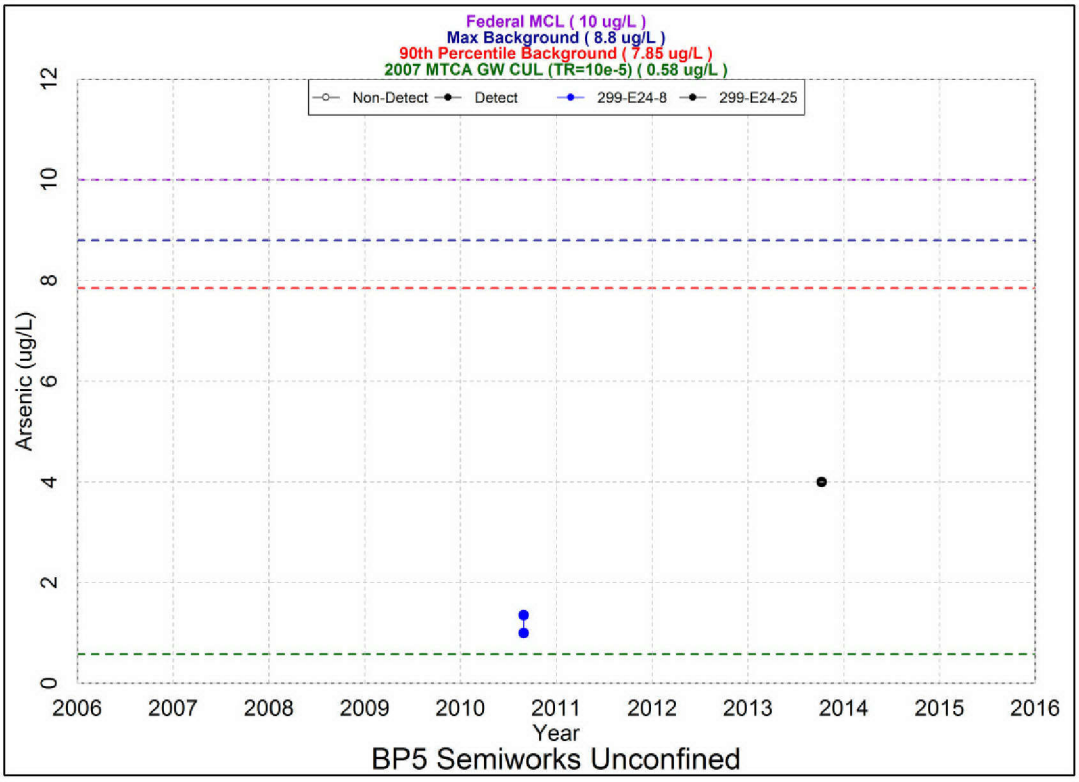

Figure H-6. Unfiltered Arsenic Concentrations for Wells within the Semiworks Exposure Area

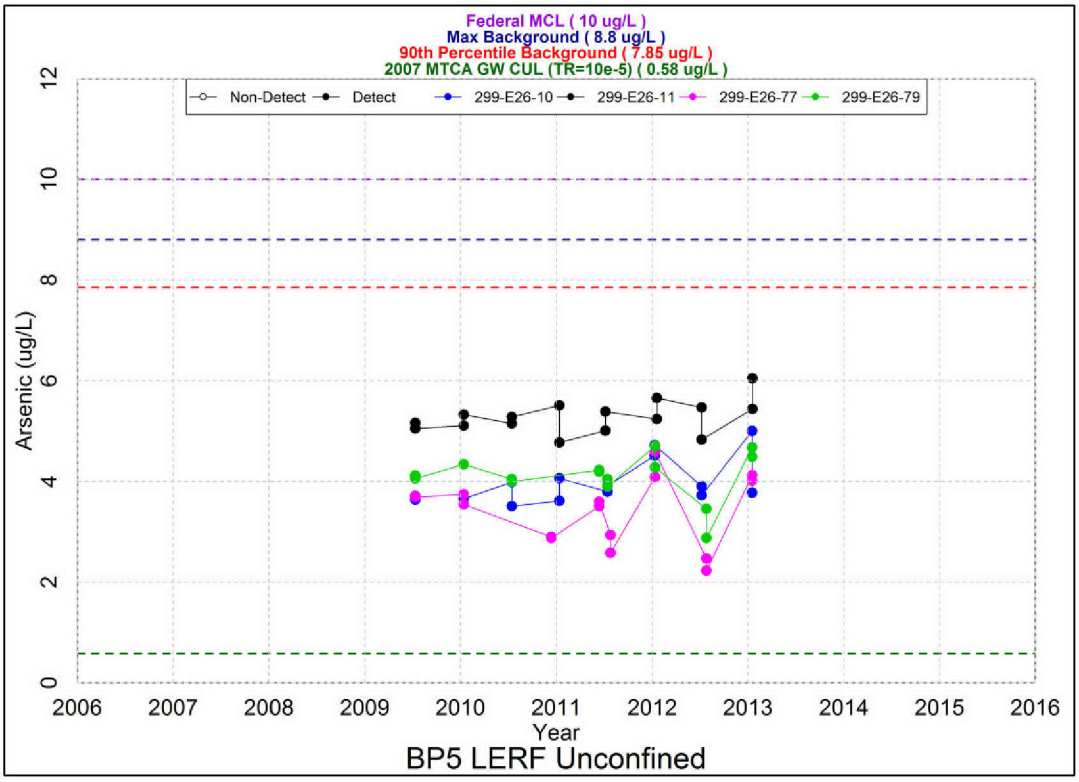

Figure H-7. Unfiltered Arsenic Concentrations for Wells within the Liquid Effluent Retention Facility Exposure Area

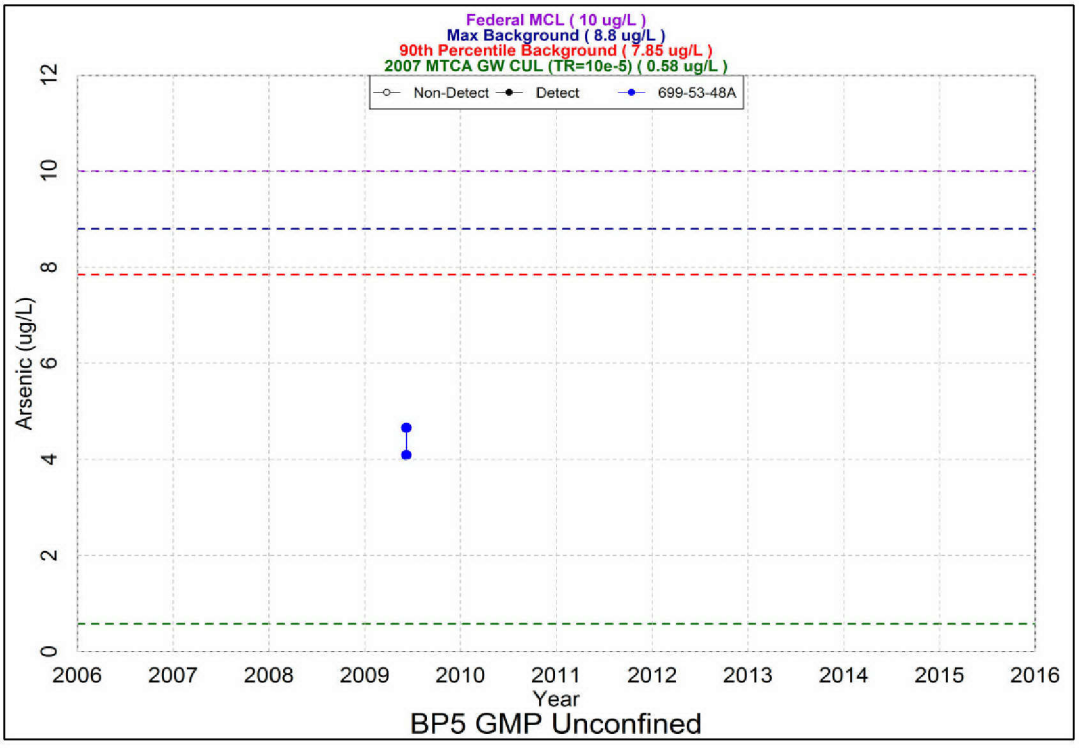

Figure H-8. Unfiltered Arsenic Concentrations for Wells within the Gable Mountain Pond Exposure Area

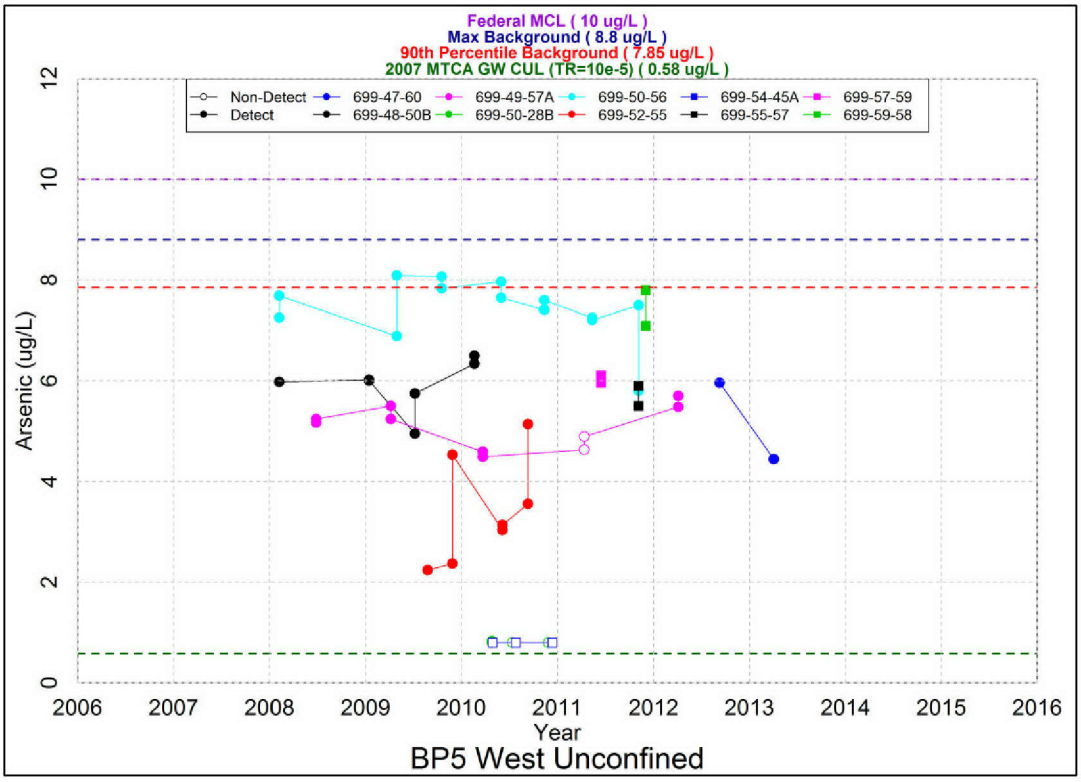

Figure H-9. Unfiltered Arsenic Concentrations for Wells within the 200-BP-5 West Exposure Area

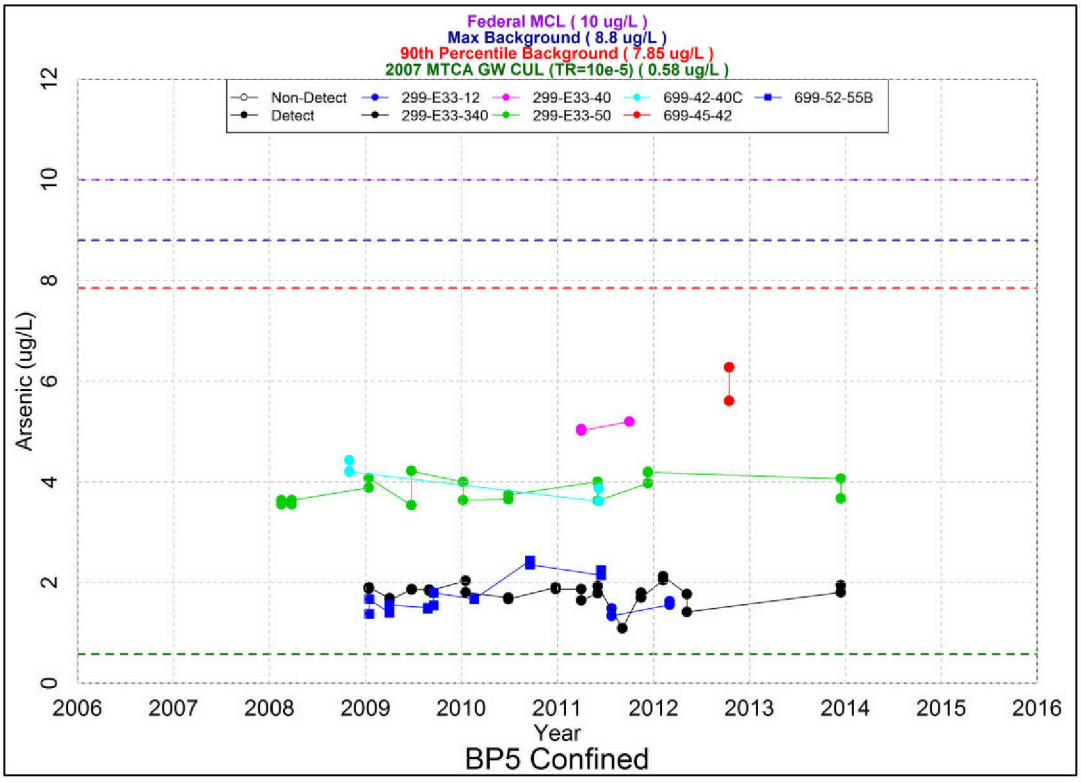

Figure H-10. Unfiltered Arsenic Concentrations for Wells within the 200-BP-5 Confined Exposure Area

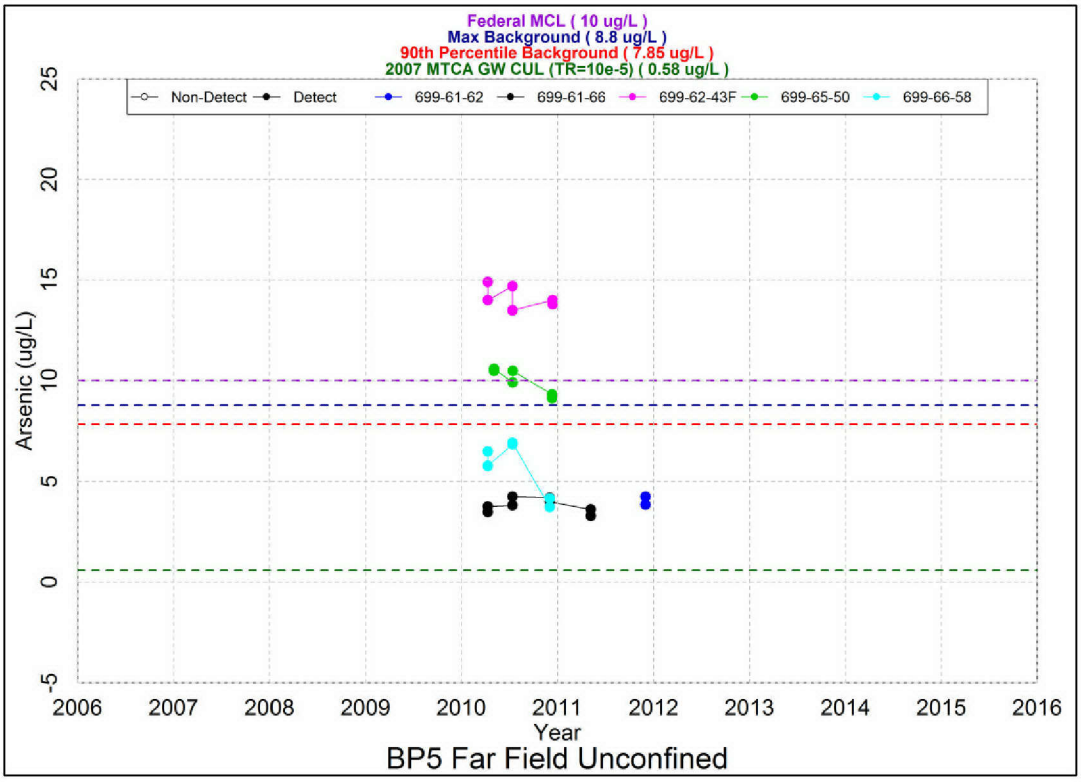

Figure H-11. Unfiltered Arsenic Concentrations for Wells within the 200-BP-5 Far-Field Exposure Area

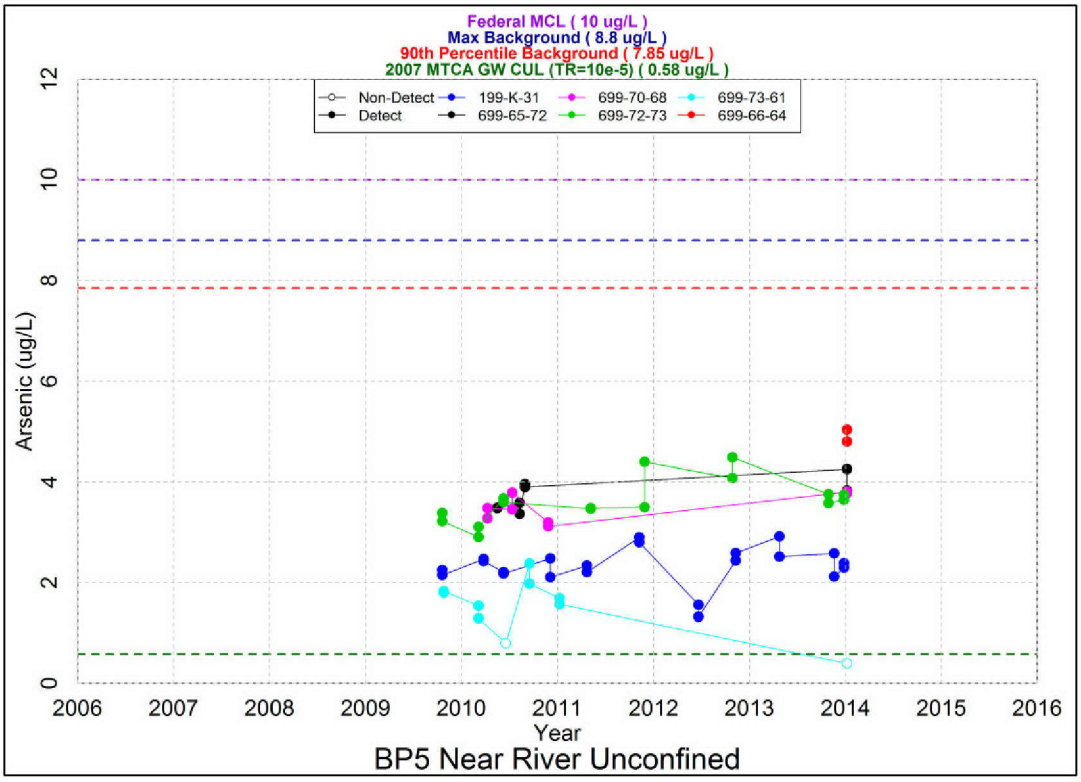

Figure H-12. Unfiltered Arsenic Concentrations for Wells within the 200-BP-5 Near-River Exposure Area

H4.2 Evaluation of Antimony Results

The evaluation of measured groundwater concentrations provided in Section 4.5 in the main text determined that antimony results reported by Method 6010 are not accurate at concentrations at or near the DWS (6 µg/L) or the Hanford Site background concentration (55 µg/L), whereas antimony concentrations reported by EPA Method 200.8 are less than the DWS. As a result, the EPCs for antimony are elevated where measured concentrations reflect false-positive results. Because antimony concentrations reflect false-positive results, noncancer hazards for antimony are not calculated or reported for any of the wells in this evaluation.

H4.3 Evaluation of Cumulative Noncancer Effects

When the reported HI is above the 2007 MTCA (WAC 173-340-708(5), "Model Toxics Control Act—Cleanup," "Human Health Risk Assessment Procedures" [hereafter referred to as MTCA HHRA Procedures]) target HI of 1 (unity), then EPA guidance (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*) recommends segregating HIs by critical effect and mechanism of action. If exposure levels exceed the reference dose (RfD) (unity), then adverse effects in addition to the critical toxic effect may begin to appear. The RfD is developed from a no observable adverse effect level for the most sensitive, or critical, toxic effect based in part on the assumption that if the critical toxic effect is prevented, then all toxic effects are prevented. EPA/540/1-89/002 indicates that "…although higher exposure levels may be required to produce adverse health effects other than the critical effect, the RfD can be used as the toxicity value for each effect category as a conservative and simplifying step." Based on the results of the well-specific evaluation presented in the following discussion, each analyte that is determined to contribute greater than 1 percent of the total HI is listed in Table H-14. For each analyte, the critical effect associated with the RfD is also listed.

H5 Well-Specific Cancer Risk and Noncancer Hazard Results

The results of the well-specific risk evaluation are provided in Tables H-6 through H-13. Each table lists the well name, the total cumulative cancer risk, the major risk contributors, the HI, and the major noncancer hazard contributors.

H5.1 Results for Wells Included in the Low-Level Waste Management Area 1 Exposure Area

Table H-6 provides a summary of the cancer risk and noncancer hazards for each of the four wells selected for well-specific evaluation within the Low-Level Waste Management Area (LLWMA)-1 exposure area. Figures H-13 and H-14 show the primary cancer risk and noncancer hazard contributors for wells within the LLWMA-1 exposure area, respectively. Figure H-1 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the LLWMA-1 exposure area.

H5.1.1 Well 299-E28-28

As shown in Table H-6, the total cumulative excess lifetime cancer risk (ELCR) for Well 299-E28-28 is 6.1×10^{-6}. The total ELCR for radiological analytes is 6.1×10^{-6}, which is less than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (2.2×10^{-6}; 36 percent contribution) and tritium (3.9×10^{-6}; 64 percent contribution).

Table H-14. Noncancer Hazard Contributors and Associated Critical Effect

Contaminant Name	Critical Effect
Blood Effects	
Cobalt	Increased production of red blood cells
Nitrate	Early clinical signs of methemoglobinemia
Nitrite	Methemoglobinemia
Zinc	Decreased erythrocyte copper, zinc-superoxide dismutase (ESOD)
Body or Organ Weight Loss	
Cyanide	Decreased cauda epididymis weight in male F344/N rats
Nickel	Decreased body and organ weights
Uranium	Initial body weight loss
Central Nervous System Effects	
Lithium	Nervous system
Manganese	Central nervous system
Kidney Effects	
Cadmium	Significant proteinuria
Lithium	Kidney effects (nephrogenic diabetes insipidus)
Molybdenum	Increased uric acid levels
Uranium	Moderate nephrotoxicity
Liver and Liver Enzyme Effects	
Bis(2-ethylhexyl) phthalate	Increased relative liver weight
Carbon tetrachloride	Elevated serum sorbitol dehydrogenase activity
Chloroform	Moderate marked fatty cyst formation in the liver and elevated serum glutamic pyruvic transaminase
Skin Effects	
Arsenic	Hyperpigmentation, keratosis, and possible vascular complications
Silver	Argyria (skin effects)
Miscellaneous Effects	
Copper	Gastrointestinal system irrigation
Cr(VI)	Nasal septum atrophy
Cyanide	Thyroid enlargement and altered iodide uptake

Table H-14. Noncancer Hazard Contributors and Associated Critical Effect

Contaminant Name	Critical Effect
Fluoride	Objectionable dental fluorosis, a cosmetic effect
Iron	Gastrointestinal effects (epigastric pain, nausea, vomiting, and diarrhea)
Selenium	Clinical selenosis (loss of hair and nails)
Trichloroethene	Adult immunological effects, developmental immunotoxicity, heart malfunctions
Vanadium	Decreased hair cysteine

Cr(VI) = hexavalent chromium

As shown in Table H-6, the HI is 5.2, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (hazard quotient [HQ] = 4.4; 84 percent contribution), fluoride (HQ = 0.22; 4.2 percent contribution), nitrate (HQ = 0.20; 3.9 percent contribution), and vanadium (HQ = 0.2; 3.0 percent contribution); the remaining analytes (hexavalent chromium [Cr(VI)] and uranium) report an HQ less than 0.1.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.1.2 Well 299-E33-34

As shown in Table H-6, the total cumulative ELCR is 1.0×10^{-3}. The total ELCR for radiological analytes is 1.0×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cobalt-60 (1.1×10^{-5}; 1.1 percent contribution), iodine-129 (1.1×10^{-5}; 1.1 percent contribution), technetium-99 (8.9×10^{-4}; 87 percent contribution), and tritium (1.1×10^{-4}; 11 percent contribution).

As shown in Table H-6, the HI is 298, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 292; 98 percent contribution) and nitrate (HQ = 3.4; 1.2 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

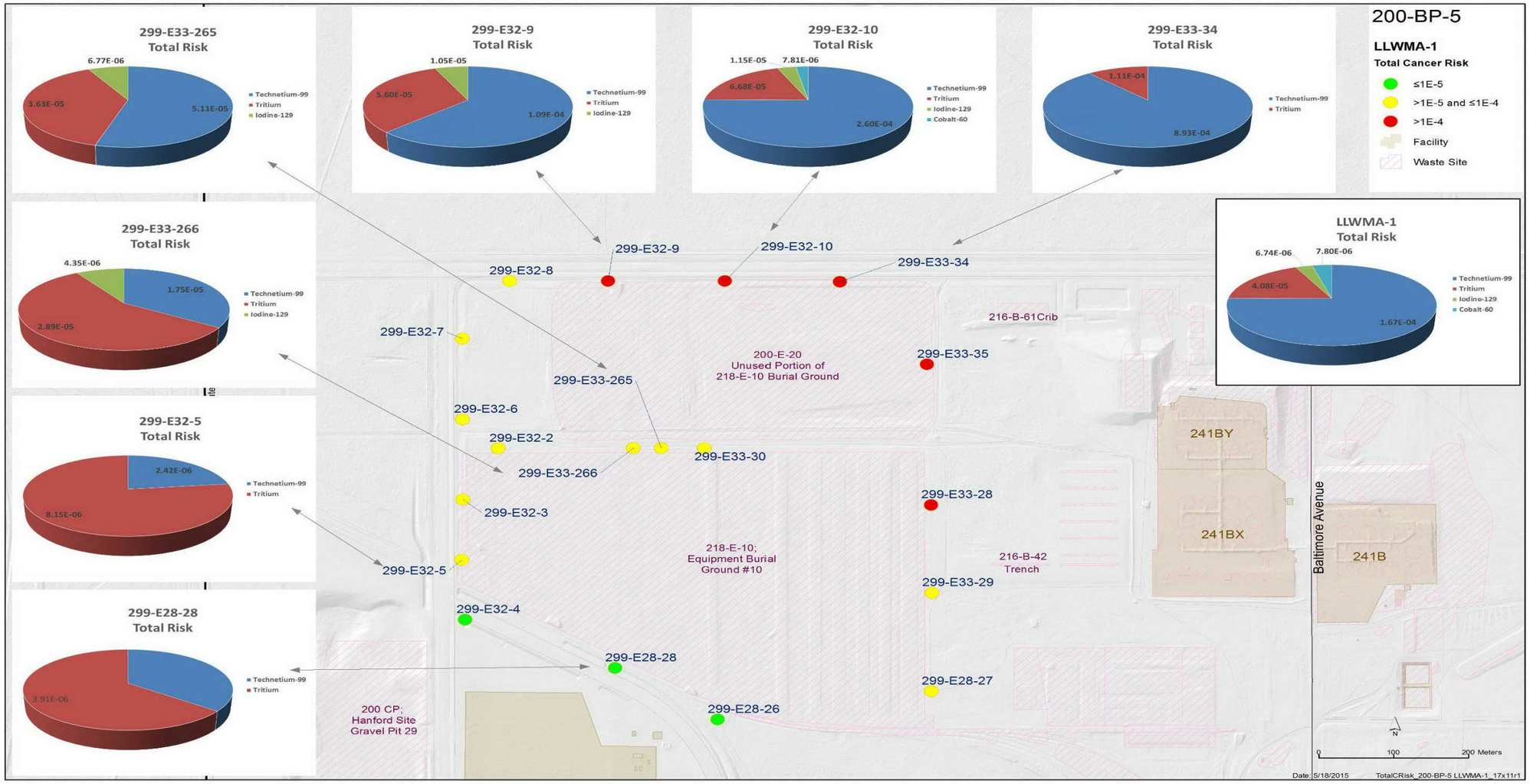

Figure H-13. Cancer Risk Contributors for Wells within the LLWMA-1 Exposure Area

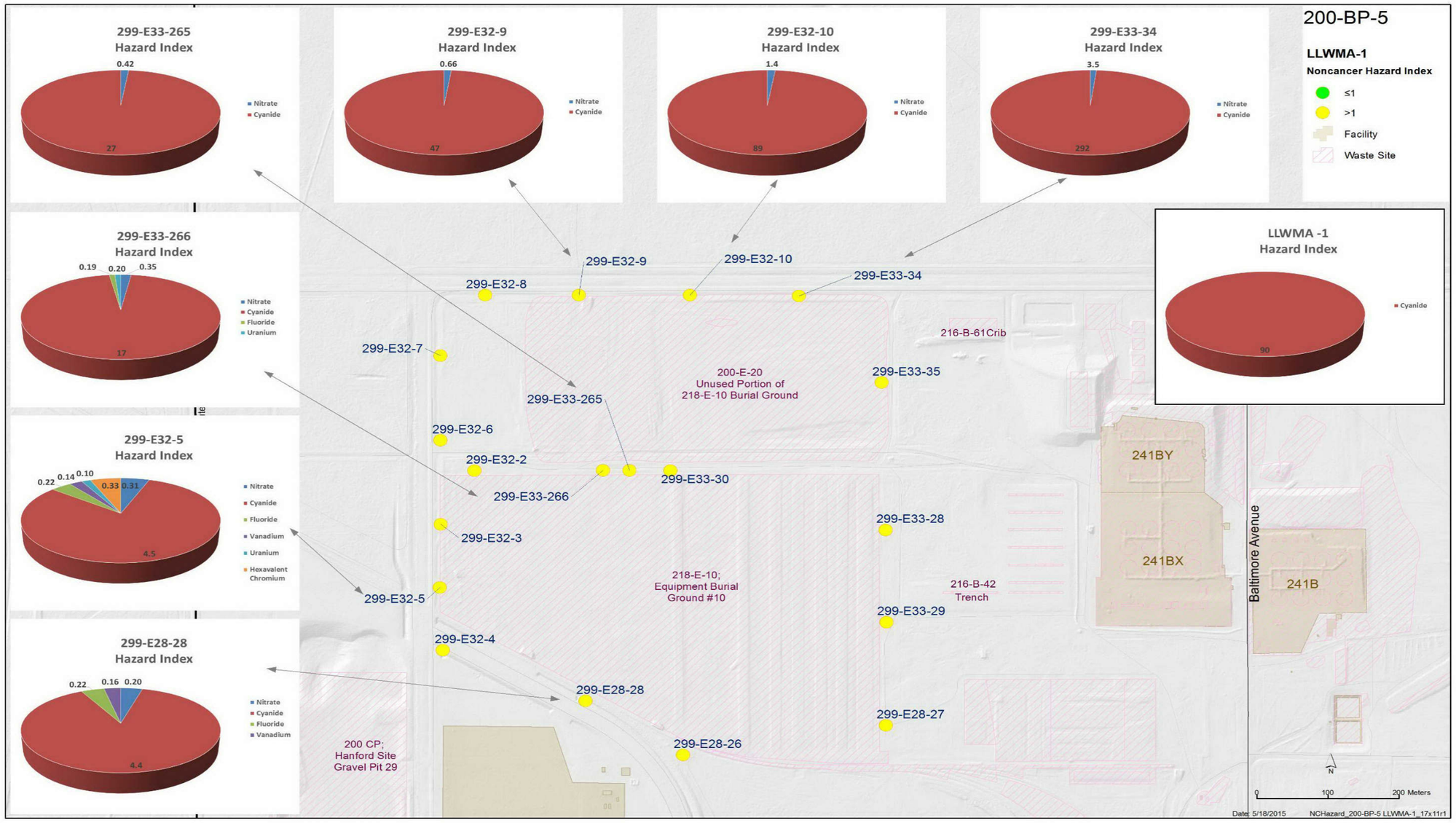

Figure H-14. Noncancer Hazard Contributors for Wells within the LLWMA-1 Exposure Area

H5.1.3 Well 299-E33-265

As shown in Table H-6, the total cumulative ELCR is 9.4×10^{-5}. The total ELCR for nonradiological analytes is 5.9×10^{-7}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.4×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (6.8×10^{-6}; 7.2 percent contribution), technetium-99 (5.1×10^{-5}; 54 percent contribution), and tritium (3.6×10^{-5}; 39 percent contribution).

As shown in Table H-6, the HI is 29, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 28; 96 percent contribution) and nitrate (HQ = 0.4; 1.5 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.1.4 Well 299-E33-266

As shown in Table H-6, the total cumulative ELCR is 5.1×10^{-5}. The total ELCR for nonradiological analytes is 1.8×10^{-8}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 5.1×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (4.3×10^{-6}; 8.6 percent contribution), technetium-99 (1.8×10^{-5}; 34 percent contribution), and tritium (2.9×10^{-5}; 57 percent contribution).

As shown in Table H-6, the HI is 18, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 17; 94 percent contribution), nitrate (HQ = 0.4; 1.9 percent contribution), and uranium (HQ = 0.2; 1.1 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.2 Results for Wells Included in the Low-Level Waste Management Area 2 and 216-B-63 Trench Exposure Area

Table H-7 provides a summary of the cancer risk and noncancer hazards for the single well selected for well-specific evaluation within the LLWMA-2 and 216-B-63 Trench exposure area. Figures H-15 and H-16 show the primary cancer risk and noncancer hazard contributors for wells within the LLWMA-2 and 216-B-63 Trench exposure area, respectively. Figure H-2 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the LLWMA-2 and 216-B-63 Trench exposure area.

H5.2.1 Well 299-E33-33

As shown in Table H-7, the total cumulative ELCR is 3.6×10^{-5}. The total ELCR for radiological analytes is 3.6×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (7.2×10^{-6}; 20 percent contribution), technetium-99 (2.6×10^{-5}; 72 percent contribution), and tritium (2.8×10^{-6}; 7.8 percent contribution).

As shown in Table H-7, the HI is 14, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 13; 93 percent contribution), nitrate (HQ = 0.4; 2.6 percent contribution), Cr(VI) (HQ = 0.3; 1.8 percent contribution), and vanadium (HQ = 0.2; 1.3 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.3 Results for Wells Included in the Waste Management Area B-BX-BY Tank Farms Exposure Area

Table H-8 provides a summary of the cancer risk and noncancer hazards for each of the 21 wells selected for well-specific evaluation within the Waste Management Area (WMA) B-BX-BY Tank Farms exposure area. Figures H-17, H-18, and H-19 show the primary cancer risk contributors for wells within this exposure area. Figures H-20, H-21, and H-22 show the primary noncancer hazard contributors for wells within this exposure area. Figure H-3 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the WMA B-BX-BY Tank Farms exposure area.

H5.3.1 Well 299-E33-1A

As shown in Table H-8, the total cumulative ELCR is 1.3×10^{-3}. The total ELCR for radiological analytes is 1.3×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (1.2×10^{-3}; 90 percent contribution) and tritium (1.0×10^{-4}; 7.8 percent contribution).

As shown in Table H-8, the HI is 523, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 514; 98 percent contribution) and nitrate (HQ = 5.4; 1.0 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

H5.3.2 Well 299-E33-4

As shown in Table H-8, the total cumulative ELCR is 3.1×10^{-4}. The total ELCR for radiological analytes is 3.1×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributor to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) is cobalt-60 (3.1×10^{-4}; 100 percent contribution).

There were no noncarcinogenic nonradiological contaminants reported in this well; therefore, a noncancer HI was not reported.

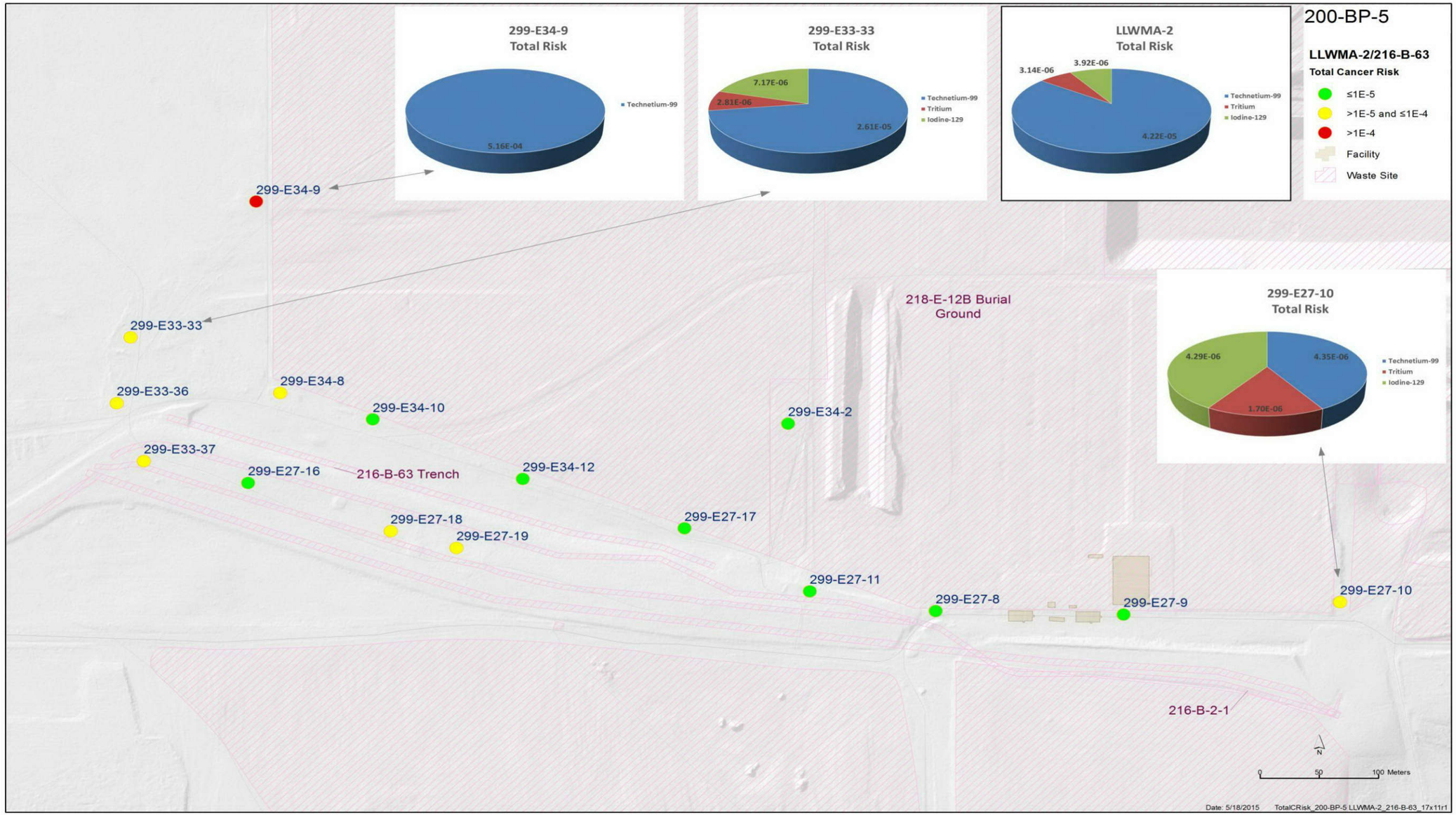

Figure H-15. Cancer Risk Contributors for Wells within the LLWMA-2 and 216-B-63 Trench Exposure Area

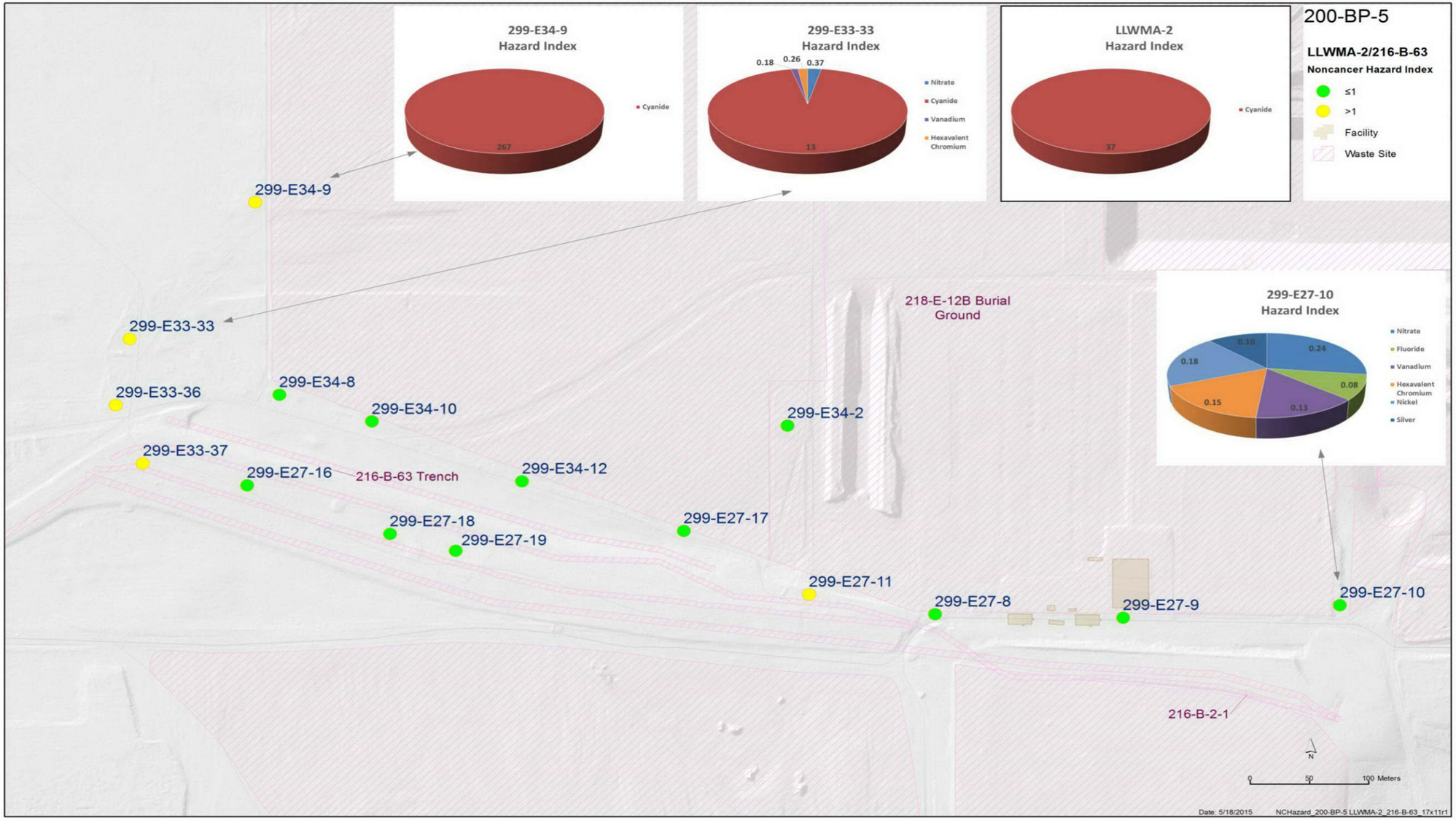

Figure H-16. Noncancer Hazard Contributors for Wells within the LLWMA-2 and 216-B-63 Trench Exposure Area

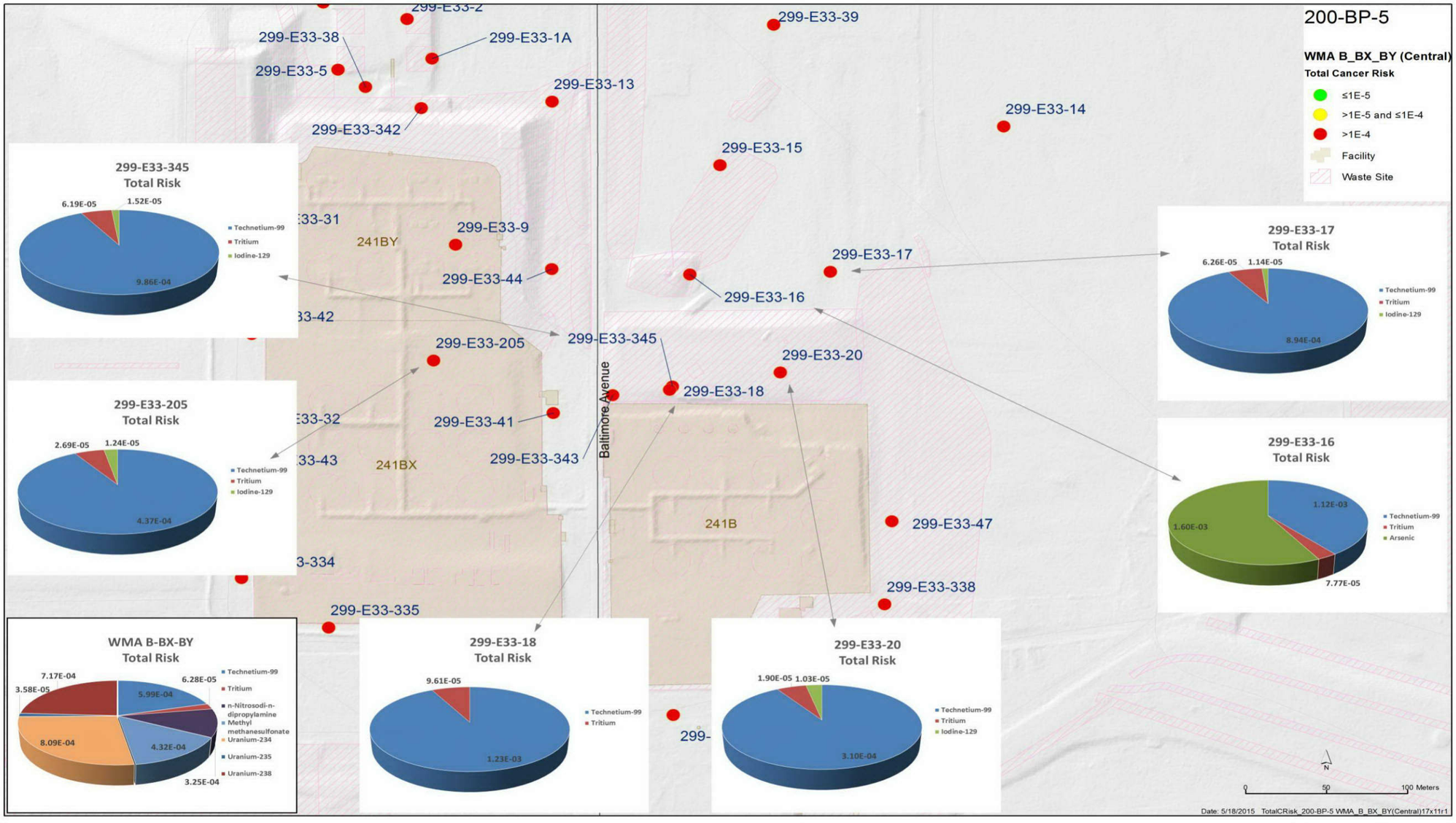

Figure H-17. Cancer Risk Contributors for Wells within the Central Area of the WMA B-BX-BY Tank Farms Exposure Area

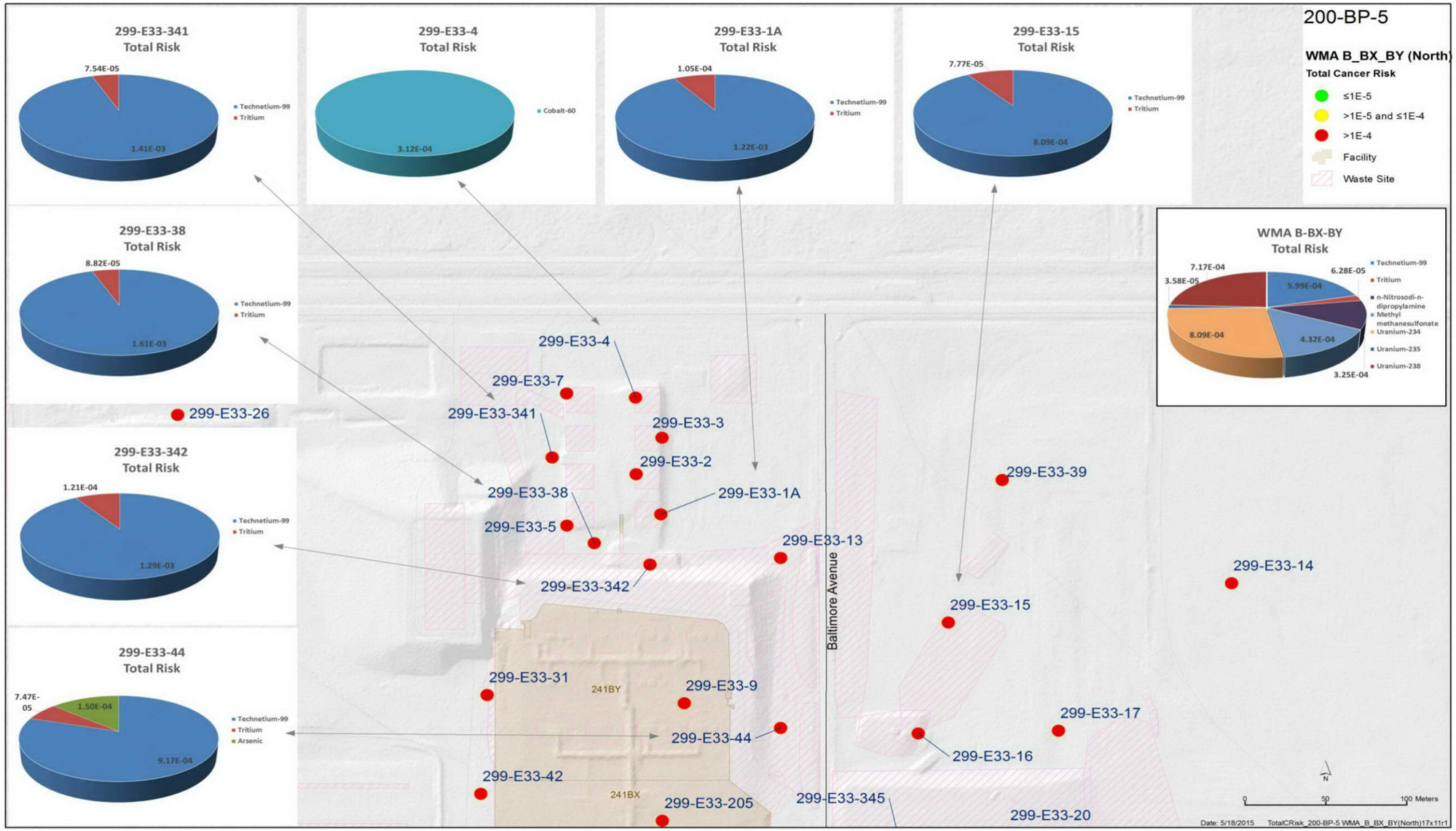

Figure H-18. Cancer Risk Contributors for Wells within the North Area of the WMA B-BX-BY Tank Farms Exposure Area

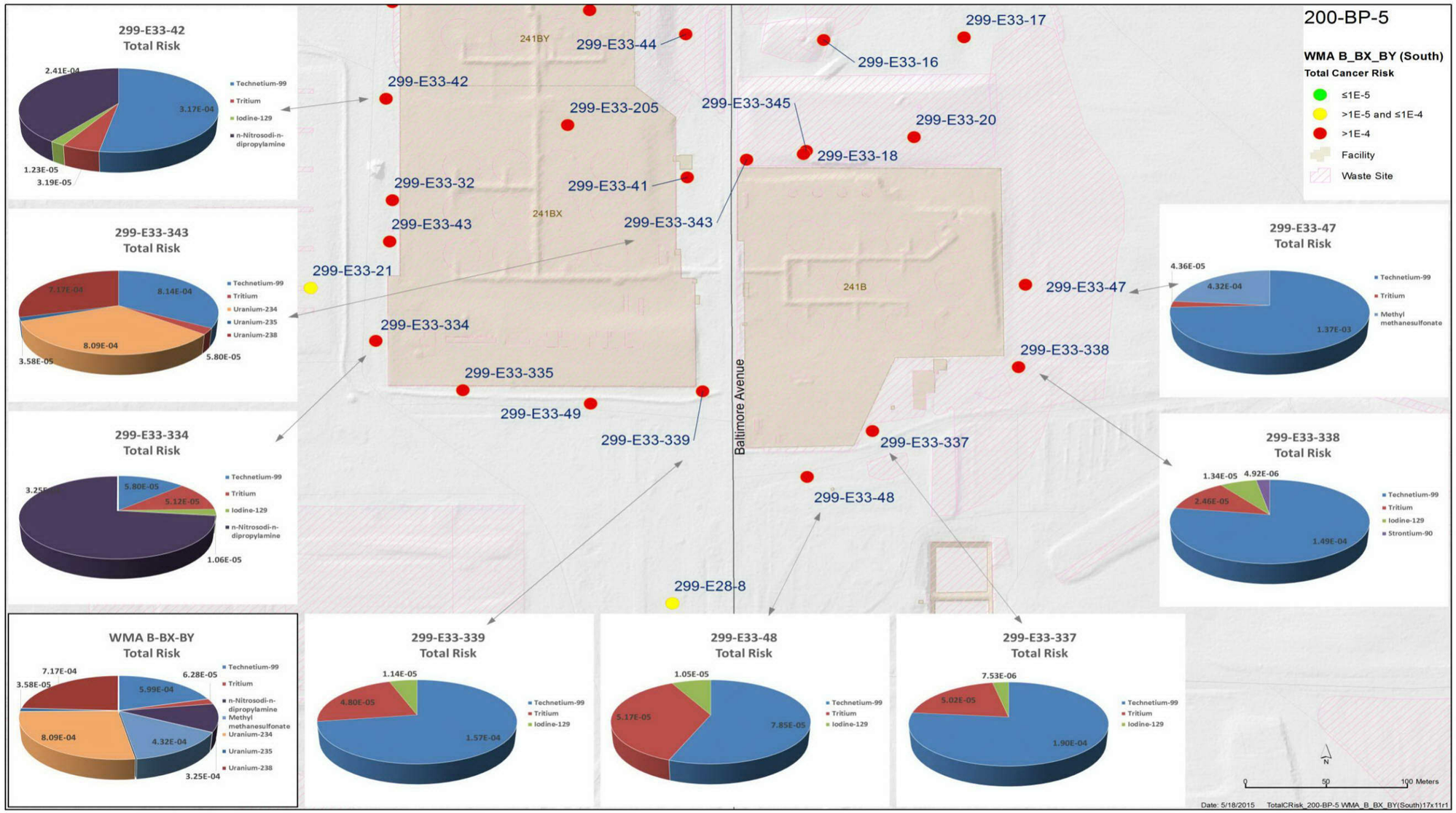

Figure H-19. Cancer Risk Contributors for Wells within the South Area of the WMA B-BX-BY Tank Farms Exposure Area

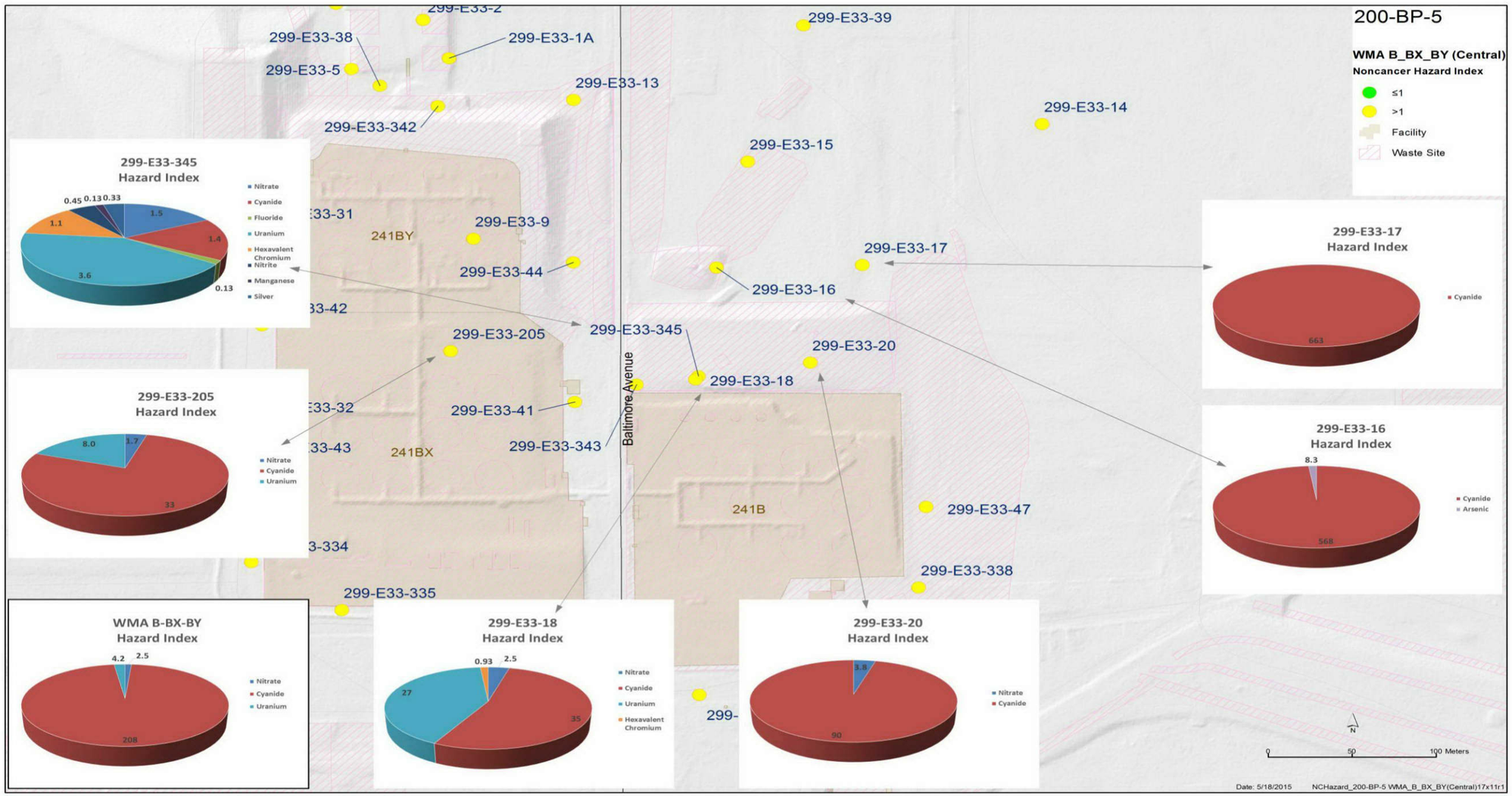

Figure H-20. Noncancer Hazard Contributors for Wells within the Central Area of the WMA B-BX-BY Tank Farms Exposure Area

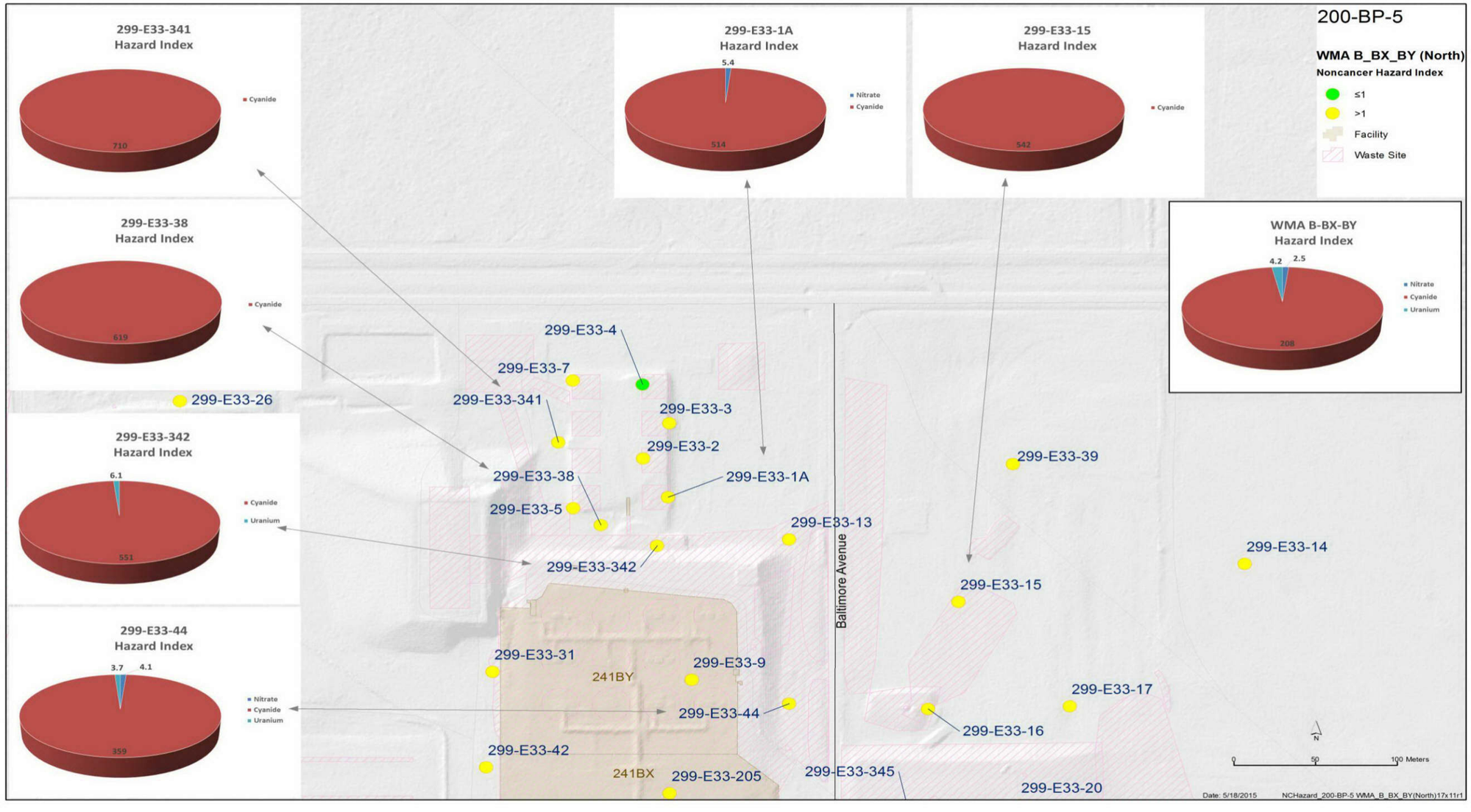

Figure H-21. Noncancer Hazard Contributors for Wells within the North Area of the WMA B-BX-BY Tank Farms Exposure Area

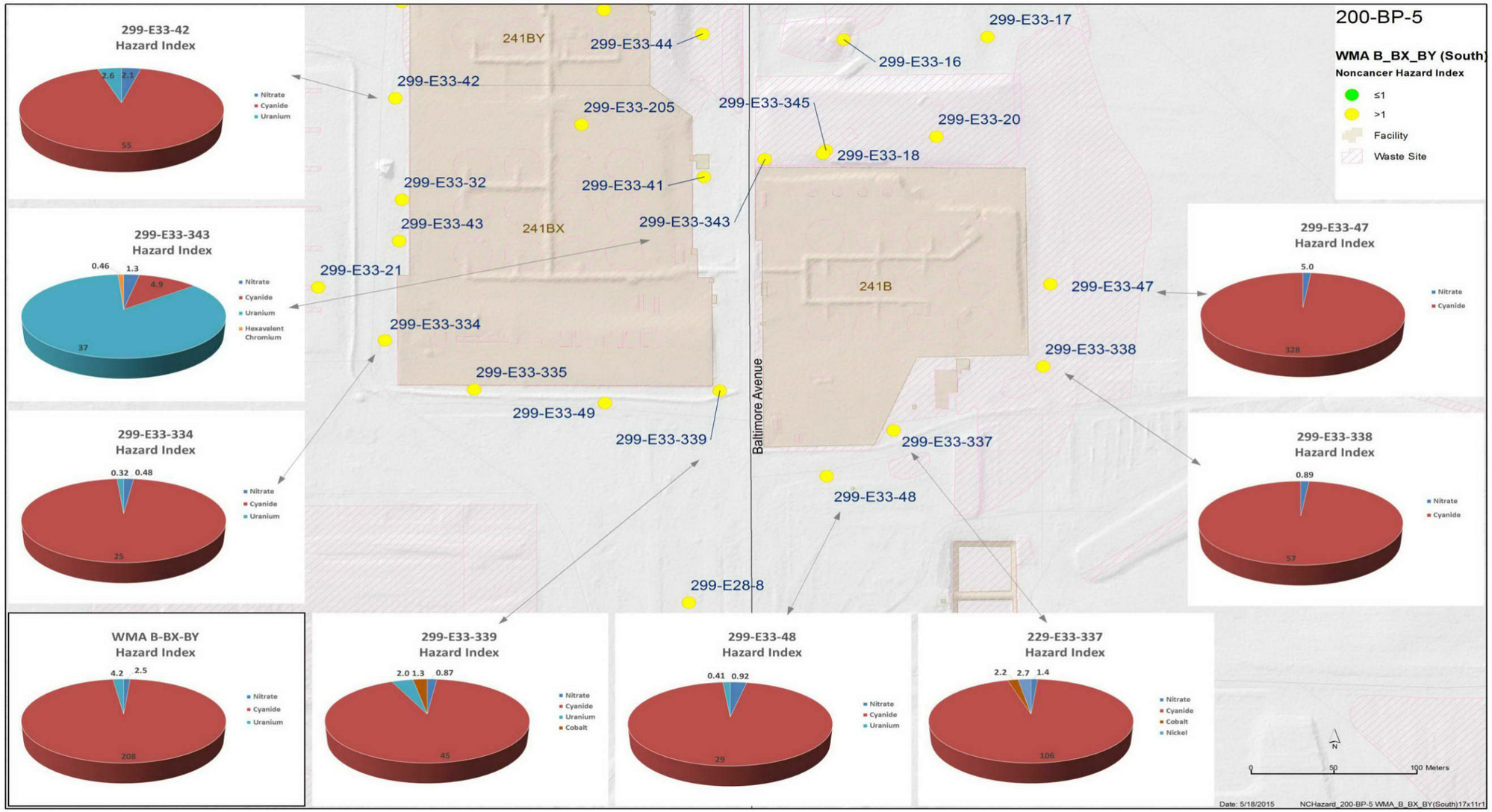

Figure H-22. Noncancer Hazard Contributors for Wells within the South Area of the WMA B-BX-BY Tank Farms Exposure Area

H5.3.3 Well 299-E33-15

As shown in Table H-8, the total cumulative ELCR is 9.0×10^{-4}. The total ELCR for radiological analytes is 9.0×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (8.1×10^{-4}; 90 percent contribution) and tritium (7.8×10^{-5}; 8.6 percent contribution).

As shown in Table H-8, the HI is 550, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 542; 99 percent contribution).

H5.3.4 Well 299-E33-16

As shown in Table H-8, the total cumulative ELCR is 2.8×10^{-3}. The total ELCR for nonradiological analytes is 1.6×10^{-3}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.2×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are arsenic (1.6×10^{-3}; 57 percent contribution), technetium-99 (1.1×10^{-3}; 40 percent contribution), and tritium (7.8×10^{-5}; 2.8 percent contribution). Contribution to ELCR is elevated for arsenic where measured concentrations for unfiltered samples range between 33 µg/L and 98.8 µg/L. The total cumulative ELCR is 1.2×10^{-3} without contribution from arsenic. Figure H-23 provides a times-series chart showing unfiltered and filtered arsenic concentrations over the past 10 years (if available) at Well 299-E33-16.

As shown in Table H-8, the HI is 588, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 568; 97 percent contribution) and arsenic (HQ = 8.3; 1.4 percent contribution).

As discussed in Chapter 4 (Sections 4.4.12 and 4.5.1.2) in the main text, arsenic concentrations at Well 299-E33-16 are associated with a downward trend. Arsenic concentrations measured at Well 299-E33-16 were approximately 99 µg/L in 2011 and decreased to approximately 35 µg/L in 2013. The presence of arsenic at Well 299-E33-16 may be the result of hydrolysis of natural arsenic when hydrochloric acid and acetic acid were discharged to the 216-B-8 Crib to improve poor drainage conditions at this waste site.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and arsenic each report an HI greater than 1.

H5.3.5 Well 299-E33-18

As shown in Table H-8, the total cumulative ELCR is 1.3×10^{-3}. The total ELCR for radiological analytes is 1.3×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (1.2×10^{-3}; 92 percent contribution) and tritium (9.6×10^{-5}; 7.1 percent contribution).

As shown in Table H-8, the HI is 65, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that

contribute greater than 1 percent of the total HI) are cyanide (HQ = 35; 53 percent contribution), Cr(VI) (HQ = 0.9; 4.0 percent contribution), nitrate (HQ = 2.5; 3,8 percent contribution), and uranium (HQ = 27; 41 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide, nitrate, and uranium each report an HI greater than 1.

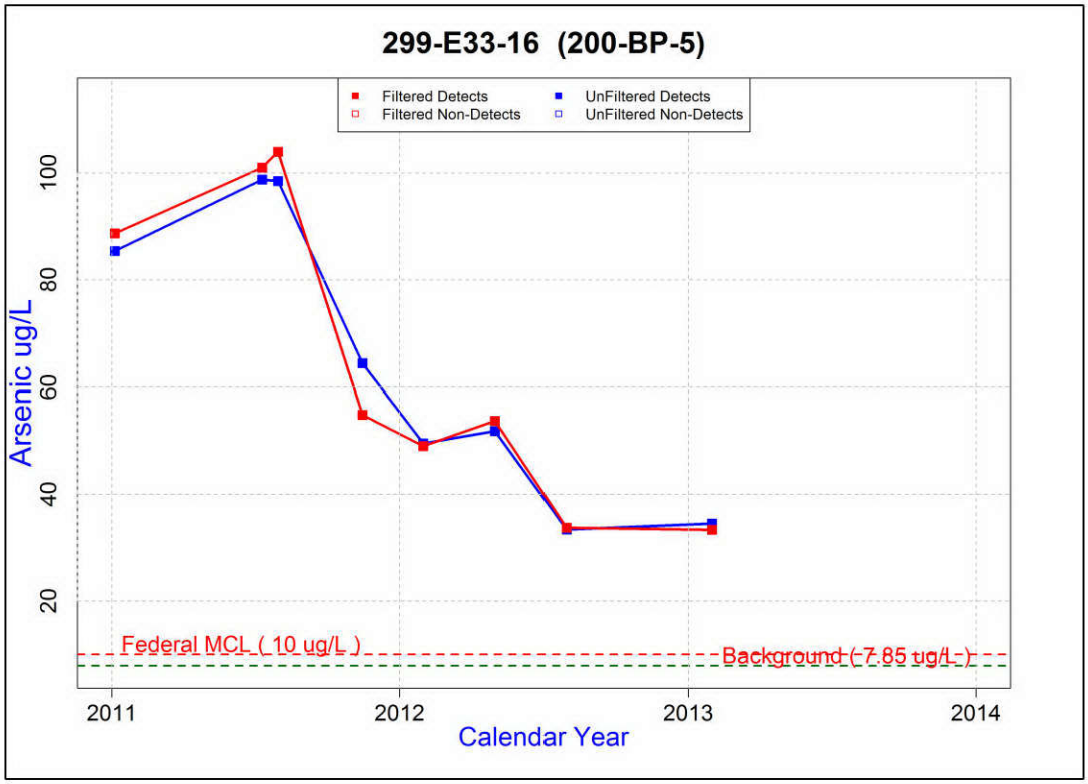

Figure H-23. Unfiltered and Filtered Arsenic Concentrations for Well 299-E33-16 (WMA B-BX-BY Tank Farms Exposure Area)

H5.3.6 Well 299-E33-17

As shown in Table H-8, the total cumulative ELCR is 9.8×10^{-4}. The total ELCR for radiological analytes is 9.8×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.1×10^{-5}; 1.2 percent contribution), technetium-99 (8.9×10^{-4}; 92 percent contribution), and tritium (6.3×10^{-5}; 6.4 percent contribution).

As shown in Table H-8, the HI is 669, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 663; 99 percent contribution).

H5.3.7 Well 299-E33-20

As shown in Table H-8, the total cumulative ELCR is 3.4×10^{-4}. The total ELCR for radiological analytes is 3.4×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.0×10^{-5}; 3.0 percent contribution), technetium-99 (3.1×10^{-4}; 91 percent contribution), and tritium (1.9×10^{-5}; 5.6 percent contribution).

As shown in Table H-8, the HI is 96, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 90; 94 percent contribution) and nitrate (HQ = 3.8; 4.0 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

H5.3.8 Well 299-E33-38

As shown in Table H-8, the total cumulative ELCR is 1.7×10^{-3}. The total ELCR for radiological analytes is 1.7×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (1.6×10^{-3}; 93 percent contribution) and tritium (8.8×10^{-5}; 5.1 percent contribution).

As shown in Table H-8, the HI is 631, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 619; 98 percent contribution).

H5.3.9 Well 299-E33-42

As shown in Table H-8, the total cumulative ELCR is 6.0×10^{-4}. The total ELCR for nonradiological analytes is 2.4×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.6×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are n-nitrosodi-n-dipropylamine (2.4×10^{-4}; 40 percent contribution), iodine-129 (1.2×10^{-5}; 2.0 percent contribution), technetium-99 (3.2×10^{-4}; 53 percent contribution), and tritium (3.2×10^{-5}; 5.3 percent contribution).

As discussed in Section 4.5.1.2 in Chapter 4 of the main text, n-nitrosodi-n-dipropylamine was detected in Well 299-E33-42 at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 0.013 µg/L. n-Nitrosodi-n-dipropylamine is not associated with a trend at this well. It was analyzed five times over the past 10 years; it was detected once, and it was reported as nondetected in four samples. Figure H-24 provides a times-series chart showing n-nitrosodi-n-dipropylamine concentrations over the past 10 years (if available) at Well 299-E33-42. The presence of n-nitrosodi-n-dipropylamine is determined to be associated with data quality issues and is not the result of a site release. Therefore, n-nitrosodi-n-dipropylamine is not considered a contributor to cancer risk.

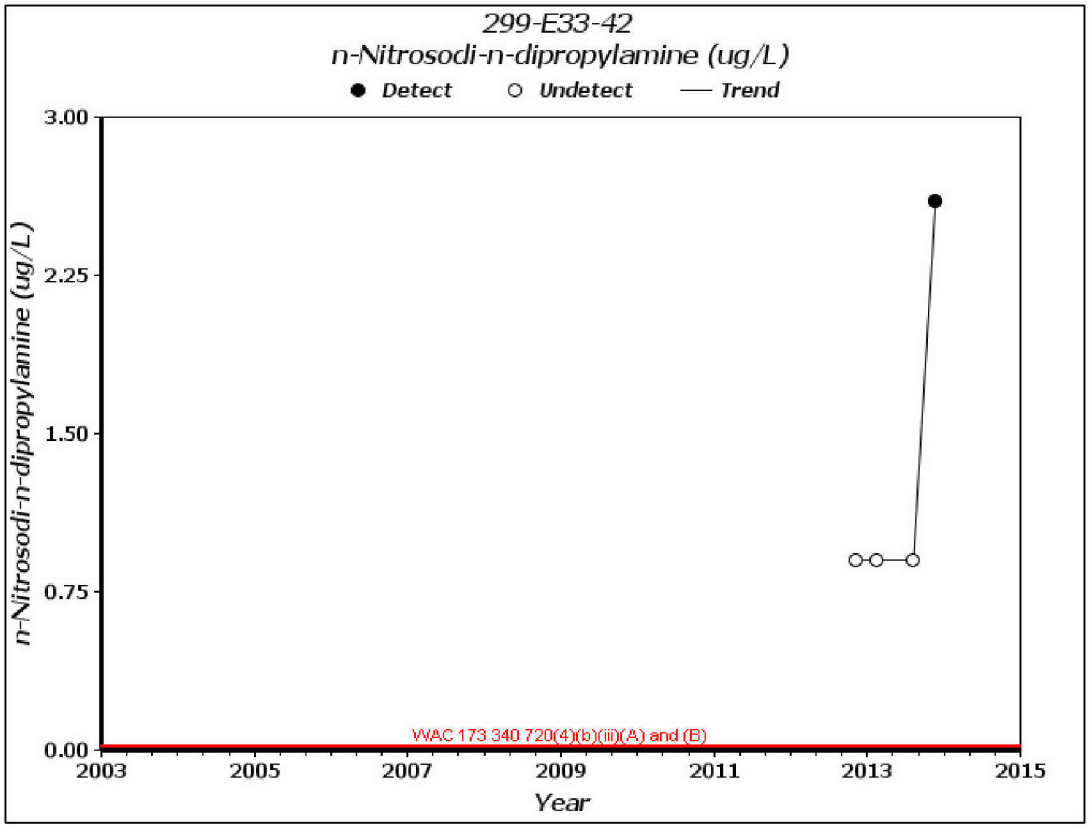

Figure H-24. n-Nitrosodi-n-dipropylamine Concentrations in Well 299-E33-42

As shown in Table H-8, the HI is 61, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 55; 90 percent contribution), nitrate (HQ = 2.1; 3.5 percent contribution), silver (HQ = 0.6; 1.1 percent contribution), and uranium (HQ = 2.6; 4.3 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

H5.3.10 Well 299-E33-44

As shown in Table H-8, the total cumulative ELCR is 1.2×10^{-3}. The total ELCR for nonradiological analytes is 1.5×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.0×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are arsenic (1.5×10^{-4}; 13 percent contribution), technetium-99 (9.2×10^{-4}; 79 percent contribution), and tritium (7.5×10^{-5}; 6.4 percent contribution). Contribution to ELCR is elevated for arsenic where measured concentrations for unfiltered samples range between 0.8 µg/L and 10.8 µg/L. The total cumulative ELCR is 1.0×10^{-3} without contribution from arsenic. Figure H-25 provides a times-series chart showing unfiltered and filtered arsenic concentrations over the past 10 years (if available) at Well 299-E33-44.

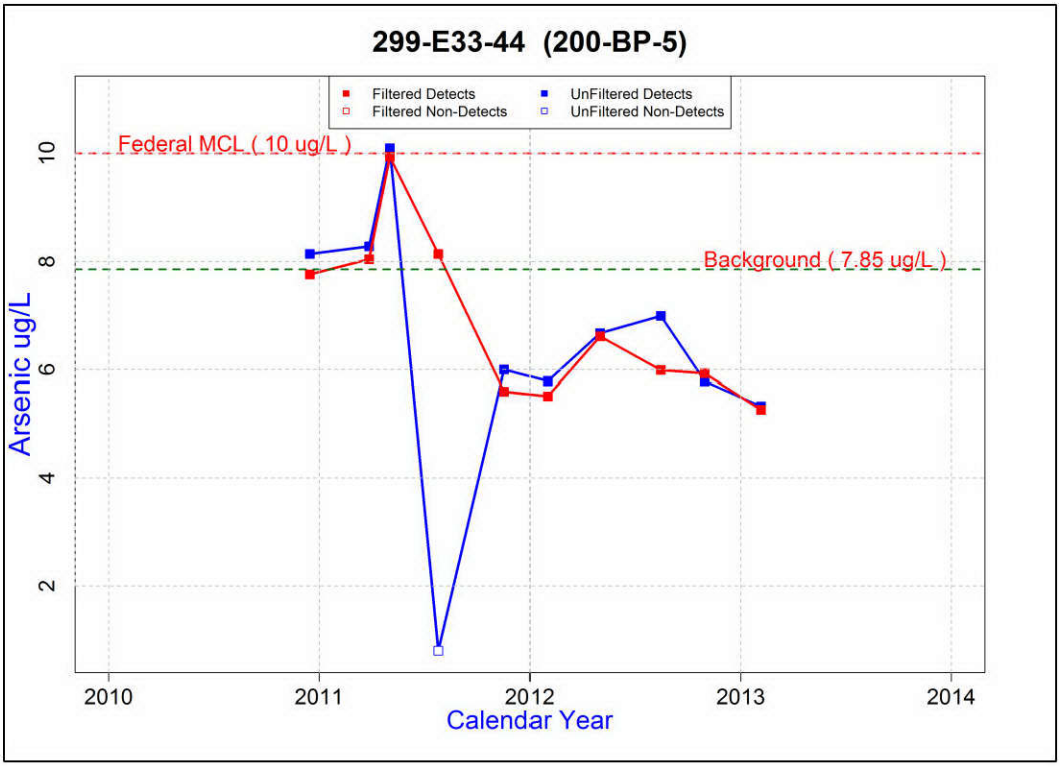

Figure H-25. Unfiltered and Filtered Arsenic Concentrations for Well 299-E33-44 (WMA B-BX-BY Tank Farms Exposure Area)

As shown in Table H-8, the HI is 370, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 359; 97 percent contribution), nitrate (HQ = 4.1; 1.1 percent contribution), and uranium (HQ = 3.7; 1.0 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide, nitrate, and uranium each report an HI greater than 1.

H5.3.11 Well 299-E33-47

As shown in Table H-8, the total cumulative ELCR is 1.9×10^{-3}. The total ELCR for nonradiological analytes is 4.3×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.4×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are methyl methanesulfonate (4.3×10^{-4}; 23 percent contribution), technetium-99 (1.4×10^{-3}; 73 percent contribution), and tritium (4.4×10^{-5}; 2.3 percent contribution).

As discussed in Chapter 4 (Section 4.5.1.2 in the main text), methyl methanesulfonate was detected in Well 299-E33-47 at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 0.013 µg/L. Methyl methanesulfonate is not associated with a trend at this well. It was analyzed 6 times over the past 10 years; a parent and field duplicate were collected on February 7, 2013; one sample was reported as nondetected, and the second sample was reported at a concentration of 340 µg/L. The remaining five sample results were all reported as nondetected. Figure H-26 provides a times-series chart showing methyl methanesulfonate concentrations over the past 10 years (if available) at

Well 299-E33-47. The presence of methyl methanesulfonate is determined to be associated with data quality and is not the result of a site release. Therefore, methyl methanesulfonate is not considered a contributor to cancer risk.

As shown in Table H-8, the HI is 335, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 328; 98 percent contribution) and nitrate (HQ = 5.0; 1.5 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

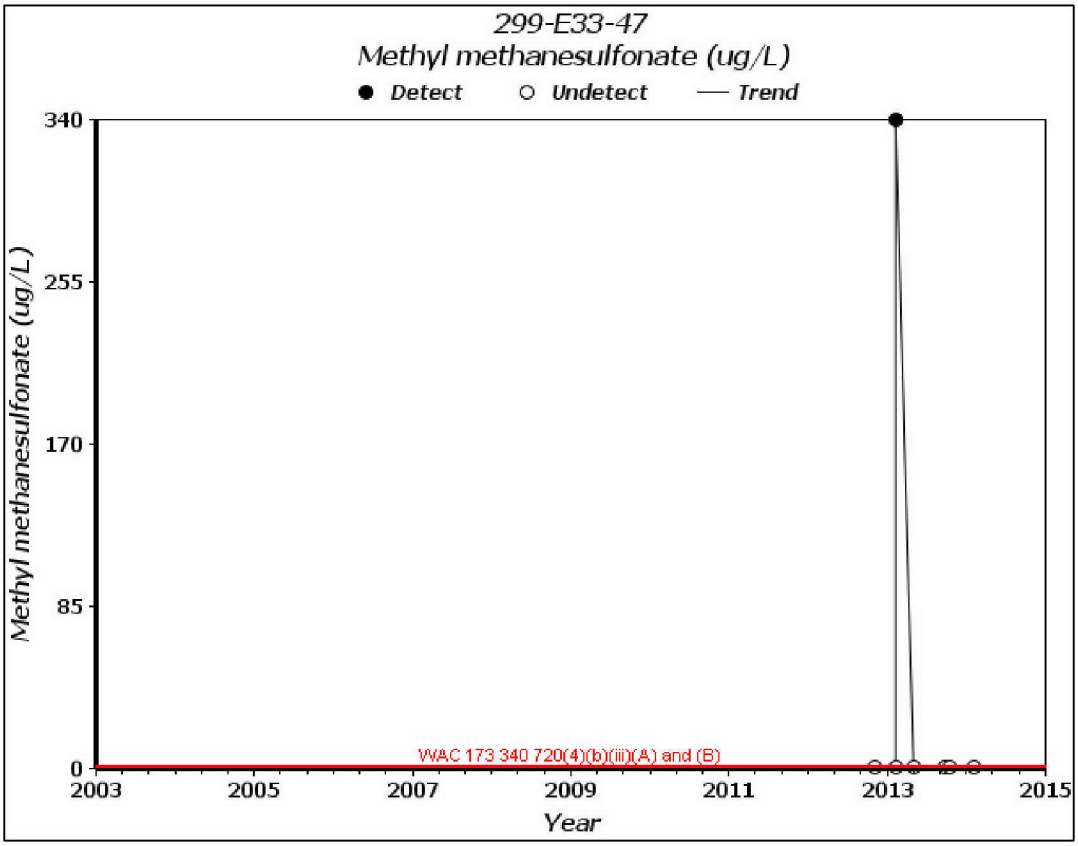

Figure H-26. Methyl Methanesulfonate Concentrations in Well 299-E33-47

H5.3.12 Well 299-E33-48

As shown in Table H-8, the total cumulative ELCR is 1.4×10^{-4}. The total ELCR for radiological analytes is 1.4×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.1×10^{-5}; 7.4 percent contribution), technetium-99 (7.9×10^{-5}; 56 percent contribution), and tritium (5.2×10^{-5}; 37 percent contribution).

As shown in Table H-8, the HI is 31, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that

contribute greater than 1 percent of the total HI) are cyanide (HQ = 29; 93 percent contribution), nitrate (HQ = 0.9; 3.0 percent contribution), and uranium (HQ = 0.4; 1.3 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.3.13 Well 299-E33-205

As shown in Table H-8, the total cumulative ELCR is 4.8×10^{-4}. The total ELCR for radiological analytes is 4.8×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.2×10^{-5}; 2.6 percent contribution), technetium-99 (4.4×10^{-4}; 91 percent contribution), and tritium (2.7×10^{-5}; 5.6 percent contribution).

As shown in Table H-8, the HI is 43, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 33; 76 percent contribution), nitrate (HQ = 1.7; 3.9 percent contribution), and uranium (HQ = 8.0; 18 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide, nitrate, and uranium each report an HI greater than 1.

H5.3.14 Well 299-E33-334

As shown in Table H-8, the total cumulative ELCR is 4.4×10^{-4}. The total ELCR for nonradiological analytes is 3.2×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.2×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are n-nitrosodi-n-propylamine (3.2×10^{-4}; 73 percent contribution), iodine-129 (1.1×10^{-5}; 2.4 percent contribution), technetium-99 (5.8×10^{-5}; 13 percent contribution), and tritium (5.1×10^{-5}; 12 percent contribution).

As discussed in Chapter 4 (Section 4.5.1.2 in the main text), n-nitrosodi-n-dipropylamine was detected in Well 299-E33-334 at a concentration greater than the 2007 MTCA (WAC 173-340-720) level of 0.013 µg/L. n-Nitrosodi-n-dipropylamine is not associated with a trend at this well. It was analyzed 6 times over the past 10 years; it was detected once, and it was reported as nondetected in five samples. Figure H-27 provides a times-series chart showing n-nitrosodi-n-dipropylamine concentrations over the past 10 years (if available) at Well 299-E33-334. The presence of n-nitrosodi-n-dipropylamine is determined to be associated with data quality issues and is not the result of a site release. Therefore, n-nitrosodi-n-dipropylamine is not considered a contributor to cancer risk.

As shown in Table H-8, the HI is 27, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 25; 95 percent contribution), nitrate (HQ = 0.5; 1.8 percent contribution), and uranium (HQ = 0.3; 1.2 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

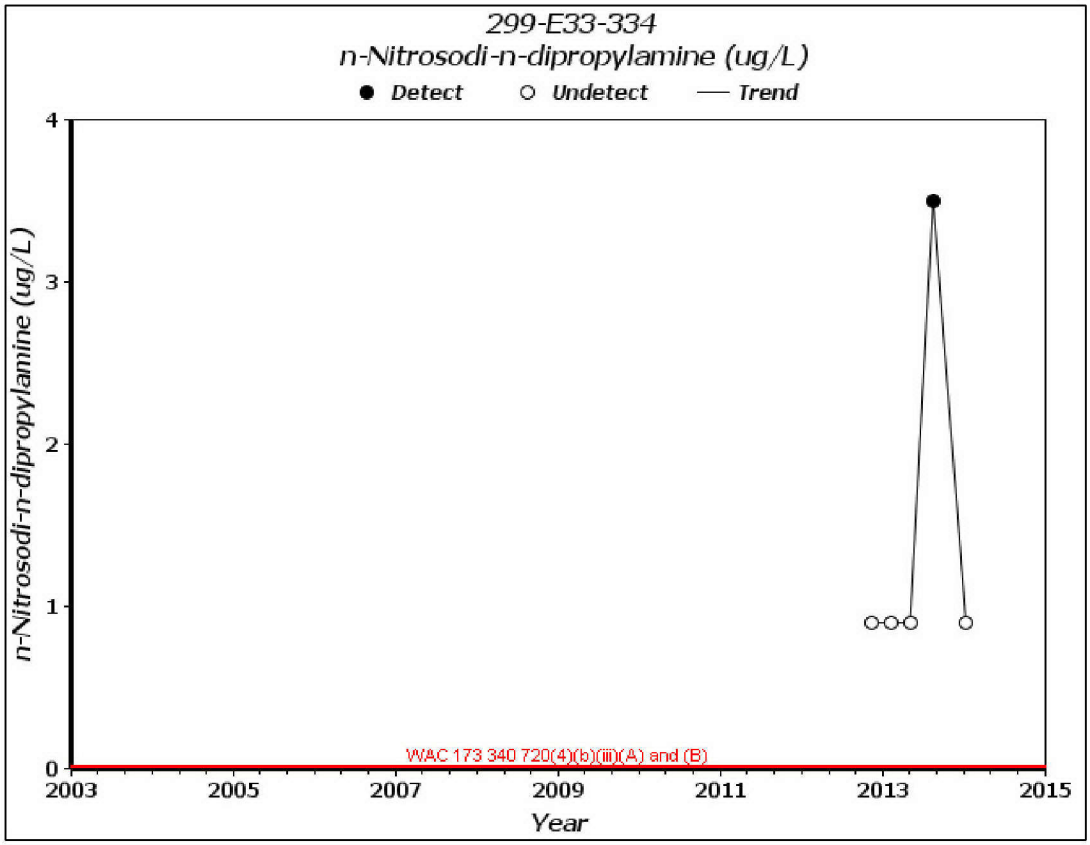

Figure H-27. n-Nitrosodi-n-Dipropylamine Concentrations in Well 299-E33-334

H5.3.15 Well 299-E33-337

As shown in Table H-8, the total cumulative ELCR is 2.5×10^{-4}. The total ELCR for radiological analytes is 2.5×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (7.5×10^{-6}; 3.0 percent contribution), technetium-99 (1.9×10^{-4}; 77 percent contribution), and tritium (5.0×10^{-5}; 20 percent contribution).

As shown in Table H-8, the HI is 114, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 106; 93 percent contribution), nickel (HQ = 2.7; 2.3 percent contribution), cobalt (HQ = 2.2; 1.9 percent contribution), and nitrate (HQ = 1.4; 1.2 percent contribution).

As discussed in Chapter 4 (Sections 4.4.16 and 4.5.1.2 in the main text), the presence of nickel, iron, cobalt, and chromium was determined to be associated with casing corrosion based on television surveys and sample results of amorphous material from the well screen. Nickel, iron, cobalt, and chromium are not the result of discharge and are not considered contributors to cumulative noncancer effects.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

H5.3.16 Well 299-E33-338

As shown in Table H-8, the total cumulative ELCR is 1.9×10^{-4}. The total ELCR for radiological analytes is 1.9×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.3×10^{-5}; 7.0 percent contribution), strontium-90 (4.9×10^{-6}; 2.6 percent contribution), technetium-99 (1.5×10^{-4}; 78 percent contribution), and tritium (2.5×10^{-5}; 13 percent contribution).

As shown in Table H-8, the HI is 59, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 57; 96 percent contribution) and nitrate (HQ = 0.9; 1.5 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.3.17 Well 299-E33-339

As shown in Table H-8, the total cumulative ELCR is 2.2×10^{-4}. The total ELCR for radiological analytes is 2.2×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.2×10^{-5}; 5.3 percent contribution), technetium-99 (1.6×10^{-4}; 72 percent contribution), and tritium (4.8×10^{-5}; 22 percent contribution).

As shown in Table H-8, the HI is 50, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cobalt (HQ = 1.3; 2.6 percent contribution), cyanide (HQ = 45; 90 percent contribution), nitrate (HQ = 0.9; 1.7 percent contribution) and uranium (HQ = 2.0; 3.9 percent contribution.

As discussed in Chapter 4 (Sections 4.4.16 and 4.5.1.2 in the main text), the presence of nickel, iron, cobalt, and chromium was determined to be associated with casing corrosion based on television surveys and sample results of amorphous material from the well screen. Nickel, iron, cobalt, and chromium are not the result of discharge and are not considered contributors to cumulative noncancer effects.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and uranium each report an HI greater than 1.

H5.3.18 Well 299-E33-341

As shown in Table H-8, the total cumulative ELCR is 1.5×10^{-3}. The total ELCR for nonradiological analytes is 8.5×10^{-6}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.5×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cobalt-60 (1.6×10^{-5}; 1.1 percent contribution), technetium-99 (1.4×10^{-3}; 92 percent contribution), and tritium (7.5×10^{-5}; 4.9 percent contribution).

As shown in Table H-8, the HI is 719, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 710; 99 percent contribution).

H5.3.19 Well 299-E33-342

As shown in Table H-8, the total cumulative ELCR is 1.5×10^{-3}. The total ELCR for nonradiological analytes is 2.0×10^{-5}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.4×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (1.3×10^{-3}; 88 percent contribution) and tritium (1.2×10^{-4}; 8.3 percent contribution).

As shown in Table H-8, the HI is 564, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 551; 98 percent contribution) and uranium (HQ = 6.1; 1.1) percent contribution.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and uranium each report an HI greater than 1.

H5.3.20 Well 299-E33-343

As shown in Table H-8, the total cumulative ELCR is 2.5×10^{-3}. The total ELCR for nonradiological analytes is 1.2×10^{-5}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.5×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (8.1×10^{-4}; 33 percent contribution), tritium (5.8×10^{-5}; 2.4 percent contribution), uranium-234 (8.1×10^{-4}; 33 percent contribution), uranium-235 (3.6×10^{-5}; 1.5 percent contribution), and uranium-238 (7.2×10^{-4}; 29 percent contribution).

As shown in Table H-8, the HI is 45, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are uranium (HQ = 38; 84 percent contribution), cyanide (HQ = 4.9; 11 percent contribution), and nitrate (HQ = 1.3; 2.9 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide, nitrate, and uranium each report an HI greater than 1.

H5.3.21 Well 299-E33-345

As shown in Table H-8, the total cumulative ELCR is 1.1×10^{-3}. The total ELCR for nonradiological analytes is 9.0×10^{-7}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 1.1×10^{-3}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.5×10^{-5}; 1.4 percent contribution), technetium-99 (9.9×10^{-4}; 92 percent contribution), and tritium (6.2×10^{-5}; 5.8 percent contribution).

As shown in Table H-8, the HI is 8.8, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are uranium (HQ = 3.6; 41 percent contribution), nitrate (HQ = 1.5; 17 percent contribution), cyanide (HQ = 1.4; 16 percent contribution), Cr(VI)

(HQ = 1.1; 12 percent contribution), nitrite (HQ = 0.5; 5.1 percent contribution), silver (HQ = 0.3; 3.8 percent contribution), manganese (HQ = 0.1; 1.5 percent contribution), and fluoride (HQ = 0.1; 1.5 percent contribution).

The critical effect for each analyte is listed in Table H-14. With the exception of nitrate and nitrite, exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Exposure to nitrate and nitrite both result in blood effects; summing the HQs for nitrate and nitrite result in an HI of 2. Cyanide, nitrate and nitrite, Cr(VI), and uranium each report an HI greater than 1.

H5.4 Results for Wells Included in the Waste Management Area C Tank Farm Exposure Area

Table H-9 provides a summary of the cancer risk and noncancer hazards for each of the four wells selected for well-specific evaluation within the WMA C Tank Farm exposure area. Figures H-28 and H-29 show the primary cancer risk and noncancer hazard contributors for wells within the WMA C Tank Farm exposure area, respectively. Figure H-4 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the WMA C Tank Farm exposure area.

H5.4.1 Well 299-E27-7

As shown in Table H-9, the total cumulative ELCR is 2.6×10^{-5}. The total ELCR for radiological analytes is 2.6×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.7×10^{-5}; 66 percent contribution), technetium-99 (4.3×10^{-6}; 16 percent contribution), and tritium (4.6×10^{-6}; 17 percent contribution).

As shown in Table H-9, the HI is 14, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 14; 95 percent contribution) and nitrate (HQ = 0.2; 1.1 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.4.2 Well 299-E27-14

As shown in Table H-9, the total cumulative ELCR is 6.2×10^{-4}. The total ELCR for nonradiological analytes is 3.2×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 3.0×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are arsenic (3.2×10^{-4}; 51 percent contribution), iodine-129 (1.3×10^{-5}; 2.1 percent contribution), and technetium-99 (2.8×10^{-4}; 46 percent contribution). Contribution to ELCR is elevated for arsenic where measured concentrations for unfiltered samples range between 5.5 µg/L and 16.3 µg/L. The total cumulative ELCR is 3.0×10^{-4} without contribution from arsenic. Figure H-30 provides a times-series chart showing unfiltered and filtered arsenic concentrations over the past 10 years (if available) at Well 299-E27-14.

As shown in Table H-9, the HI is 13, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that

contribute greater than 1 percent of the total HI) are arsenic (HQ = 1.6; 13 percent contribution), copper (HQ = 0.7; 5.7 percent contribution), cyanide (HQ = 9.6; 74 percent contribution), and nitrate (HQ = 0.4; 3.0 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Arsenic and cyanide each report an HI greater than 1.

H5.4.3 Well 299-E27-15

As shown in Table H-9, the total cumulative ELCR is 2.5×10^{-4}. The total ELCR for nonradiological analytes is 2.3×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.7×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are arsenic (2.3×10^{-4}; 89 percent contribution), iodine-129 (1.6×10^{-5}; 6.3 percent contribution), technetium-99 (4.2×10^{-6}; 1.7 percent contribution), and tritium (6.6×10^{-6}; 2.6 percent contribution). Contribution to ELCR is elevated for arsenic where measured concentrations for unfiltered samples range between 5.8 µg/L and 11.7 µg/L. The total cumulative ELCR is 2.8×10^{-5} without contribution from arsenic. Figure H-31 is a times-series chart showing unfiltered and filtered arsenic concentrations over the past 10 years (if available) at Well 299-E27-15.

As shown in Table H-9, the HI is 1.9, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are arsenic (HQ = 1.2; 62 percent contribution), selenium (HQ = 0.1; 5.3 percent contribution), uranium (HQ = 0.1; 6.1 percent contribution) and vanadium (HQ = 0.1; 6.8 percent contribution); the remaining analytes (fluoride, Cr(VI), nickel, and nitrate) report an HQ less than 0.1.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Arsenic is the only analyte in this well that reports an HI greater than 1.

H5.4.4 Well 299-E27-155

As shown in Table H-9, the total cumulative ELCR is 4.5×10^{-4}. The total ELCR for nonradiological analytes is 9.9×10^{-5}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 4.5×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.2×10^{-5}; 2.7 percent contribution), technetium-99 (4.3×10^{-4}; 94 percent contribution), and tritium (8.7×10^{-6}; 1.9 percent contribution).

As shown in Table H-9, the HI is 5.4, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 4.5; 83 percent contribution), nitrate (HQ = 0.2; 4.0 percent contribution), vanadium (HQ = 0.1; 2.4 percent contribution), and Cr(VI) (HQ = 0.1; 2.0 percent contribution); the remaining analytes (fluoride, selenium, and uranium) report an HQ less than 0.1.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

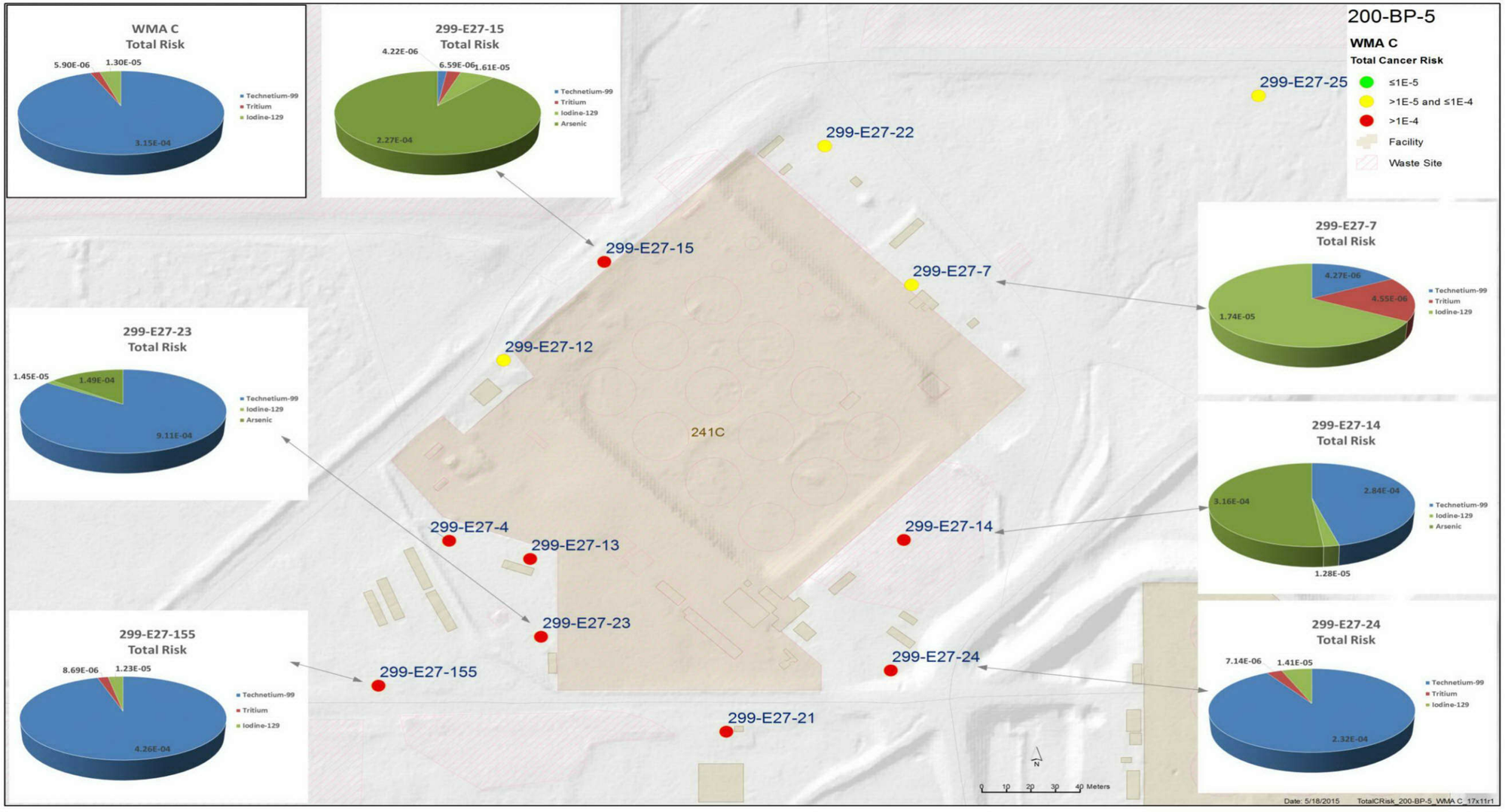

Figure H-28. Cancer Risk Contributors for Wells within the WMA C Tank Farm Exposure Area

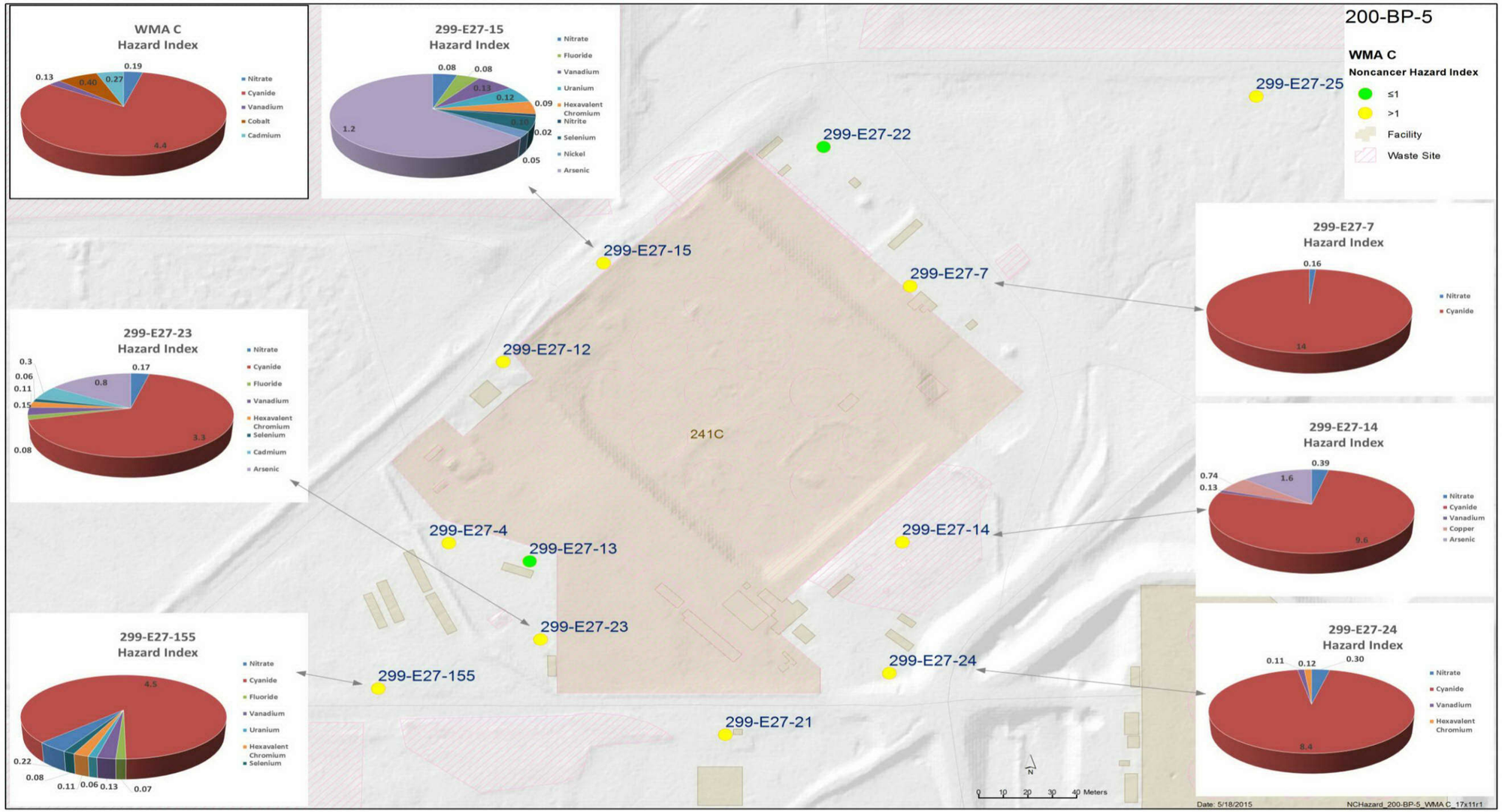

Figure H-29. Noncancer Hazard Contributors for Wells within the WMA C Tank Farm Exposure Area

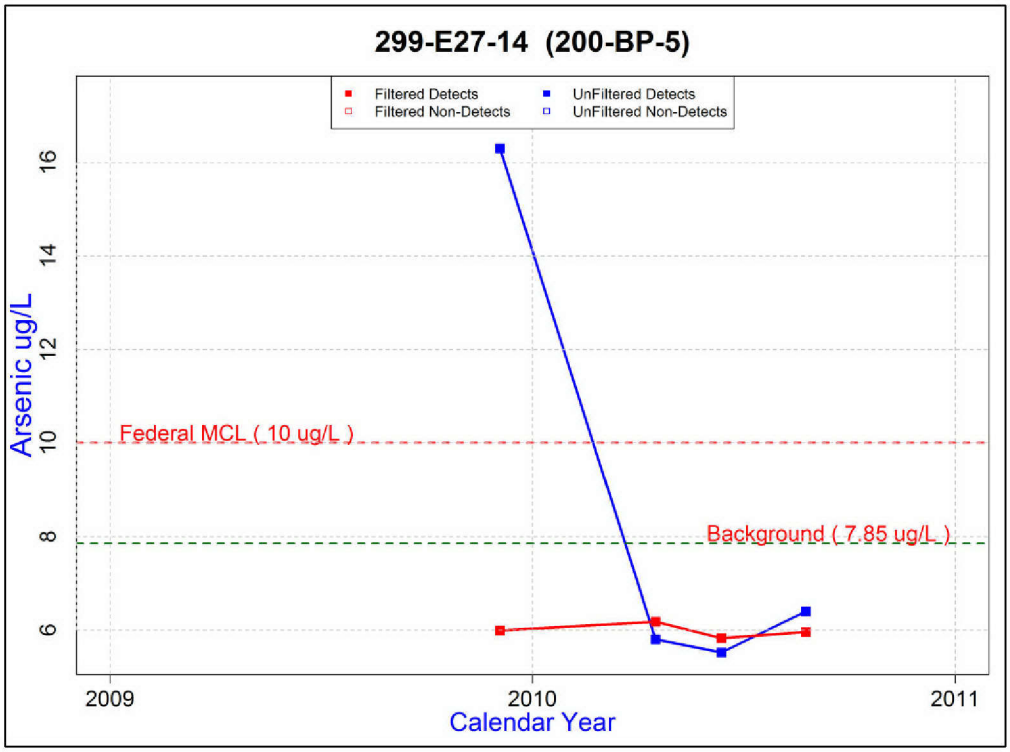

Figure H-30. Unfiltered and Filtered Arsenic Concentrations for Well 299-E27-14 (WMA C Tank Farm Exposure Area)

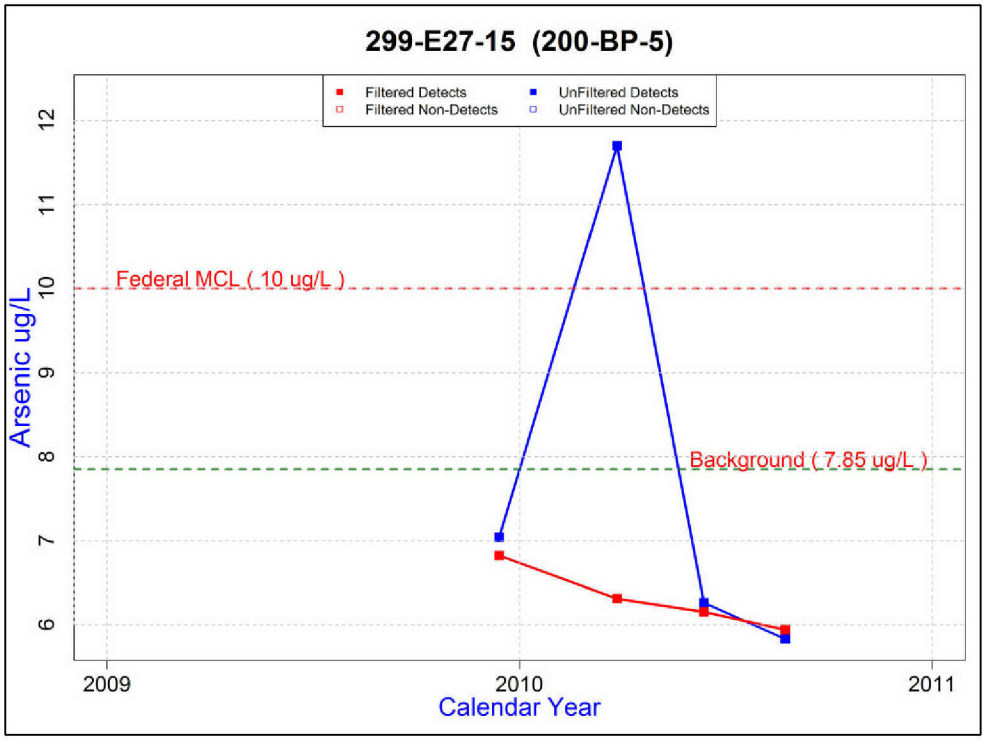

Figure H-31. Unfiltered and Filtered Arsenic Concentrations for Well 299-E27-15 (WMA C Tank Farm Exposure Area)

H5.5 Results for Wells Included in the B Plant Exposure Area

Table H-10 provides a summary of the cancer risk and noncancer hazards for each of the three wells selected for well-specific evaluation within the B Plant exposure area. Figures H-32 and H-33 show in the primary cancer risk and noncancer hazard contributors for wells within the exposure area, respectively. Figure H-5 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the B Plant exposure area.

H5.5.1 Well 299-E28-23

As shown in Table H-10, the total cumulative ELCR is 6.9×10^{-3}. The total ELCR for radiological analytes is 6.9×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cesium-137 (1.4×10^{-3}; 21 percent contribution), plutonium-239/240 (1.3×10^{-4}; 2.0 percent contribution), and strontium-90 (5.2×10^{-3}; 76 percent contribution).

As shown in Table H-10, the HI is 0.73, which is less than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1.

H5.5.2 Well 299-E28-24

As shown in Table H-10, the total cumulative ELCR is 1.2×10^{-3}. The total ELCR for radiological analytes is 1.2×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cesium-137 (5.2×10^{-5}; 4.4 percent contribution), strontium-90 (7.3×10^{-4}; 63 percent contribution), technetium-99 (3.0×10^{-4}; 26 percent contribution), and tritium (4.2×10^{-5}; 3.6 percent contribution).

As shown in Table H-10, the HI is 3.7, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are fluoride (HQ = 1.6; 44 percent contribution), nitrate (HQ = 1.8; 48 percent contribution), and uranium (HQ = 0.3; 6.9 percent contribution).

As discussed in Chapter 4 (Sections 4.4.11 and 4.5.1.2 in the main text), fluoride was detected in Well 299-E28-24 at concentrations greater than the 2007 MTCA (WAC 173-340-720) level of 960 µg/L. Figure H-34 provides a times-series chart showing fluoride concentrations over the past 10 years (if available) at Well 299-E28-24. The presence of fluoride at Well 299-E28-24 may be the result of lanthanum fluoride waste discharges. Fluoride concentrations at this location remain elevated because the well screen may be within less permeable Ringold sediments, which have not yet established equilibrium conditions. Based on these results, fluoride is considered a contributor to cumulative noncancer effects.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Fluoride and nitrate each report an HI greater than 1.

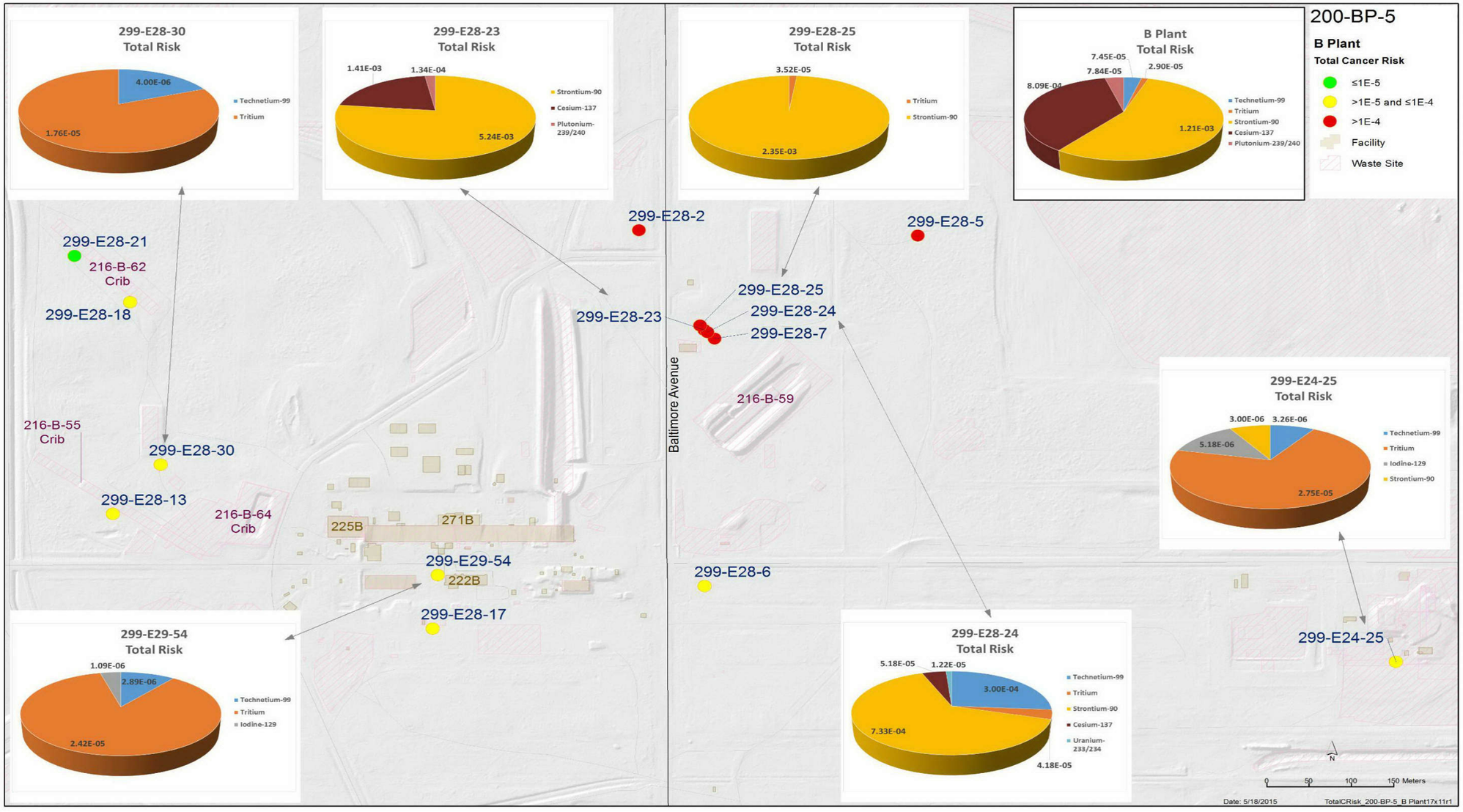

Figure H-32. Cancer Risk Contributors for Wells within the B Plant Exposure Area

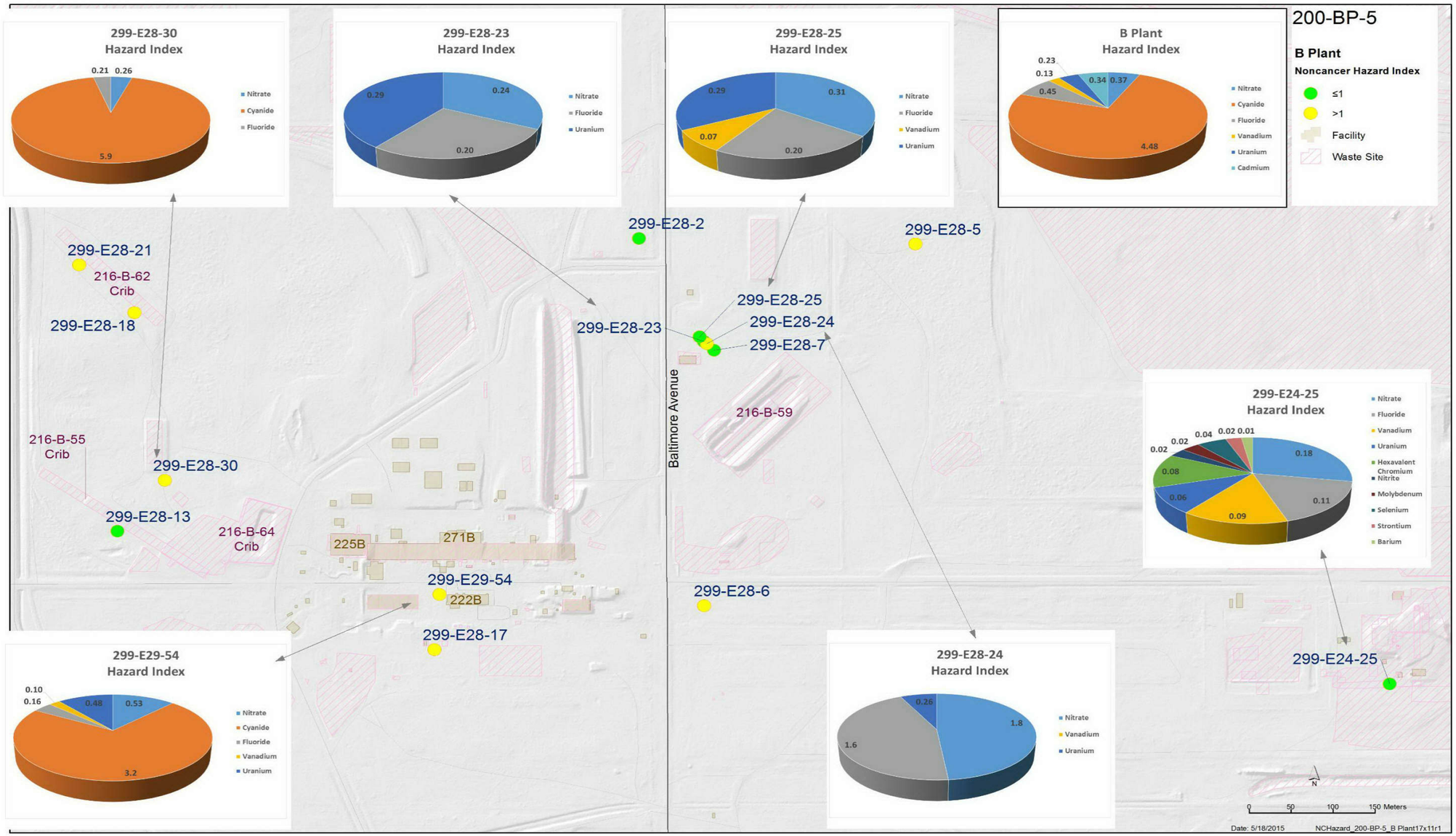

Figure H-33. Noncancer Hazard Contributors for Wells within the B Plant Exposure Area

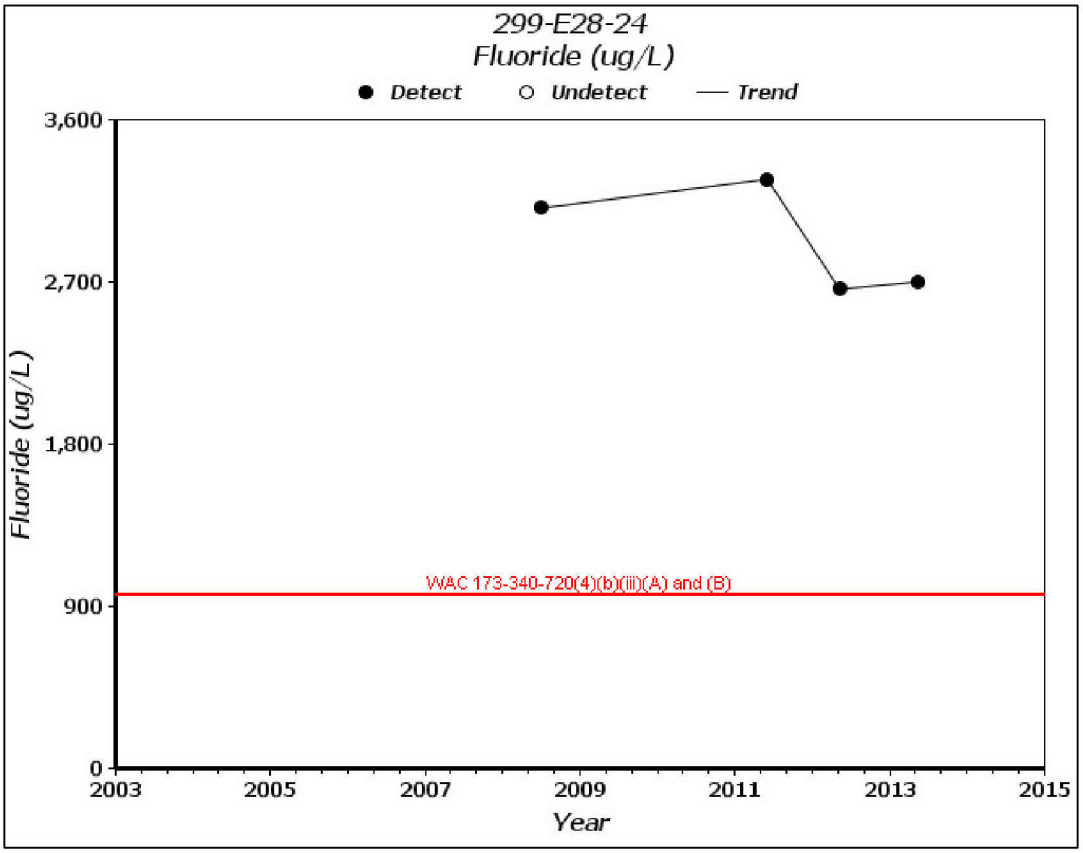

Figure H-34. Fluoride Concentrations in Well 299-E28-24

H5.5.3 Well 299-E28-25

As shown in Table H-10, the total cumulative ELCR is 2.5×10^{-3}. The total ELCR for radiological analytes is 2.5×10^{-3}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (2.4×10^{-3}; 96 percent contribution), and tritium (3.5×10^{-5}; 1.4 percent contribution).

As shown in Table H-10, the HI is 0.96, which is less than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1.

H5.6 Results for Wells Included in the 200-BP-5 West Exposure Area

Table H-11 provides a summary of the cancer risk and noncancer hazards for each of the eight wells selected for well-specific evaluation within the 200-BP-5 west exposure area. Figures H-35 and H-36 show the primary cancer risk contributors for wells within the 200-BP-5 west exposure area. Figures H-37 and H-38 show the primary noncancer hazard contributors for wells within the exposure area. Figure H-9 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the 200-BP-5 west exposure area.

H5.6.1 Well 699-49-57A

As shown in Table H-11, the total cumulative ELCR is 3.6×10^{-4}. The total ELCR for radiological analytes is 3.6×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (9.5×10^{-6}; 2.6 percent contribution), technetium-99 (2.8×10^{-4}; 78 percent contribution), and tritium (6.5×10^{-5}; 18 percent contribution).

As shown in Table H-11, the HI is 101, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 99; 98 percent contribution) and nitrate (HQ = 1.2; 1.2 percent contribution).

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide and nitrate each report an HI greater than 1.

H5.6.2 Well 699-50-56

As shown in Table H-11, the total cumulative ELCR is 2.6×10^{-4}. The total ELCR for nonradiological analytes is 1.4×10^{-6}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.6×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are strontium-90 (1.9×10^{-4}; 75 percent contribution), technetium-99 (5.7×10^{-5}; 22 percent contribution), and tritium (4.8×10^{-6}; 1.9 percent contribution).

As shown in Table H-11, the HI is 37, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cobalt (HQ = 1.1; 2.9 percent contribution) and cyanide (HQ = 35; 95 percent contribution).

As discussed in Chapter, Sections 4.4.16 and 4.5.1.2 in the main text, the presence of cobalt is not representative of aquifer conditions. Cobalt concentrations are isolated to this well and are detected intermittently. No source of cobalt near this well has been identified. Cobalt is not associated with a discharge and is not considered a contributor to the cumulative noncancer effects.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.6.3 Well 699-50-59

As shown in Table H-11, the total cumulative ELCR is 1.4×10^{-4}. The total ELCR for radiological analytes is 1.4×10^{-4}, which is less than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are iodine-129 (1.1×10^{-5}; 8.3 percent contribution), technetium-99 (8.2×10^{-5}; 60 percent contribution), and tritium (4.4×10^{-5}; 32 percent contribution).

As shown in Table H-11, the HI is 35, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 34; 97 percent contribution) and nitrate (HQ = 0.48; 1.4 percent contribution).

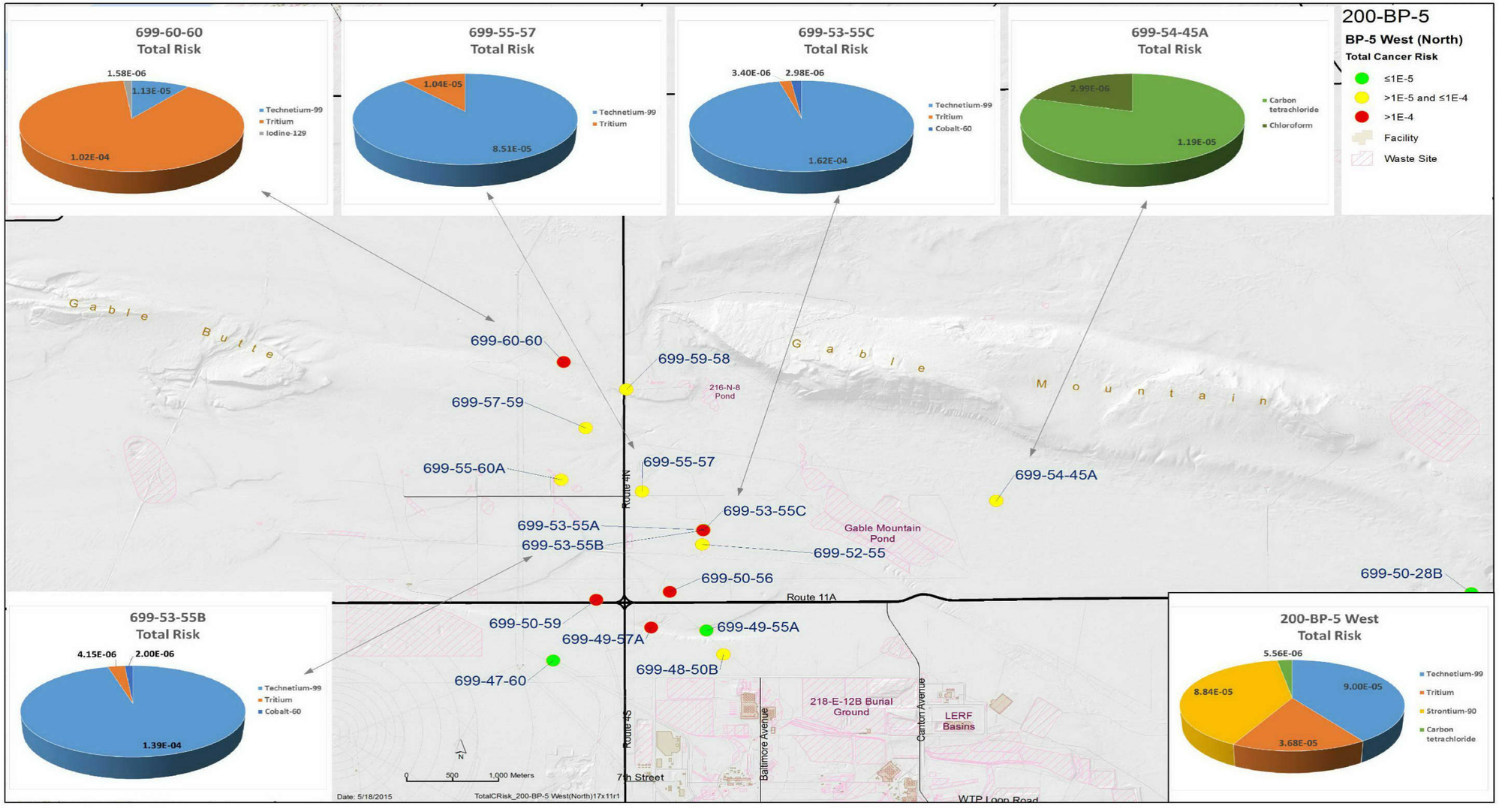

Figure H-35. Cancer Risk Contributors for Wells within the North Area of 200-BP-5 West Exposure Area

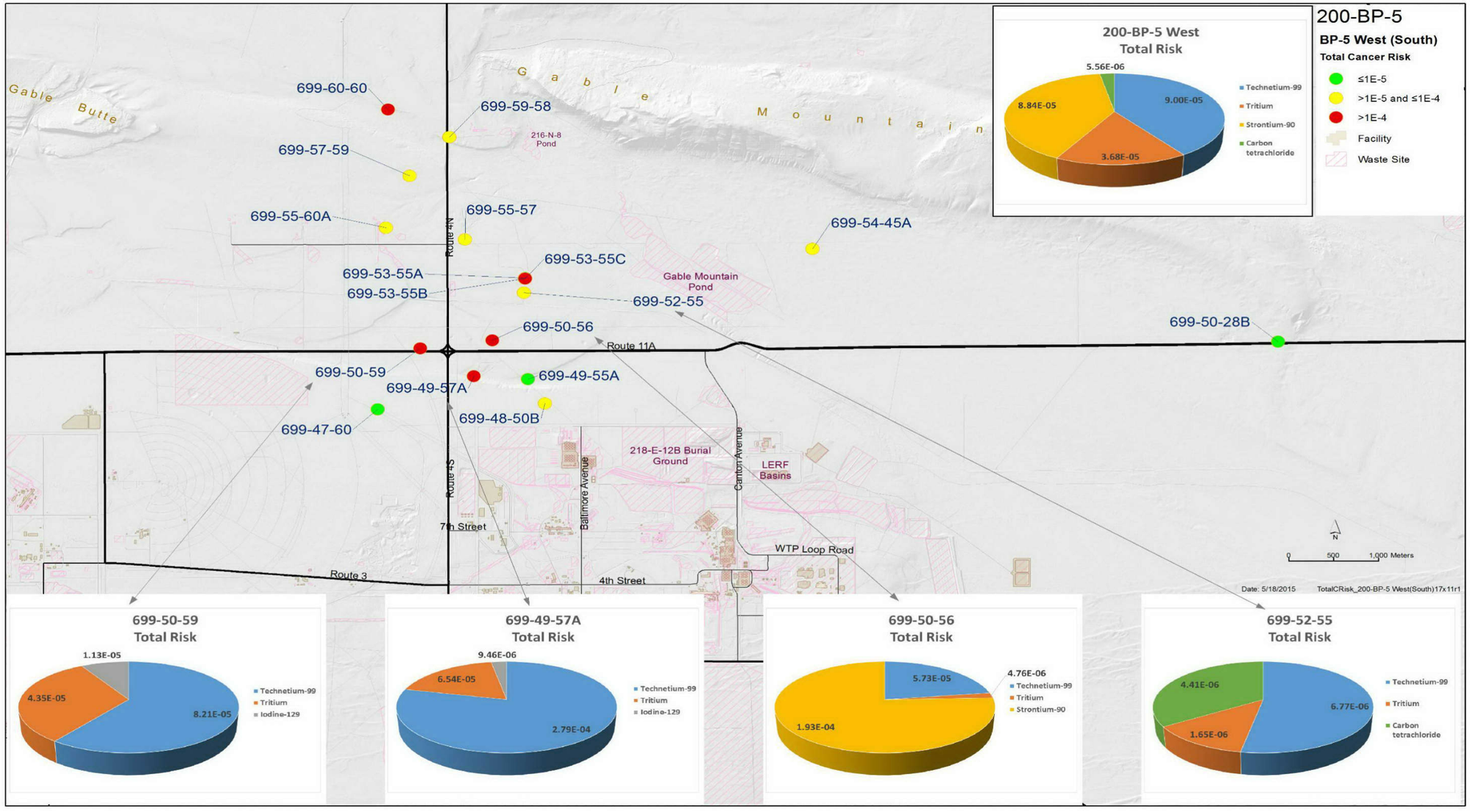

Figure H-36. Cancer Risk Contributors for Wells within the South Area of 200-BP-5 West Exposure Area

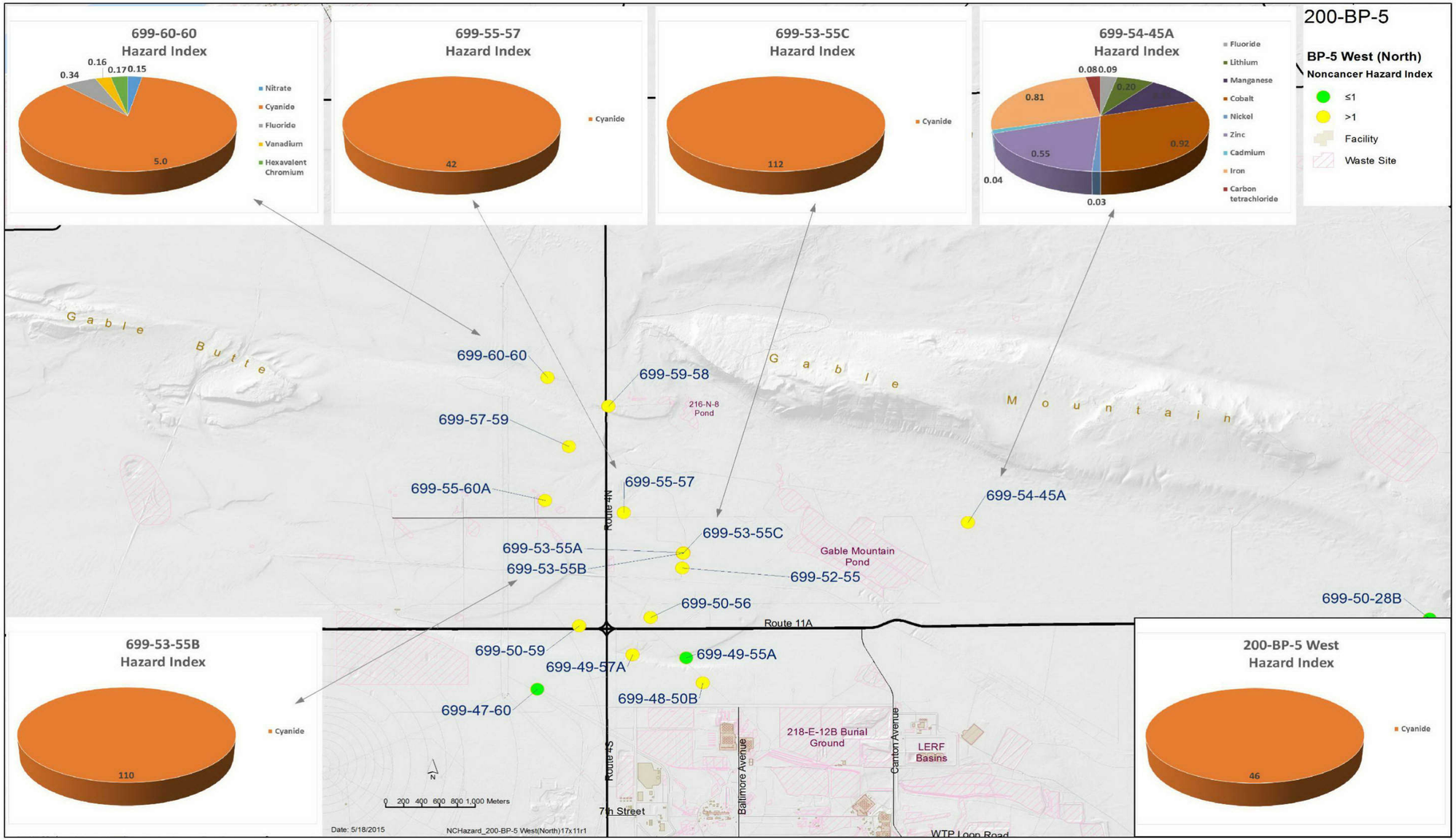

Figure H-37. Noncancer Hazard Contributors for Wells within the North Area of the 200-BP-5 West Exposure Area

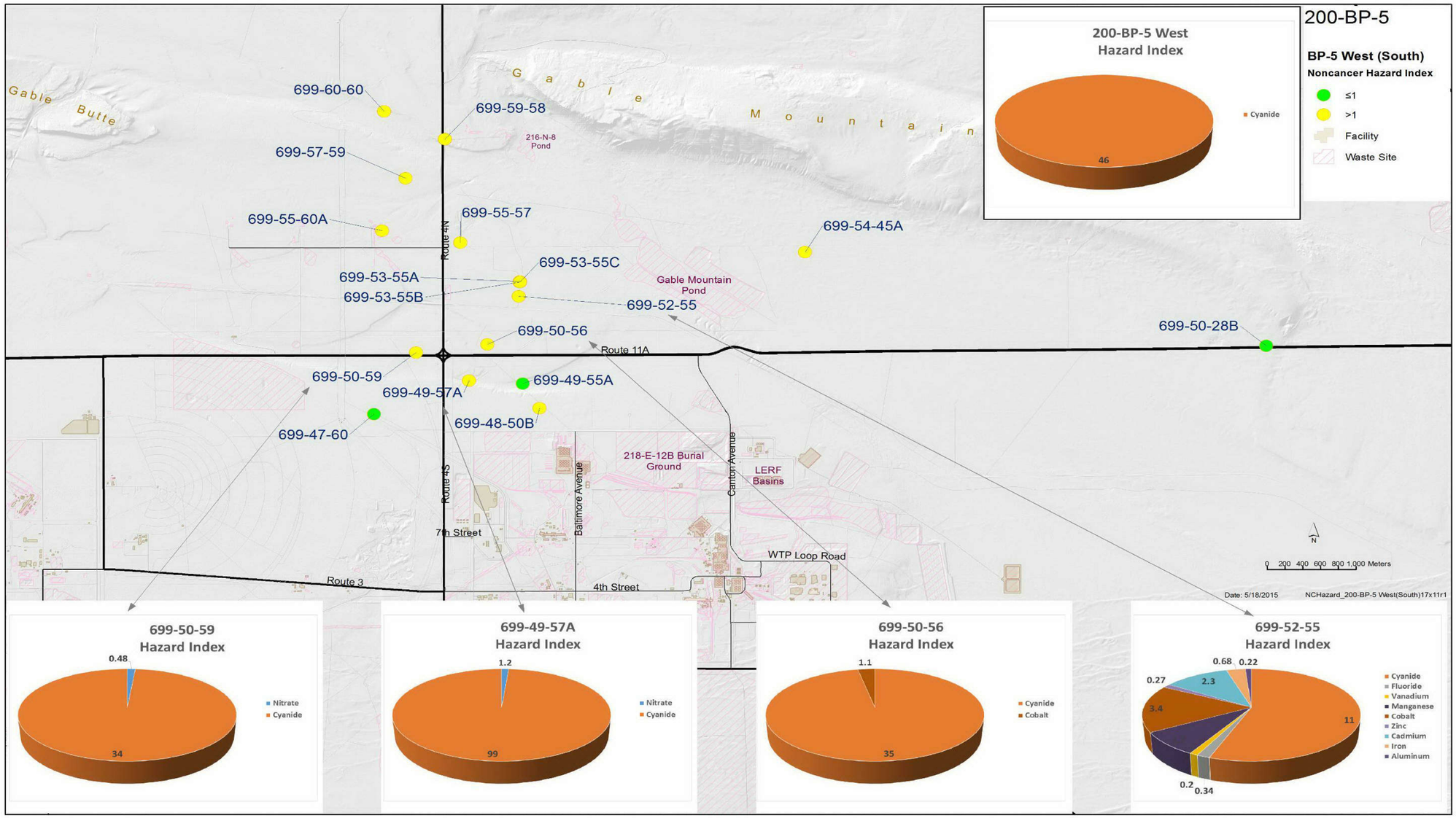

Figure H-38. Noncancer Hazard Contributors for Wells within the South Area of the 200-BP-5 West Exposure Area

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.6.4 Well 699-52-55

As shown in Table H-11, the total cumulative ELCR is 1.5×10^{-5}. The total ELCR for nonradiological analytes is 5.7×10^{-6}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 9.3×10^{-6}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are bis(2-ethylhexyl) phthalate (BEHP) (1.1×10^{-6}; 7.0 percent contribution), carbon tetrachloride (4.4×10^{-6}; 30 percent contribution), technetium-99 (6.8×10^{-6}; 45 percent contribution), and tritium (1.7×10^{-6}; 11 percent contribution).

As discussed in Chapter 4 (Section 4.5.1.2 in the main text), the single carbon tetrachloride concentration at Well 699-52-56 is not associated with a trend. Carbon tetrachloride was detected in one of four samples collected from Well 699-52-55 (2 µg/L); this result was flagged with a "J" laboratory qualifier, indicating that it is an estimated result. Figure H-39 provides a times-series chart showing carbon tetrachloride concentrations over the past 10 years (if available) at Well 699-52-55. All BEHP results (detected concentrations and method detection limits) are less than the DWS. Additionally, BEHP is a common laboratory contaminant that is introduced into the sample after it is collected in the field. Based on these results, carbon tetrachloride and BEHP are not associated with a release and are not considered contributors to the cumulative cancer effects.

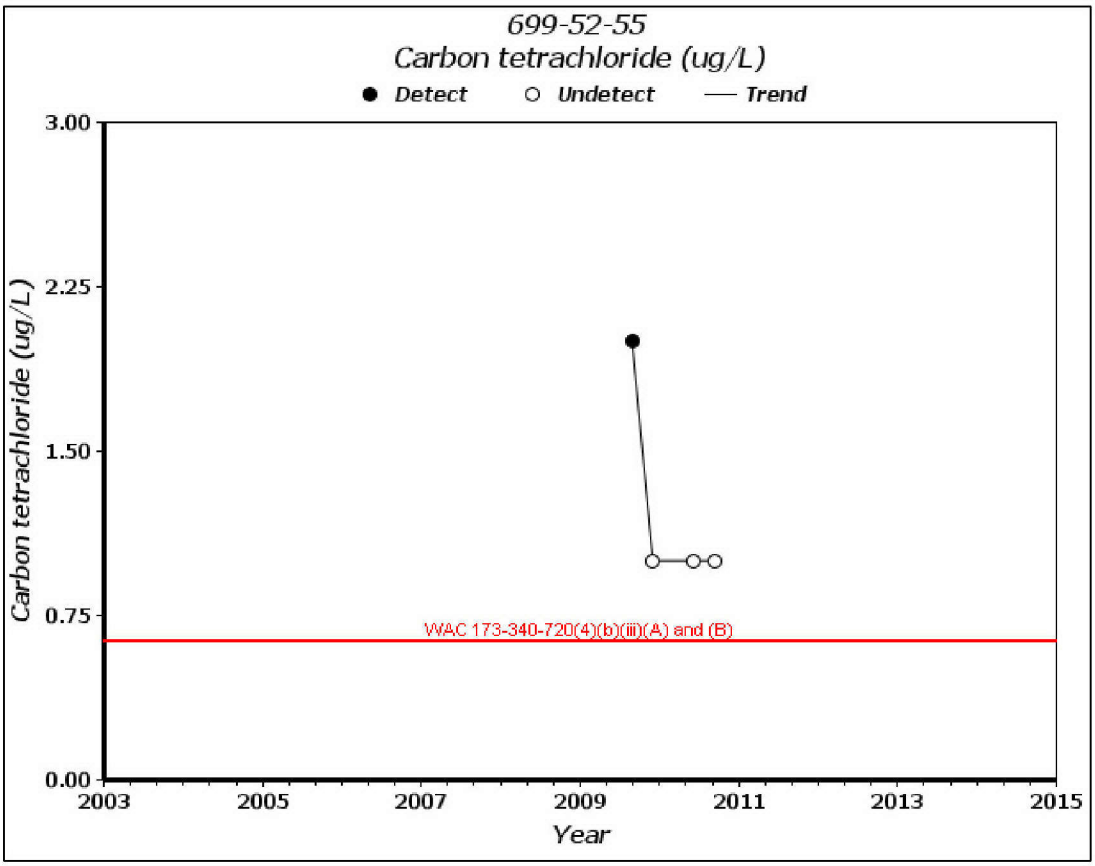

Figure H-39. Carbon Tetrachloride Concentrations in Well 699-52-55

As shown in Table H-11, the HI is 21, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cyanide (HQ = 11; 54 percent contribution), cobalt (HQ = 3.4; 16 percent contribution), cadmium (HQ = 2.3; 11 percent contribution), manganese (HQ = 1.7; 8.1 percent contribution), iron (HQ = 0.7; 3.2 percent contribution), fluoride (HQ = 0.3; 1.6 percent contribution), and zinc (HQ = 0.3; 1.3 percent contribution).

As discussed in Chapter 4 (Sections 4.4.16 and 4.5.1.2 in the main text), the presence of cadmium, cobalt, iron, and manganese was determined to be associated with the corrosion of the well casing. Although it has not been television surveyed, these constituents are also not considered representative of aquifer conditions. Cadmium, cobalt, iron, and manganese are not considered contributors to cumulative noncancer effects.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Cyanide is the only analyte in this well that reports an HI greater than 1.

H5.6.5 Well 699-53-55B

As shown in Table H-11, the total cumulative ELCR is 1.5×10^{-4}. The total ELCR for radiological analytes is 1.5×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cobalt-60 (2.0×10^{-6}; 1.4 percent contribution), technetium-99 (1.4×10^{-4}; 96 percent contribution), and tritium (4.2×10^{-6}; 2.9 percent contribution).

As shown in Table H-11, the HI is 111, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 110; 99 percent contribution).

H5.6.6 Well 699-53-55C

As shown in Table H-11, the total cumulative ELCR is 1.7×10^{-4}. The total ELCR for radiological analytes is 1.7×10^{-4}, which is greater than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are cobalt-60 (3.0×10^{-6}; 1.8 percent contribution), technetium-99 (1.6×10^{-4}; 96 percent contribution), and tritium (3.4×10^{-6}; 2.0 percent contribution).

As shown in Table H-11, the HI is 113, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 112; 99 percent contribution).

H5.6.7 Well 699-54-45A

As shown in Table H-11, the total cumulative ELCR is 1.5×10^{-5}. The total ELCR for nonradiological analytes is 1.5×10^{-5}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. There were no radiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are carbon tetrachloride (1.2×10^{-5}; 80 percent contribution) and chloroform (3.0×10^{-6}; 20 percent contribution).

As discussed in Chapter 4 (Section 4.5.1.2 in the main text), the single carbon tetrachloride concentration at Well 699-54-45A is not associated with a trend. Carbon tetrachloride was detected in one of three

samples collected from Well 699-54-45A (5.4 µg/L); this result was flagged with a "J" laboratory qualifier, indicating that it is an estimated result. Figure H-40 provides a times-series chart showing carbon tetrachloride concentrations over the past 10 years (if available) at Well 699-54-45A. Based on these results, carbon tetrachloride is not associated with a release and is not considered a contributor to the cumulative cancer effects.

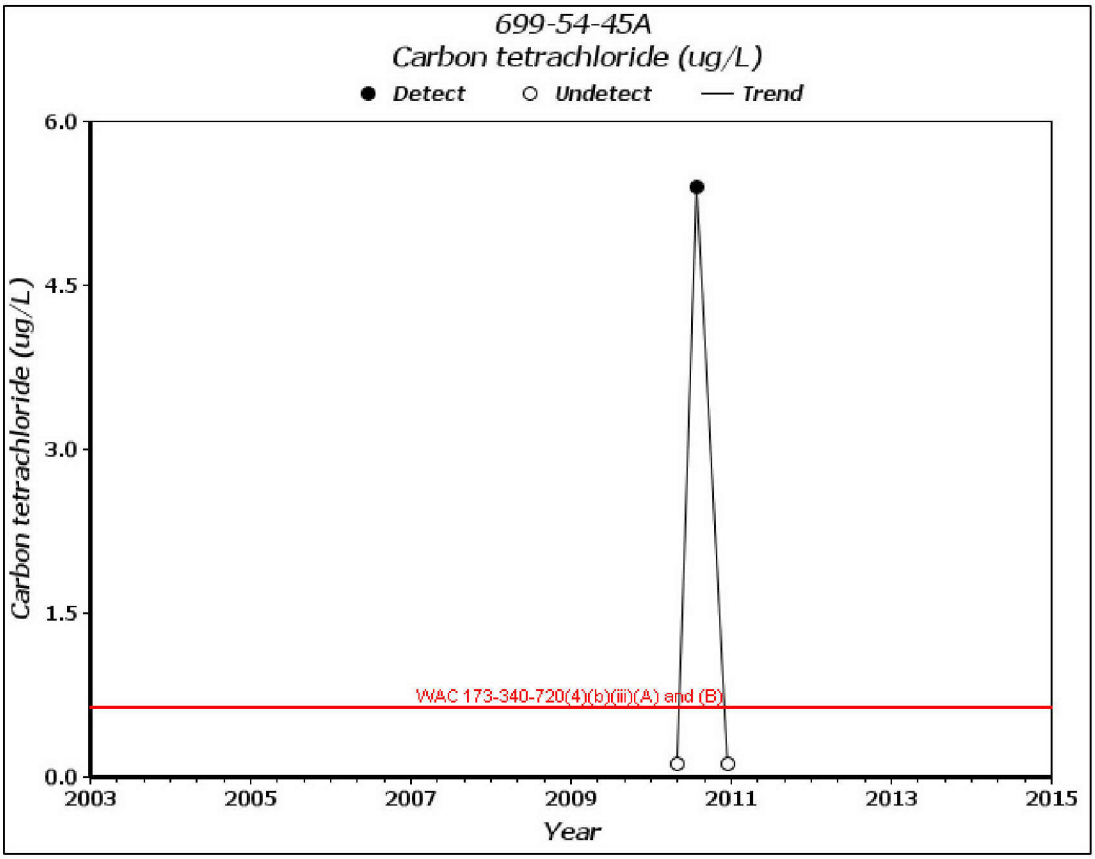

Figure H-40. Carbon Tetrachloride Concentrations in Well 699-54-45A

As shown in Table H-11, the HI is 3.1, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are cobalt (HQ = 0.9; 29 percent contribution), iron (HQ = 0.8; 26 percent contribution), zinc (HQ = 0.6; 18 percent contribution), manganese (HQ = 0.3; 9.8 percent contribution), and lithium (HQ = 0.2; 6.3 percent contribution); the remaining analytes (cadmium, carbon tetrachloride, and fluoride) report an HQ less than 0.1.

As discussed in Chapter 4 (Section 4.5.1.2 in the main text), the presence of cobalt, iron, manganese, and zinc was determined to be associated with the corrosion of the well casing based on the results of a television survey. Cobalt, iron, manganese, and zinc are not associated with a discharge and are not considered contributors to cumulative noncancer effects.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. There are no individual analytes in this well that report an HI greater than 1.

H5.6.8 Well 699-55-57

As shown in Table H-11, the total cumulative ELCR is 9.6×10^{-5}. The total ELCR for radiological analytes is 9.6×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. There were no carcinogenic nonradiological contaminants reported in this well; therefore, a cancer risk was not reported. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are technetium-99 (8.5×10^{-5}; 89 percent contribution) and tritium (1.0×10^{-5}; 11 percent contribution).

As shown in Table H-11, the HI is 43, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributor to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) is cyanide (HQ = 42; 97 percent contribution).

H5.7 Results for Wells Included in the 200-BP-5 Far-Field Exposure Area

Table H-12 provides a summary of the cancer risk and noncancer hazards for both wells selected for well-specific evaluation within the 200-BP-5 far-field exposure area. Figures H-41 and H-42 show the primary cancer risk and noncancer hazard contributors for wells within the exposure area, respectively. Figure H-11 is a time-series chart showing unfiltered arsenic concentrations for all wells within the 200-BP-5 far-field exposure area.

H5.7.1 Well 699-62-43F

As shown in Table H-12, the total cumulative ELCR is 3.1×10^{-4}. The total ELCR for nonradiological analytes is 2.9×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.5×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are arsenic (2.9×10^{-4}; 92 percent contribution), technetium-99 (6.3×10^{-6}; 2.0 percent contribution) and tritium (1.8×10^{-5}; 5.6 percent contribution). Contribution to ELCR is elevated for arsenic where measured concentrations for unfiltered samples range between 13.5 µg/L and 14.9 µg/L. The total cumulative ELCR is 2.5×10^{-5} without contribution from arsenic. Figure H-43 provides a times-series chart showing unfiltered and filtered arsenic concentrations over the past 10 years (if available) at Well 699-62-43F.

As shown in Table H-12, the HI is 2.7, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are arsenic (HQ = 1.5; 56 percent contribution), fluoride (HQ = 0.4; 14 percent contribution), Cr(VI) (HQ = 0.2; 9.0 percent contribution), vanadium (HQ = 0.2; 7.6 percent contribution), and lithium (HQ = 0.2; 6.8 percent contribution); the remaining analytes (molybdenum and nitrate) report an HQ less than 0.1.

The critical effect for each analyte is listed in Table H-14. Exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Arsenic is the only analyte in this well that is reported with an HI greater than 1.

H5.7.2 Well 699-65-50

As shown in Table H-12, the total cumulative ELCR is 2.3×10^{-4}. The total ELCR for nonradiological analytes is 2.1×10^{-4}, which is greater than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 2.5×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are arsenic (2.1×10^{-4}; 89 percent contribution), technetium-99 (6.1×10^{-6};

2.7 percent contribution) and tritium (1.8×10^{-5}; 7.9 percent contribution). Contribution to ELCR is elevated for arsenic where measured concentrations for unfiltered samples range between 9.1 µg/L and 10.6 µg/L. The total cumulative ELCR is 2.5×10^{-5} without contribution from arsenic. Figure H-44 provides a times-series chart showing unfiltered and filtered arsenic concentrations over the past 10 years (if available) at Well 699-65-50.

As shown in Table H-12, the HI is 2.1, which is less than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are arsenic (HQ = 1.1; 50 percent contribution), fluoride (HQ = 0.4; 18 percent contribution), Cr(VI) (HQ = 0.2; 8.2 percent contribution), lithium (HQ = 0.2; 8.4 percent contribution), and vanadium (HQ = 0.2; 9.3 percent contribution); the remaining analytes (molybdenum, nitrate, and nitrite) report an HQ less than 0.1.

The critical effect for each analyte is listed in Table H-14. Except for nitrate and nitrite, exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Exposure to nitrate and nitrite both result in blood effects (methemoglobinemia); summing the HQs for nitrate and nitrite result in an HQ of 0.08, which is less than the target HI of 1. Arsenic is the only analyte in this well that is reported with an HI greater than 1.

H5.8 Results Wells Included in the 200-BP-5 Near-River Exposure Area

Table H-13 provides a summary of the cancer risk and noncancer hazards for the single well selected for well-specific evaluation within the 200-BP-5 near-river exposure area. Figures H-45 and H-46 show the primary cancer risk and noncancer hazard contributors for wells within the exposure area, respectively. Figure H-12 provides a time-series chart showing unfiltered arsenic concentrations for all wells within the 200-BP-5 near-river exposure area.

H5.8.1 Well 699-70-68

As shown in Table H-13, the total cumulative ELCR is 6.9×10^{-5}. The total ELCR for nonradiological analytes is 2.4×10^{-6}, which is less than the MTCA cumulative risk threshold of 1×10^{-5}. The total ELCR for radiological analytes is 6.6×10^{-5}, which is less than the upper risk threshold of 1×10^{-4}. The major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are trichloroethene (2.4×10^{-6}; 3.5 percent contribution), technetium-99 (5.4×10^{-6}; 7.9 percent contribution), and tritium (6.0×10^{-5}; 87 percent contribution).

As discussed in Chapter 4 (Section 4.5.1.2 in the main text), trichloroethene was detected in all three samples collected from Well 699-70-68, with concentrations ranging between 1.1 and 1.7 µg/L (one of three detections, 1.7 µg/L, is the result of laboratory contamination); these samples were analyzed in 2010. Figure H-47 provides a times-series chart showing trichloroethene concentrations over the past 10 years (if available) at Well 699-70-68. Based on these results, trichloroethene is not associated with a release and is not considered a contributor to the cumulative cancer effects.

As shown in Table H-13, the HI is 1.3, which is greater than the 2007 MTCA HHRA Procedures (WAC 173-340-708(5)) target HI of 1. The primary contributors to noncancer HI (those analytes that contribute greater than 1 percent of the total HI) are TCE (HQ = 0.5; 42 percent contribution), fluoride (HQ = 0.2; 12 percent contribution), vanadium (HQ = 0.2; 12 percent contribution), nitrate (HQ = 0.1; 8.9 percent contribution), and lithium (HQ = 0.1; 8.2 percent contribution); the remaining analytes (Cr(VI), molybdenum, nitrite, selenium, and uranium) report an HQ less than 0.1.

The critical effect for each analyte is listed in Table H-14. With the exception of nitrate and nitrite, uranium and molybdenum, exposure to each of the analytes that contributes to the HI results in a different critical effect. Therefore, it is appropriate to segregate the contributions of each analyte. Exposure to nitrate and nitrite both result in blood effects (e.g., methemoglobinemia); summing the HQs for nitrate and nitrite results in an HQ of 0.13, which is less than the target HI of 1. Exposure to molybdenum and uranium both result in kidney effects; summing the HQs for molybdenum and uranium results in an HQ of 0.06, which is less than the target HI of 1. There are no analytes that report an HI greater than the target HI 1 based on cumulative noncancer hazards.

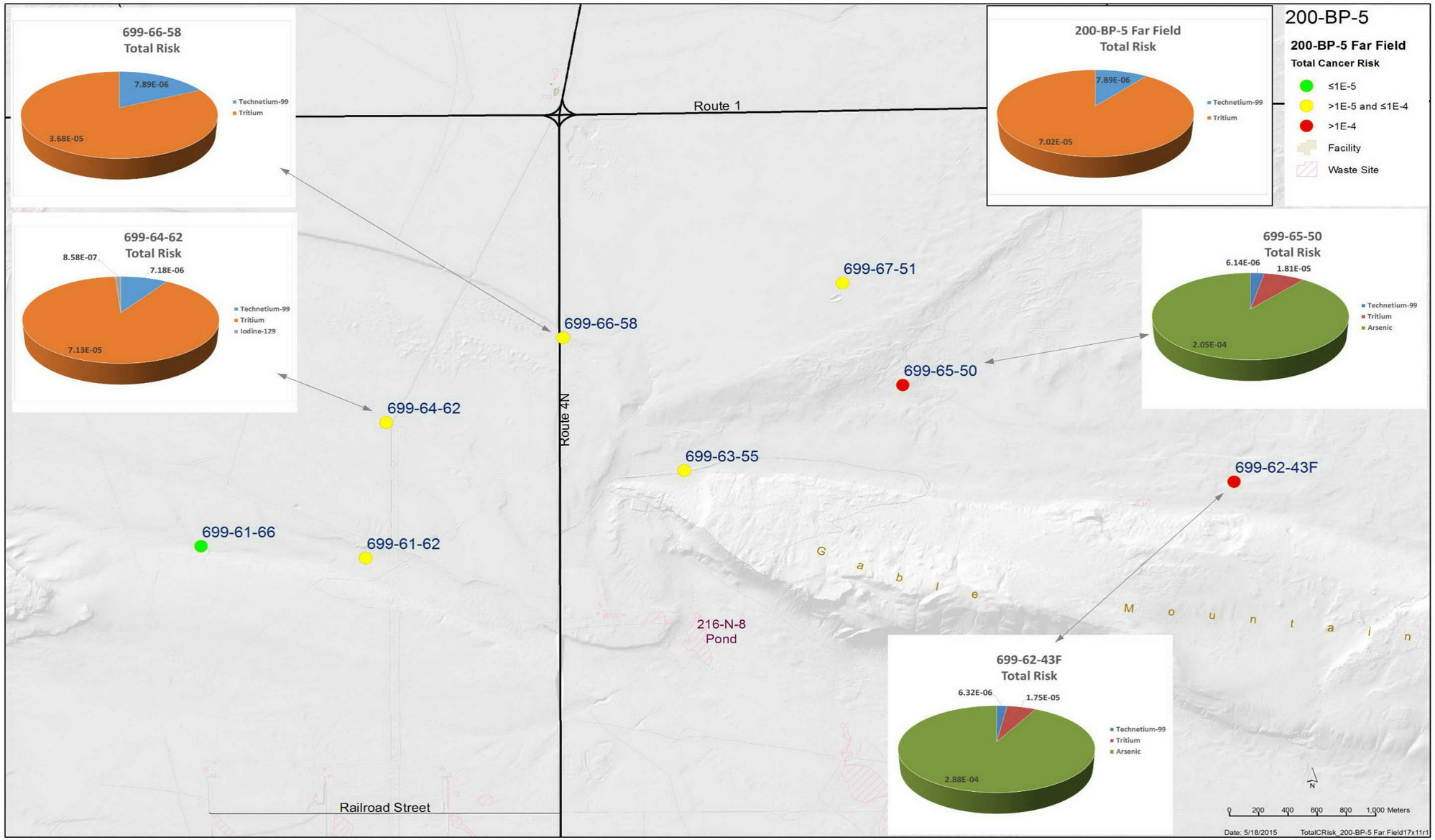

Figure H-41. Cancer Risk Contributors for Wells within the 200-BP-5 Far-Field Exposure Area

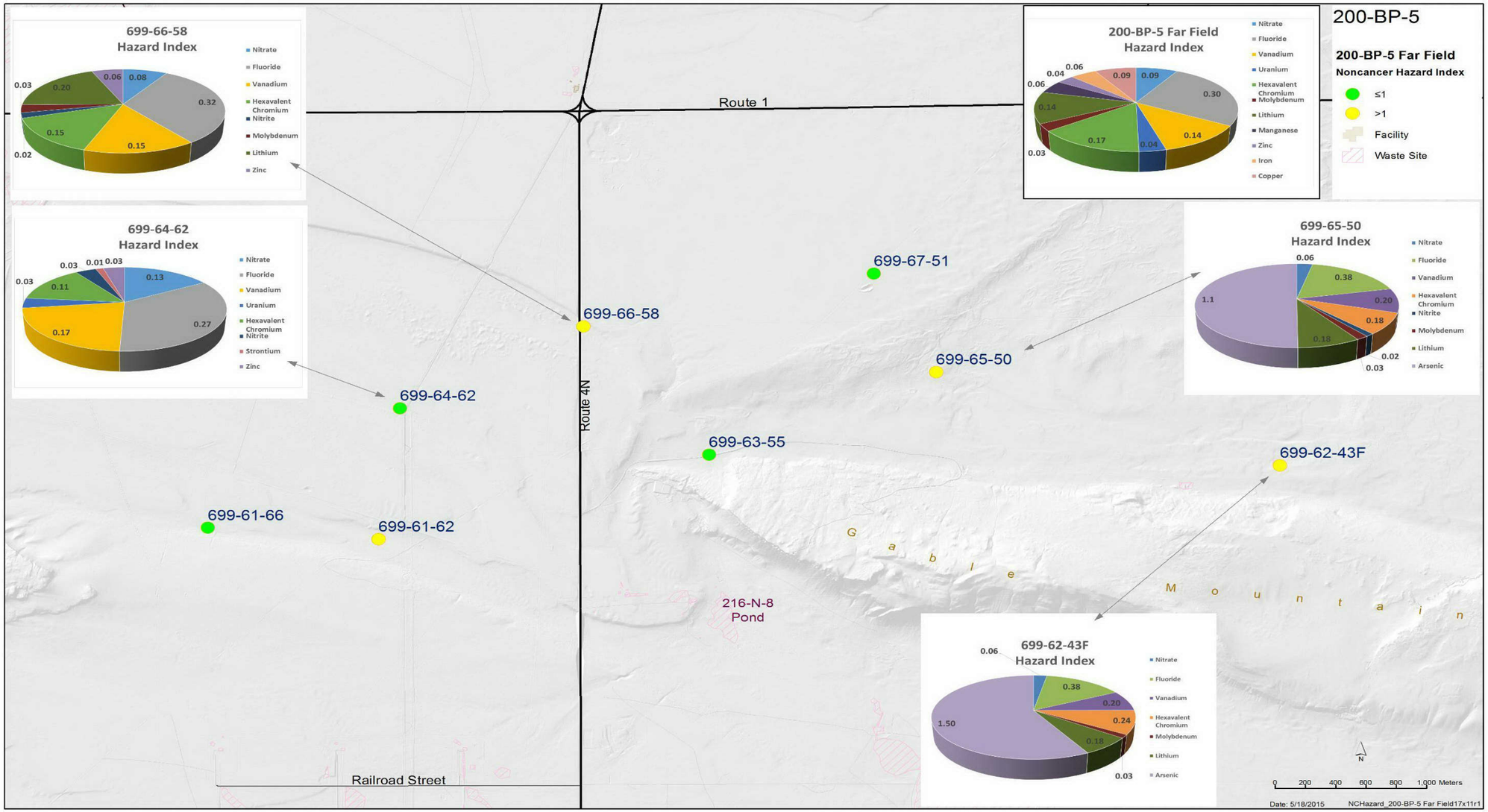

Figure H-42. Noncancer Hazard Contributors for Wells within the 200-BP-5 Far-Field Exposure Area

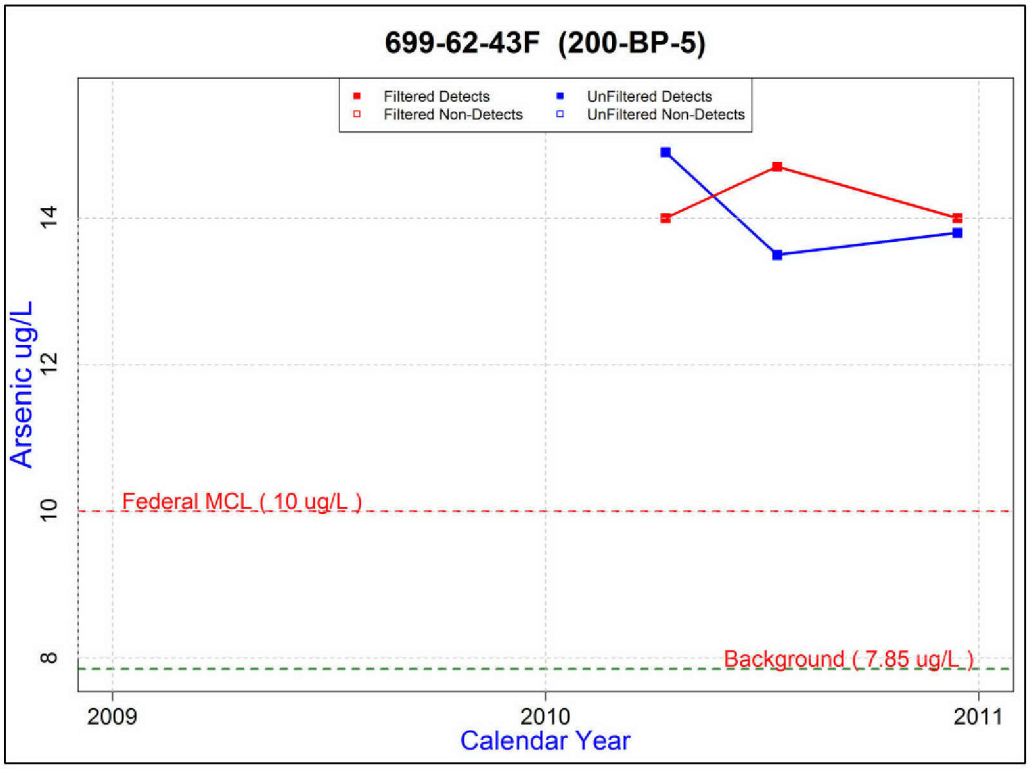

Figure H-43. Unfiltered and Filtered Arsenic Concentrations for Well 699-62-43F (200-BP-5 Far-Field Exposure Area)

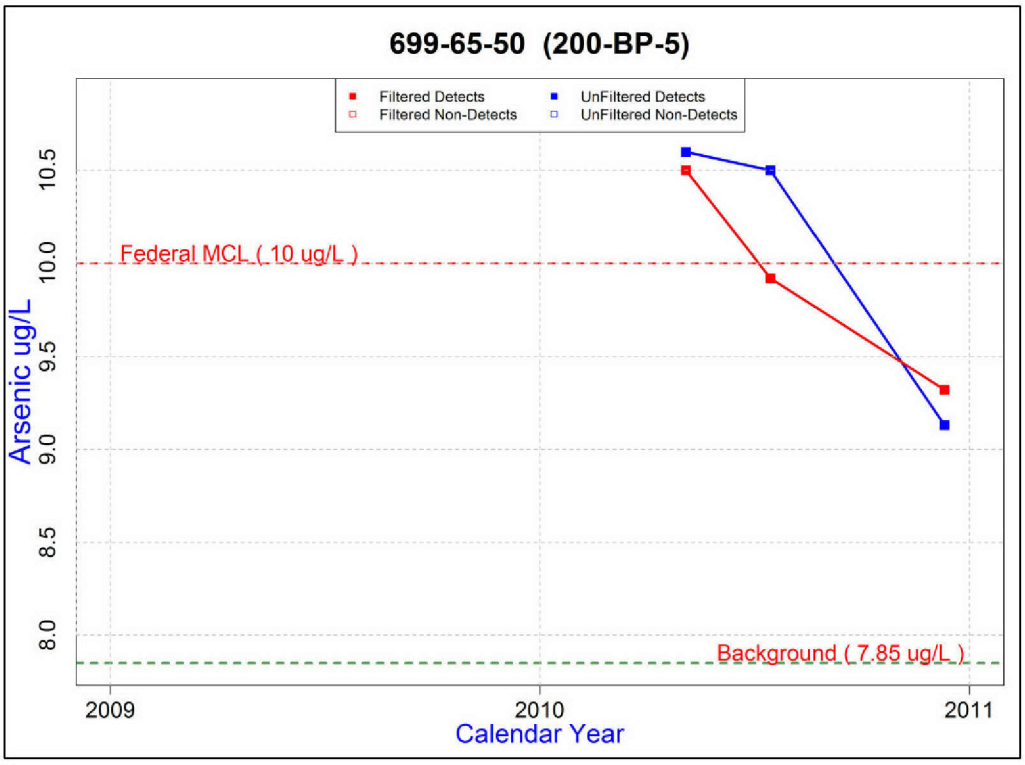

Figure H-44. Unfiltered and Filtered Arsenic Concentrations for Well 699-65-50 (200-BP-5 Far-Field Exposure Area)

H6 Summary of COPCs Retained for Further Evaluation

A summary of the COPC retained for further evaluation are summarized in Table H-15. Individual COPCs that are retained include the following:

- Radionuclides that report an individual cancer risk greater than 1×10^{-4} when the cumulative cancer risk is greater than upper end of the range (1×10^{-4}) identified in 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan"
- Hazardous chemicals that report an individual cancer risk greater than 1×10^{-6} when the cumulative cancer risk is greater than 1×10^{-5}, as defined in 2007 MTCA HHRA Procedures (WAC 173-340-708(5)(a))
- Hazardous chemicals that report an HI greater than the target HI of 1 as defined in 2007 MTCA HHRA Procedures (WAC 173-340-708(5)(a))

H7 References

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://www.ecfr.gov/cgi-bin/text-idx?SID=0cff01005f9529de9127ab4a8e355abd&node=40:28.0.1.1.1&rgn=div5.

ECF-Hanford-13-0035, 2015, *Tap Water Risk Assessment for Remedial Investigation/Feasibility Studies of the 200-BP-5 and 200-PO-1 Groundwater Operable Units*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

EPA/540/1-89/002, 1989, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://epa.gov/swerrims/riskassessment/ragsa/pdf/rags-vol1-pta_complete.pdf.

WAC 173-340, "Model Toxics Control Act—Cleanup," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

WAC 173-340-708, "Human Health Risk Assessment Procedures."

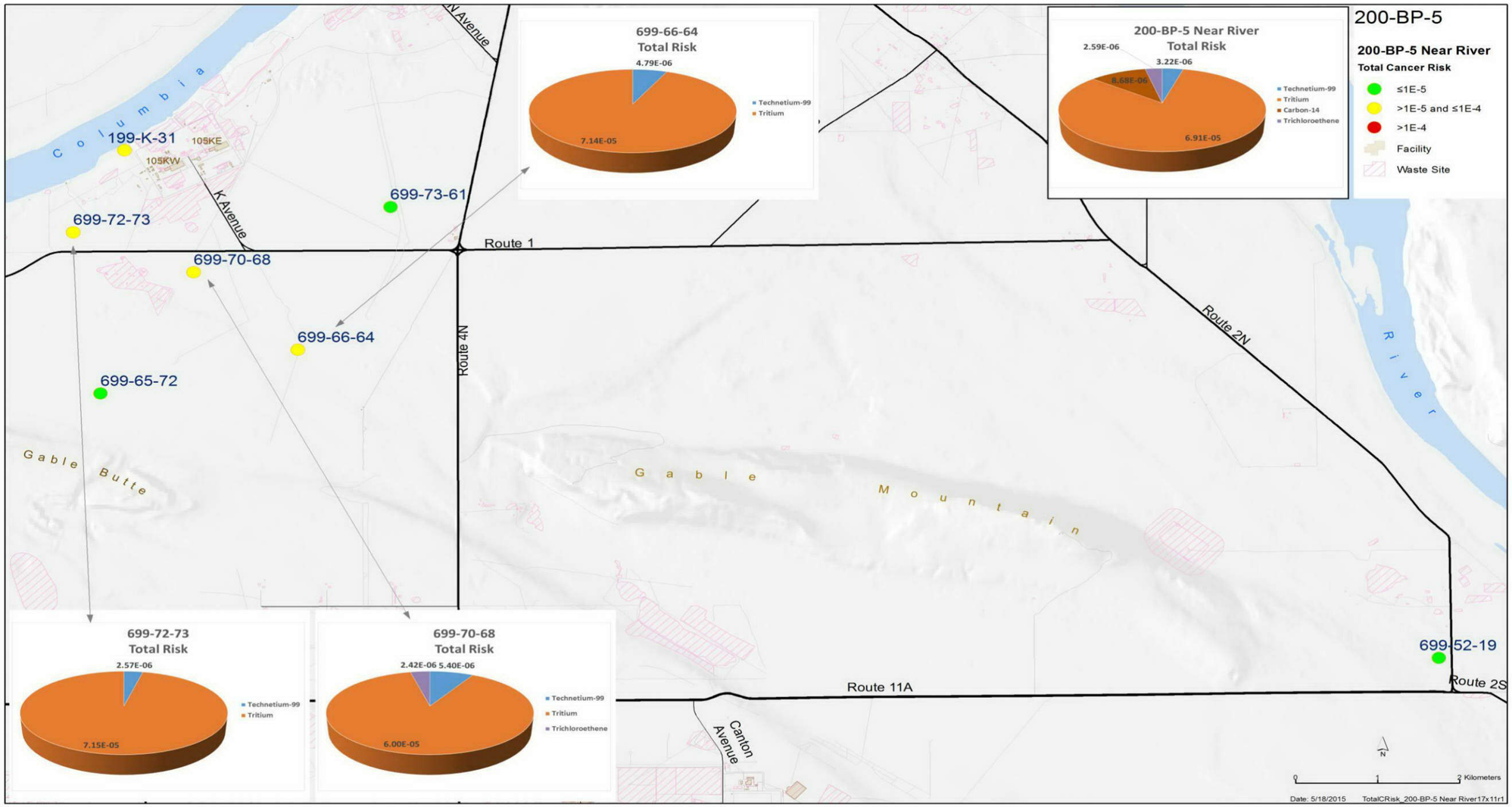

Figure H-45. Cancer Risk Contributors for Wells within the 200-BP-5 Near-River Exposure Area

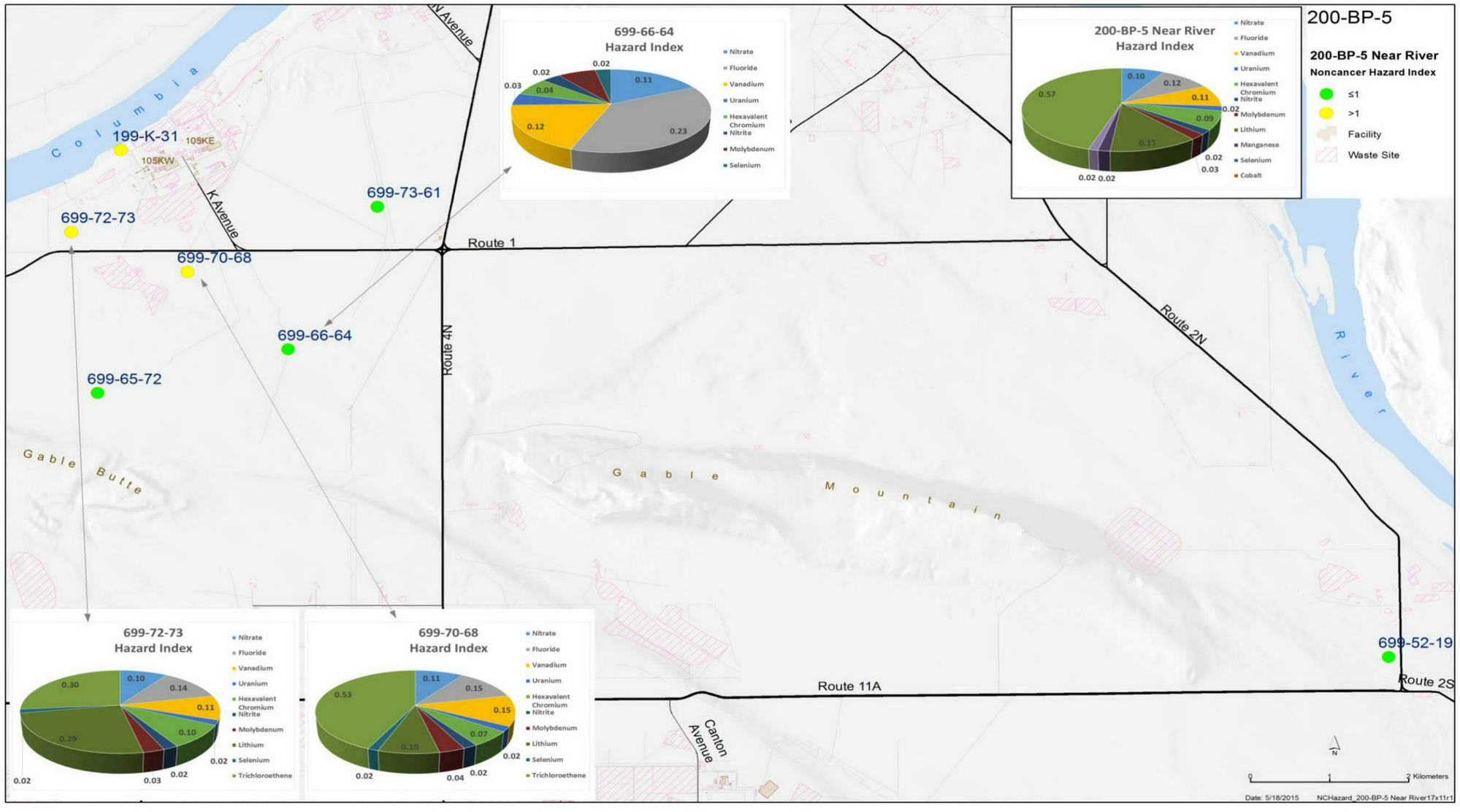

Figure H-46. Noncancer Hazard Contributors for Wells within the 200-BP-5 Near-River Exposure Area

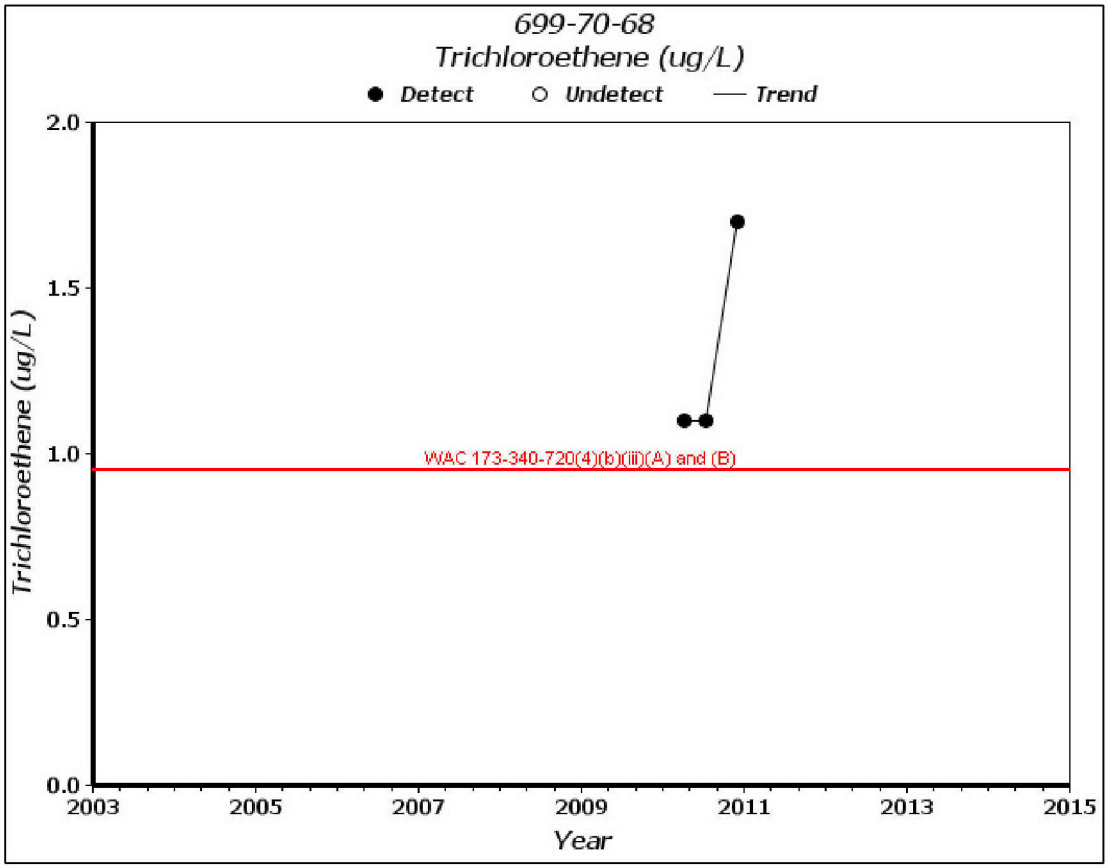

Figure H-47. Trichloroethene Concentrations in Well 699-70-68

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Table H-15. Summary of Analytes Retained as COPCs for Well-Specific Evaluation

Well Name	Exposure Area	Cyanide	Technetium-99	Nitrate	Uranium	Tritium	Arsenic	Strontium-90	Carbon Tetrachloride	Cesium-137	Cobalt-60	Cadmium	Cobalt	Cr (VI)	Fluoride	Manganese	Methyl Methanesulfonate	n-Nitrosodi-n-dipropylamine	Nickel	Nitrite	Plutonium-239/240	Trichloroethene
299-E28-28	LLWMA-1 (218-E-10)	X																				
299-E33-34	LLWMA-1 (200-E-21)	X	X	X		X																
299-E33-265	LLWMA-1 (218-E-10[?])	X																				
299-E33-266	LLWMA-1 (218-E-10[?])	X																				
299-E33-33	LLWMA-2 and 216-B-63 Trench	X																				
299-E33-1A	WMA B-BX-BY Tank Farms	X	X	X		X																
299-E33-4	WMA B-BX-BY Tank Farms										X											
299-E33-15	WMA B-BX-BY Tank Farms	X	X																			
299-E33-16	WMA B-BX-BY Tank Farms	X	X				X															
299-E33-17	WMA B-BX-BY Tank Farms	X	X																			
299-E33-18	WMA B-BX-BY Tank Farms	X	X	X	X																	
299-E33-20	WMA B-BX-BY Tank Farms	X	X	X																		
299-E33-38	WMA B-BX-BY Tank Farms	X	X																			
299-E33-42	WMA B-BX-BY Tank Farms	X	X	X	X													O				
299-E33-44	WMA B-BX-BY Tank Farms	X	X	X	X		X															
299-E33-47	WMA B-BX-BY Tank Farms	X	X	X													O					
299-E33-48	WMA B-BX-BY Tank Farms	X	X			X																
299-E33-205	WMA B-BX-BY Tank Farms	X	X	X	X																	
299-E33-334	WMA B-BX-BY Tank Farms	CyX	X			X												O				
299-E33-337	WMA B-BX-BY Tank Farms	X	X	X									O						O			
299-E33-338	WMA B-BX-BY Tank Farms	X	X																			
299-E33-339	WMA B-BX-BY Tank Farms	X	X		X								O									
299-E33-341	WMA B-BX-BY Tank Farms	X	X																			
299-E33-342	WMA B-BX-BY Tank Farms	X	X		X	X																
299-E33-343	WMA B-BX-BY Tank Farms	X	X	X	X																	
299-E33-345	WMA B-BX-BY Tank Farms	X	X	X	X									X						O		

Table H-15. Summary of Analytes Retained as COPCs for Well-Specific Evaluation

Well Name	Exposure Area	Cyanide	Technetium-99	Nitrate	Uranium	Tritium	Arsenic	Strontium-90	Carbon Tetrachloride	Cesium-137	Cobalt-60	Cadmium	Cobalt	Cr (VI)	Fluoride	Manganese	Methyl Methanesulfonate	n-Nitrosodi-n-dipropylamine	Nickel	Nitrite	Plutonium-239/240	Trichloroethene
299-E27-7	WMA C Tank Farm	X																				
299-E27-14	WMA C Tank Farm	X	X				X															
299-E27-15	WMA C Tank Farm						X															
299-E27-155	WMA C Tank Farm	X	X																			
299-E28-23	B Plant (216-B-5 Reverse Well)							X		X											X	
299-E28-24	B Plant (216-B-5 Reverse Well)		X	X				X							X							
299-E28-25	B Plant (216-B-5 Reverse Well)							X														
699-49-57A	200-BP-5 west (BY Cribs/B-BX-BY Tank Farms)	X	X	X																		
699-50-56	200-BP-5 west (north of 200 East Area)	X						X					O									
699-50-59	200-BP-5 west (north of 200 East Area)	X	X			X																
699-52-55	200-BP-5 west (west of Gable Mountain Pond)	X							O			O	O			O						
699-53-55B	200-BP-5 west (west of Gable Mountain Pond)	X	X																			
699-53-55C	200-BP-5 west (west of Gable Mountain Pond)	X	X																			
699-54-45A	200-BP-5 west (Gable Mountain Pond)								O													
699-55-57	200-BP-5 west (west of Gable Mountain Pond)	X																				
699-62-43F	Far-field area (north of Gable Mountain Pond)						X															
699-65-50	Far-field area (north of Gable Mountain Pond)						X															
699-70-68	Near-river area (south of 100-K Area)																					O

Notes:
Shaded cells in the table indicate that analyte was not included as a COPC.
An "X" indicates that the analyte was retained as a COPC; an "O" indicates that analyte was detected once or infrequently at a concentration greater than a risk-based screening level.
COPC = contaminant of potential concern
LLWMA = low-level waste management area
WMA = waste management area

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