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10-AMCP-0096

MAR 05 2010

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INTEGRATED 100 AREA REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLAN, DOE/RL-2008-46, REVISION 0, INTEGRATED 100 AREA REMEDIAL INVESTIGATION/FEASIBILITY STUDY WORK PLAN ADDENDUM 2: 100-KR-1, 100-KR-2, AND 100-KR-4 OPERABLE UNITS, DOE/RL-2008-46-ADD2, REVISION 0, AND SAMPLING AND ANALYSIS PLAN FOR THE 100-K DECISION UNIT REMEDIAL INVESTIGATION/FEASIBILITY STUDY, DOE/RL-2009-41, REVISION 0

This letter transmits the following approved documents to the U.S. Environmental Protection Agency (EPA) and State of Washington Department of Ecology (Ecology) for information:

> Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, DOE/RL-2008-46, Revision 0:
>
> Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units, DOE/RL-2008-46-ADD2, Revision 0; and
>
> Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/ Feasibility Study, DOE/RL-2009-41, Revision 0.

This remedial investigation/feasibility study (RI/FS) work plan serves as the umbrella document for the five reactor areas and corresponding 100 Area source and groundwater operable units. In addition, Addendum 2 and corresponding Sampling and Analysis Plan (SAP) describes specific RI/FS background and workscope associated with the K Area operable units. The addendums and SAPs for the remaining 100 Area operable units are in various stages of development and will be transmitted upon their completion.

If you have any questions, please contact me, or your staff may contact Briant Charboneau, of my staff, on (509) 373-6137, or Joe Franco, Assistant Manager for the River Corridor, on (509) 376-6628.

Sincerely,

Matthew S. McCormick, Assistant Manager
for the Central Plateau

AMCP:JPH

Attachments

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DOE/RL-2008-46
Revision 0

Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan

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Assistant Secretary for Environmental Management

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Approval Page

Title: *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*

Concurrence:

U.S. Department of Energy, Richland Operations Office

Signature 1-19-2010 Date

U.S. Environmental Protection Agency

Signature 1-19-10 Date

Washington State Department of Ecology

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Executive Summary

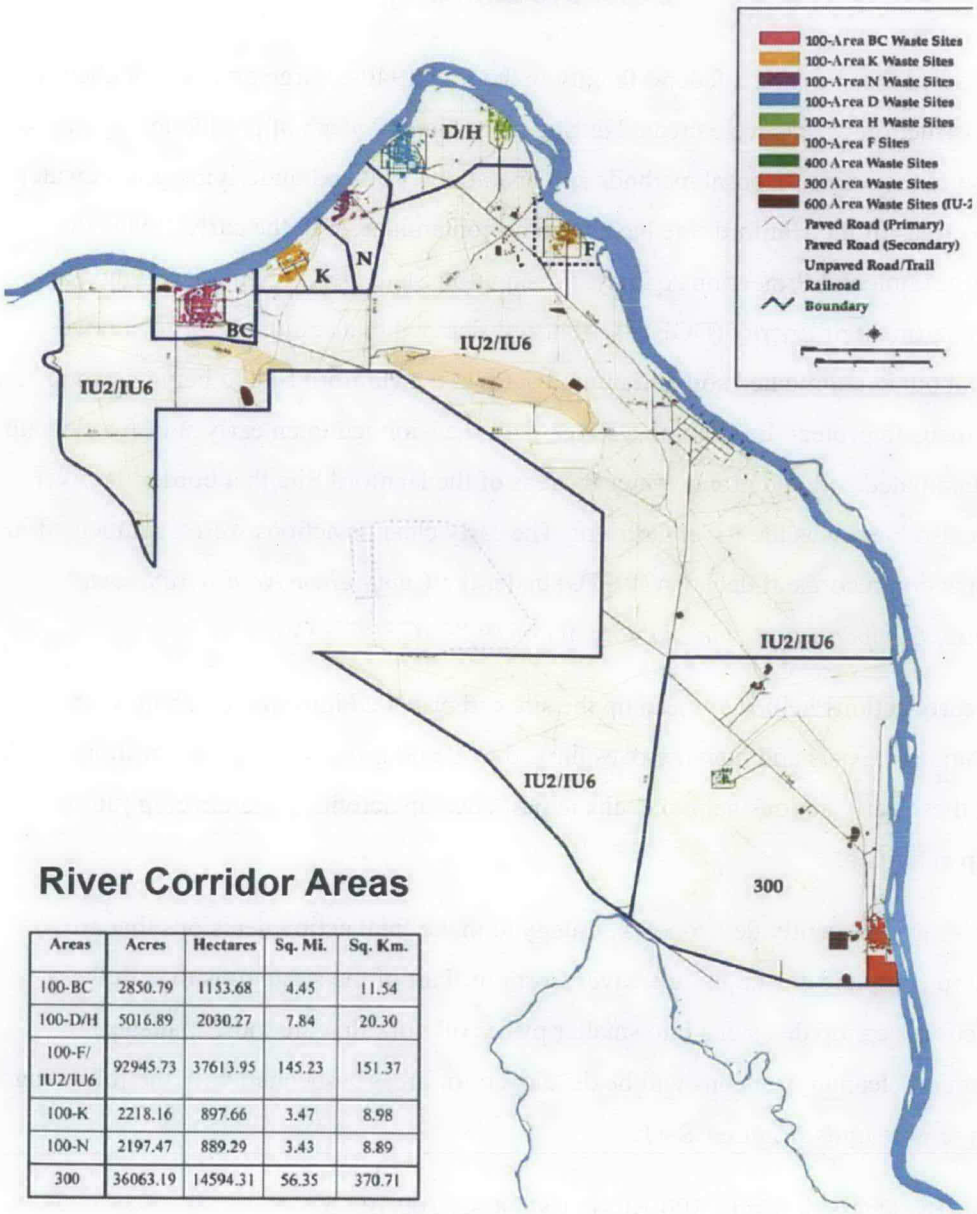
The Hanford Site became a federal facility in the mid-1940s. Large amounts of chemical and construction wastes were created during more than 40 years of production operations. Because of the waste disposal methods and operations, soil and underlying groundwater in some areas of the Hanford Site have become contaminated. In the early 1990s, the U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy (DOE) (Tri-Parties) decided that enough information was known about contaminated soil and groundwater at the Hanford Site to begin cleanup with a focus to protect the Columbia River. This decision led to an early start for cleanup of contaminated soil and groundwater in areas of the Hanford Site that border the river, an area also known as the River Corridor. The early cleanup actions were documented in interim action records of decision (RODs) under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[1] (CERCLA).

These early actions helped to clean up the site and provided information about where contamination exists and how it moves through soil and groundwater. Observations made during these early actions help to evaluate past cleanup activities and develop future cleanup activities.

The Tri-Parties recently developed a strategy to make final action decisions that are needed to complete cleanup in the River Corridor. Part of the strategy is to split these final action cleanup decisions into smaller pieces of work that are more manageable. Final action cleanup decisions will be developed for areas associated with the following areas operable units (Figure ES-1):

- 100-BC Operable Units: 100-BC-1, 100-BC-2, 100-BC-5
- 100-K Operable Units: 100-KR-1, 100-KR-2, 100-KR-4
- 100-N Operable Units: 100-NR-1, 100-NR-2
- 100-D/H Operable Units: 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, 100-HR-3
- 100-F/IU-2/IU-6 Operable Units: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, 100-IU-6
- 300 Area Operable Units: 300-FF-1, 300-FF-2, 300-FF-5

1 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et.seq. Available at: http://www4.law.cornell.edu/uscode/42/usc_sec_42_00009601-000-.html.



River Corridor Areas

Areas	Acres	Hectares	Sq. Mi.	Sq. Km.
100-BC	2850.79	1153.68	4.45	11.54
100-D/H	5016.89	2030.27	7.84	20.30
100-F/ IU2/IU6	92945.73	37613.95	145.23	151.37
100-K	2218.16	897.66	3.47	8.98
100-N	2197.47	889.29	3.43	8.89
300	36063.19	14594.31	56.35	370.71

Figure ES-1. River Corridor Boundaries

Final action decisions for the operable units will address the cleanup of contaminated soil, solid waste burial grounds, groundwater, and releases from and/or due to reactor buildings. The objective for all these decisions is to protect human health and the environment.

The CERCLA process for making final action decisions about the actions needed to complete cleanup involves the following activities:

- Gathering information about the site
- Conducting risk characterizations
- Identifying goals for the cleanup
- Evaluating different options and the associated costs to meet the cleanup goals
- Selecting the cleanup option that provides the best fit

This document, the addenda, and the sampling and analysis plans (SAPs) identify the data gaps and the data to be collected. This data will then be used to develop the remedial investigation/feasibility study (RI/FS). Selection of the final action cleanup that will be performed is documented in a ROD.

Cleanup of the Hanford Site is also subject to the *Resource Conservation and Recovery Act of 1976*[2] (RCRA). RCRA is a federal law that establishes requirements to treat, store, and dispose of hazardous wastes. The State of Washington has a federally authorized state RCRA program. RCRA also has a cleanup phase, similar to CERCLA, called corrective action. The Tri-Parties intend that cleanup in RODs will also fulfill state requirements for corrective action.

For sites undergoing cleanup under CERCLA, it is DOE policy to integrate the *National Environmental Policy Act of 1969* (NEPA) values into the procedural and documentation requirements of the RI/FS process. For the 100 Area operable units, the NEPA value analysis will be documented in conjunction with the CERCLA criteria in each FS specific to the operable units and in the resulting CERCLA ROD.

Scope and Objectives

Objectives of the work plan are to document information that is currently known about the site and to identify the additional information that needs to be gathered before final action cleanup decisions can be made. The approach to collect this information is written into the SAP.

This work plan proposes collection of additional information that is needed to support final action cleanup decisions. The data collected under this work plan will be combined

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[2] Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq. Available at: http://www.epa.gov/lawsregs/laws/rcra.html.

with historical data, data collected during continued implementation of interim action RODs, routine site monitoring activities, and specific studies to assess the potential applicability of treatment technologies. Data and results will be reported in an RI/FS report, which will lead to alternatives for final action site cleanup.

Relationship of Integrated 100 Area Work Plan, Addenda and RODs

This integrated 100 Area CERCLA RI/FS work plan has been developed to identify activities needed to gather additional data to make an integrated final action decision for all contaminated soil, sediment, and groundwater. Each 100 Area encompassing the operable units within that area will have an addendum to this work plan. The addendum for each area documents the development of the site-specific conceptual model, areas of uncertainty that require resolution to support decisions, and the SAP, which will direct the collection of new information to address these uncertainties.

After the data have been gathered and analyzed, an individual RI/FS will be prepared for each area to summarize and analyze the remedial investigation work completed and to identify and evaluate remedial alternatives. A proposed plan for each 100 area encompassing the operable units within that area, that will contain a summary of the investigation and evaluation, and includes the preferred remedial alternative, will be issued to the public for review and comment. After completion of this review and comment cycle, a final action ROD will be developed and approved by the Tri-Parties. The final action remedies will then be implemented. Appropriate land management controls and monitoring requirements will be identified in the final action cleanup plan as needed. Completed remedies are subject to reviews every 5 years to verify long-term effectiveness and protection.

Summary of Actions and Assessments

The following characterization and investigation activities were conducted to support sound interim action cleanup decisions and ongoing cleanup activities:

- Technical baseline reports summarized existing process and contamination information.
- Limited field investigations collected additional characterization data and supported qualitative risk assessments.
- Focused feasibility studies selected interim action remedial actions.

- Other routine monitoring activities evaluated air emissions and monitored environmental radiation.
- Excavated contaminated soil and sent it to a large lined landfill on the Hanford Site.
- Pumped contaminated groundwater to the surface, treated it to remove contamination, and pumped it back into the ground.
- Removed contaminated facilities and disposed of them in the large lined landfill on the Hanford Site.

Soil and groundwater cleanup actions and assessments have been performed since the early 1990s. Much of the information needed to understand contamination at the site already has been gathered and is well understood. In order to support final action cleanup decisions, the focus of this work plan is to identify the additional information needed to fill knowledge gaps regarding contamination at the site and determine how the contamination moves in the environment. Table ES-1 summarizes the current and historical work that already has been accomplished. The specific information needed for each operable unit is outlined in the addenda to this work plan.

Table ES-1. Examples of Activities Providing Information and Data to Support Development of Remedial Investigation/Feasibility Study Work Plans (Through December 2008)

Activity Name	Accomplishments/Investigations
Facility D4 Actions	Over 300 structures have been demolished in the 100 Area. In addition, five 100 Area reactors have been placed in ISS.
Waste Site Remediation Program	Remediation in accordance with the interim action RODs occurred at more than 155 waste sites, including 78 of 82 high-priority liquid waste sites*, which have been backfilled with clean soil. Approximately, a total of 8 million tonnes (9 million tons) of contaminated soil have been disposed at the ERDF.
Spent Nuclear Fuel and Related Sludge Removal Actions	Approximately 2,100 tonnes (2,300 tons) of spent nuclear fuel and up to 30 cubic meters (40 cubic yards) of sludge, 9.1 million liters (2.4 million gal.) of water, and hundreds of tons of debris and fuel racks (solid waste) were removed from two basins that are located less than a quarter-mile from the Columbia River.
Orphan Site Evaluation Program	Orphan site evaluations have been completed across 25 percent of the River Corridor. Most of the remaining area is within the "inter areas." Over 14,190 ha (35,058 ac) have been assessed through the orphan site evaluations to identify new waste sites.
River Corridor Baseline Risk Assessment	The assessment provided an analysis of human health and ecological risk in the River Corridor.

Table ES-1. Examples of Activities Providing Information and Data to Support Development of Remedial Investigation/Feasibility Study Work Plans (Through December 2008)

Activity Name	Accomplishments/Investigations
Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River	This plan described efforts to collect data for an evaluation of the nature and extent of contamination and current risk to humans, animals, and plants exposed to Hanford Site related contaminants. Samples of pore water, sediment, surface water, fish, and island soil collected in 2008 and 2009.
100-K, 100-D, 100-H, and 100-N Areas Pump-and-Treat Systems	The 100-K, 100-D, and 100-H large pump-and-treat systems have treated over 7.6 billion L (2 billion gal.) of groundwater and removed nearly one ton of CrVI from the aquifer. The 100-N Pump-and-Treat system has removed 1.8 curies of Sr-90 and is currently in cold standby.
Remediation Process Optimization	This process provides a systematic evaluation and enhancement of the current site remediation actions to foster improved cleanup performance and reduce cost.
Groundwater Monitoring	All HEIS groundwater monitoring data available through December 2008 from all groundwater monitoring wells constructed in the River Corridor will be evaluated.
Aquifer Tube Sampling	More than 400 aquifer tubes have been installed at the Hanford Site since 1997. These aquifer tubes are sampled to provide data on the nature and extent of contaminants in groundwater at locations adjacent to the Columbia River.
Biostimulation Test	Molasses was injected at the 100-D Area biostimulation treatability test site to nourish bacteria that can reduce CrVI to trivalent chromium, which is less toxic and less mobile than CrVI.
Electrocoagulation Test	New technology enabled cost-effective remediation of CrVI contaminated groundwater.
In Situ Redox Manipulation	By injecting non-toxic chemicals into an aquifer, ISRM can successfully immobilize contaminants to aquifer sediments, or reduce contaminants to a less toxic form (e.g., reduce CrVI to trivalent chromium).
Fortifying ISRM Barrier with Iron	Maintaining the ISRM barrier depends on the presence of naturally occurring iron. Studies have shown that fortifying the barrier with more iron offers a sustainable long-term repair.
Apatite Barrier Installation	The barrier removes Sr-90 from groundwater and allows it to radioactively decay in the soil by binding Sr-90 from the groundwater into the apatite mineral matrix.
Petroleum Hydrocarbon Remediation at 100-N Area	Installed boreholes and wells for ongoing monitoring, natural attenuation, and bioremediation of groundwater and vadose zone.
Polysulfide Injection	New technology was tested to reduce CrVI within groundwater.
Phytoremediation Field Demonstration	Phytoremediation, using the Coyote willow (a common plant that grows along the banks of the Columbia River), can be used to extract Sr-90 from the groundwater prior to its migration to the Columbia River.

* High priority waste sites are identified in limited field investigation (LFI) reports and interim action RODs that pose risk(s) through one or more pathways sufficient to recommend streamlined action via an interim action remedial measure.

D4 = deactivation, decontamination, decommissioning, and demolition
CrVI = hexavalent chromium
ERDF = Environmental Restoration Disposal Facility
HEIS = Hanford Environmental Information System
ISRM = in situ redox manipulation
ISS = interim safe storage
ROD = record of decision
Sr-90 = strontium-90

Schedule

The RI/FS work plan and addenda for each of the River Corridor Operable Unit areas will be submitted for regulatory review, and distributed to Tribal Nations and stakeholders throughout 2009. Following approval of the work plan and associated addenda, a 6- to 12-month field investigation will be conducted within each of the areas to collect the additional information needed to support final action decision making.

A proposed plan leading to a final action ROD will be prepared for each area's operable units that will address final action remedies for both source and groundwater operable units (OU). The proposed plan and ROD will incorporate completed remedial actions under interim action RODs. The six final action RODs are scheduled to be issued in 2013. The selected final action remedies contained in each ROD will address the respective suite of contamination for each operable unit. Each final action ROD will be comprehensive and address contamination and will establish agreed upon remedial actions. 100 area's operable units specific schedules are provided in each work plan addenda.

Integration with Remedial Investigation of Hanford Site Releases to the Columbia River

In 2008, the Tri-Parties established a plan for remedial investigation of Hanford Site releases to the Columbia River (DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to Columbia River*[3]). The purpose of the investigation work plan is to describe the initial work to accomplish the following goals:

- Collect and analyze samples to identify what Hanford Site related contaminants are present in the Columbia River, their concentrations, and their locations.
- Use the sample results to estimate the current risk to humans, animals, and plants if they are exposed to Hanford Site related contaminants while they use or live in the Columbia River.
- Determine whether any cleanup actions are needed to lower the risk to humans, animals, and plants from being exposed to Hanford Site related contaminants.

3 DOE/RL-2008-11, 2008, *Remedial Investigation Work Plan for Hanford Site Releases to Columbia River*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www.washingtonclosure.com/projects/EndState/docs/Rem_Invest/rl08-11.pdf.

Sample collection activities for the investigation began in October 2008 and will continue through late 2009. More than 1,200 samples, including river water, sediment from the river bottom and shoreline, soil from islands, groundwater, and fish, will be collected as part of this effort. The results of the laboratory tests performed on the samples will be evaluated as they are returned and summarized in a report after all the tests are complete. These results then will be combined with existing data from the river, used to estimate the potential risk to plants and animals, and help decision makers determine if additional investigation is needed. This decision point is anticipated to occur in 2011.

Evaluating the impact of the Hanford Site releases to the Columbia River is an integral piece of final action cleanup decisions for the River Corridor and Hanford Site. If contamination requiring remedial action is identified in the river and it originated from the Hanford Site, then it will be addressed by DOE through a cleanup decision. Such a cleanup decision may be associated with one or more of the river corridor operable units or it may be a separate remedial action in the river. This will depend on the source and location of the contamination.

Relationship to the Overall Plan for Hanford Site Cleanup

The DOE has developed a Hanford Site cleanup plan to protect the Columbia River. Three major plan components are the River Corridor, Central Plateau, and tank farms (Figure ES-2). The plan provides a set of principles and goals that help guide the sequence of cleanup actions to achieve this protection. The plan's goals recognize that the Columbia River is a critical resource for the people, animals, and plants of the Pacific Northwest.

Following the implementation of cleanup actions, there will be disposal facilities and other areas that will necessitate long-term management activities. Long-term stewardship activities will be required for portions of the Hanford Site to ensure protection of human health and the environment.

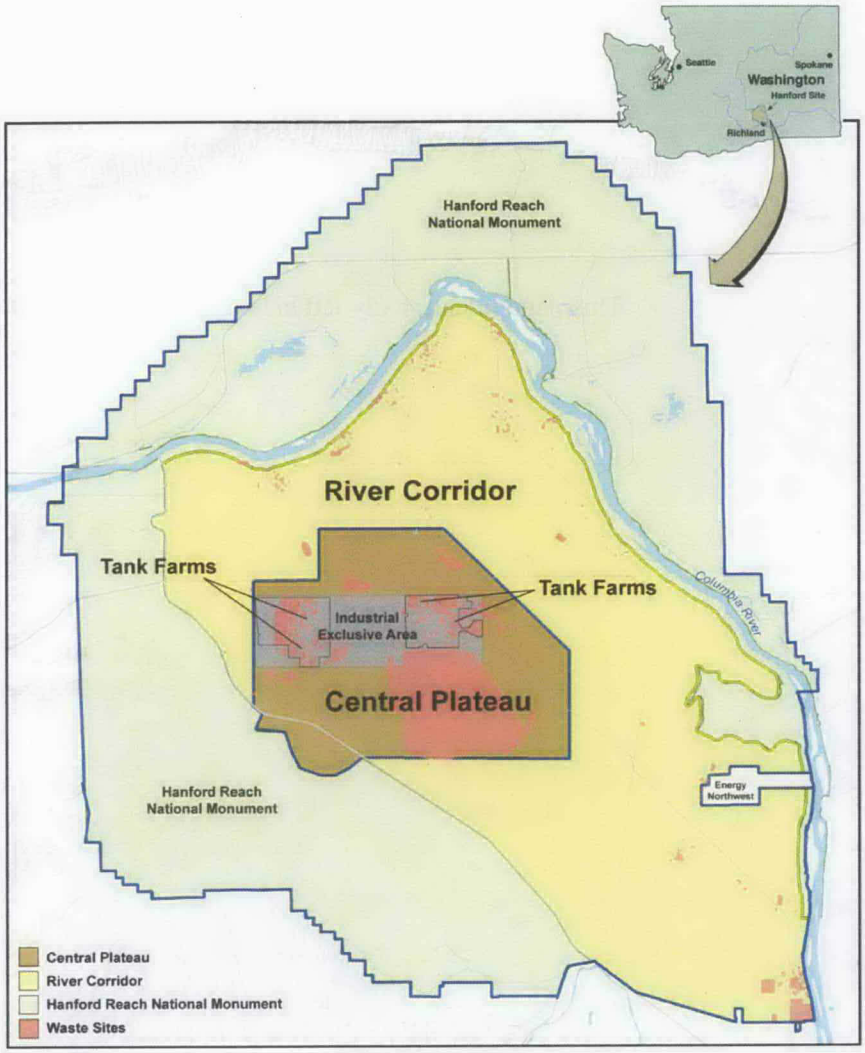

Figure ES-2. River Corridor, Central Plateau, and Tank Waste Components

Path Forward

Historical information, ongoing site clean-up and monitoring results, and remedial investigation data will be integrated into RI/FS reports for the River Corridor. Proposed plans leading to final action RODs for each of the 100 area's operable units will address remedies for both source and groundwater OUs. These final action decisions will incorporate remedial actions completed under existing interim action RODs. Each final ROD will be comprehensive and address contamination found in the operable units and will establish remedial actions.

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Terms

AEA	*Atomic Energy Act of 1954*
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
COPC	contaminant of potential concern
CrVI	hexavalent chromium
CSM	conceptual site model
CVP	cleanup verification package
D4	deactivation, decontamination, decommissioning, and demolition
DOE	U.S. Department of Energy
DOH	Washington State Department of Health
DQO	data quality objective
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ESD	explanation of significant difference
FS	feasibility study
HAB	Hanford Advisory Board
HEIS	Hanford Environmental Information System
HHRA	human health risk assessment
ISS	interim safe storage
ISRM	in situ redox manipulation
LFI	limited field investigation
MCL	maximum contaminant level
MRDL	maximum residual disinfectant level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

NEPA	*National Environmental Policy Act of 1969*
NPL	National Priorities List
nZVI	nano zero valent iron
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
Pu	plutonium
QRA	qualitative risk assessment
RAG	remedial action goal
RAO	remedial action objective
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RL	U.S. Department of Energy, Richland Operations Office
ROD	record of decision
RPO	remediation process optimization
RSVP	remaining site verification process
RTD	removal, treatment, and disposal
RUM	Ringold Upper Mud
SAP	sampling and analysis plan
SFY	state fiscal year
Sr-90	Strontium-90
TMP	technology maturation plan
TRA	technology readiness assessment
Tri-Parties	DOE, EPA, and Ecology
Tri-Party Agreement	Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*
Trustees	Hanford Natural Resources Trustee Council
TSCA	*Toxic Substances Control Act of 1976*

TSD	treatment, storage, and disposal
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WCH	Washington Closure Hanford, LLC
WIDS	Hanford Waste Information Data System
ZVI	zero valent iron

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1 Introduction

In 1989, representatives from Washington State Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE) signed the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement [Ecology et al., 1989a]). The agreement created a cohesive regulatory framework, schedule, and adjudication process to administer environmental remediation activities at the Hanford Site for both *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) response action and *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action activities. This document presents the work plan for a remedial investigation/feasibility study (RI/FS) to support final action remedy selection under the CERCLA for the 100 Area operable units at the Hanford Site. This document explains the RI/FS project background and rationale and presents detailed plans for investigation of contaminated DOE sites in the 100 Area. The 100 Area operable units being investigated for the River Corridor or within or near the 100-B/C Area, 100-K Area, 100-D and 100-H Areas, 100-N Area, and the 100-F Area combined with the 100-IU-2/IU-6 Area. The River Corridor also has a 300 Area (including nearby 600 Area waste sites and the 400 Area). A 300 Area work plan will be developed as a separate document. The 100 Area sites and the groundwater are contaminated from releases and spills of radiological and/or chemical constituents, and historical solid waste disposal practices, and encompass the 100 Area sites that are on the National Priorities List (NPL) (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan (NCP)," Appendix B, "National Priorities List").

The 100 Area contains multiple source and groundwater operable units (OUs), as defined in Chapter 2.0 of this work plan, that are part of the Hanford Site River Corridor, which encompasses approximately 570 km^2 (220 mi^2) adjacent to the Columbia River. To date, significant remediation has occurred along the River Corridor using remedial actions as authorized under interim action records of decision (RODs), RCRA corrective actions, and other activities. Integral with these cleanup activities, data have been collected and analyzed regarding the nature and extent of residual contaminants. This RI/FS work plan and its associated addenda propose additional field work, analyses, and studies that are needed to support a final action ROD for each area's operable units.

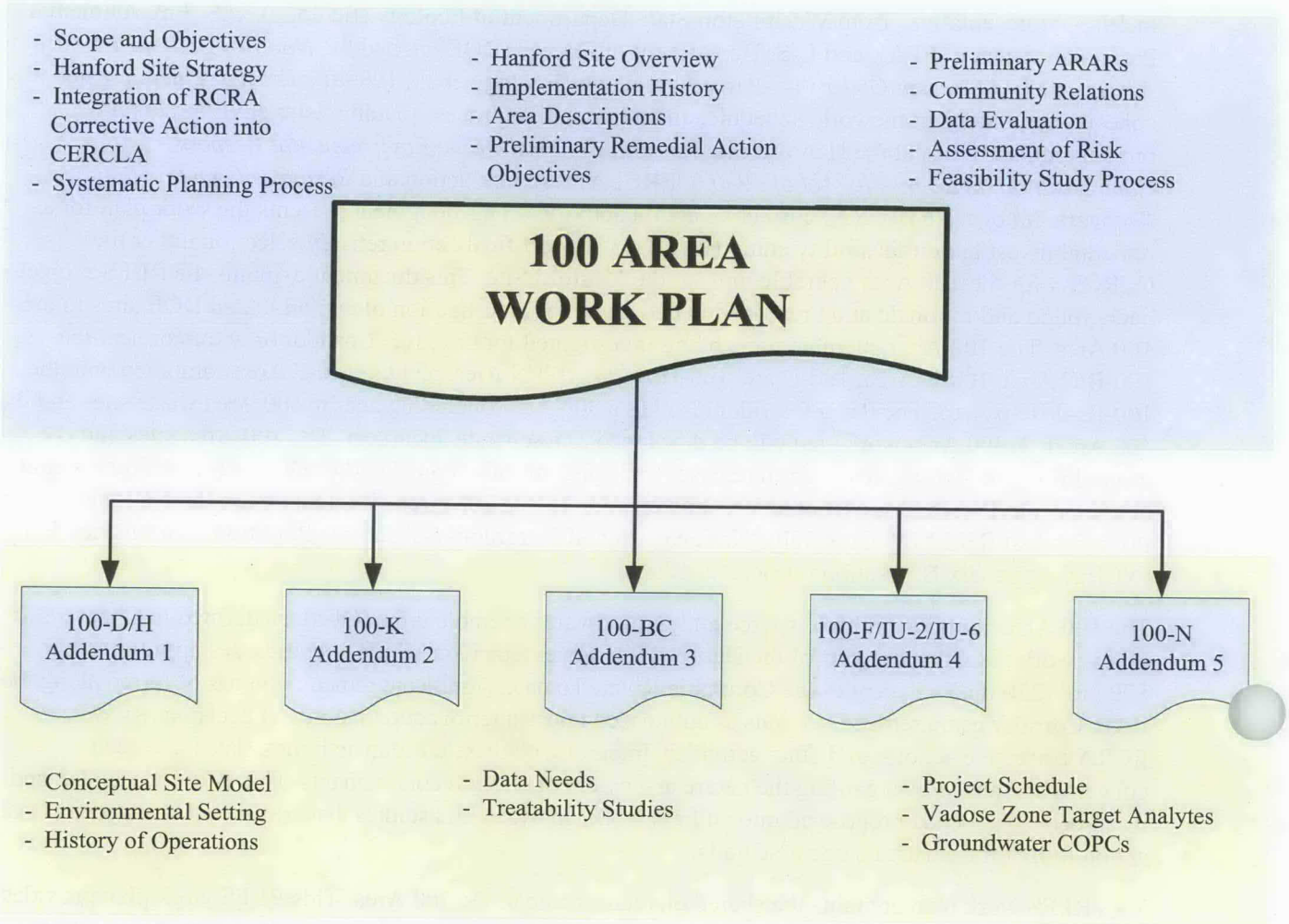
This RI/FS work plan contains the shared elements basic to the 100 Area. This RI/FS work plan provides the overall RI/FS project background, investigation rationale, and environmental setting common to the 100 Area, along with the project planning and management organization to be used. This document also includes a general overview of the investigation and remediation accomplishments in the 100 Area.

The work plan addendum for each 100 Area contains operable unit specific background, remedial investigation (RI) data needs, data collection plans, and associated sampling and analysis plans (SAPs). The SAP in each addendum includes a field sampling plan that provides the sampling strategy for a range of sampling techniques that will be used to obtain the supplemental data required for the RI. The SAP also provides a quality assurance project plan to ensure that data collected meet the appropriate quality assurance and quality control requirements.

The addenda correspond to the operable units, as follows, and will undergo phased development:

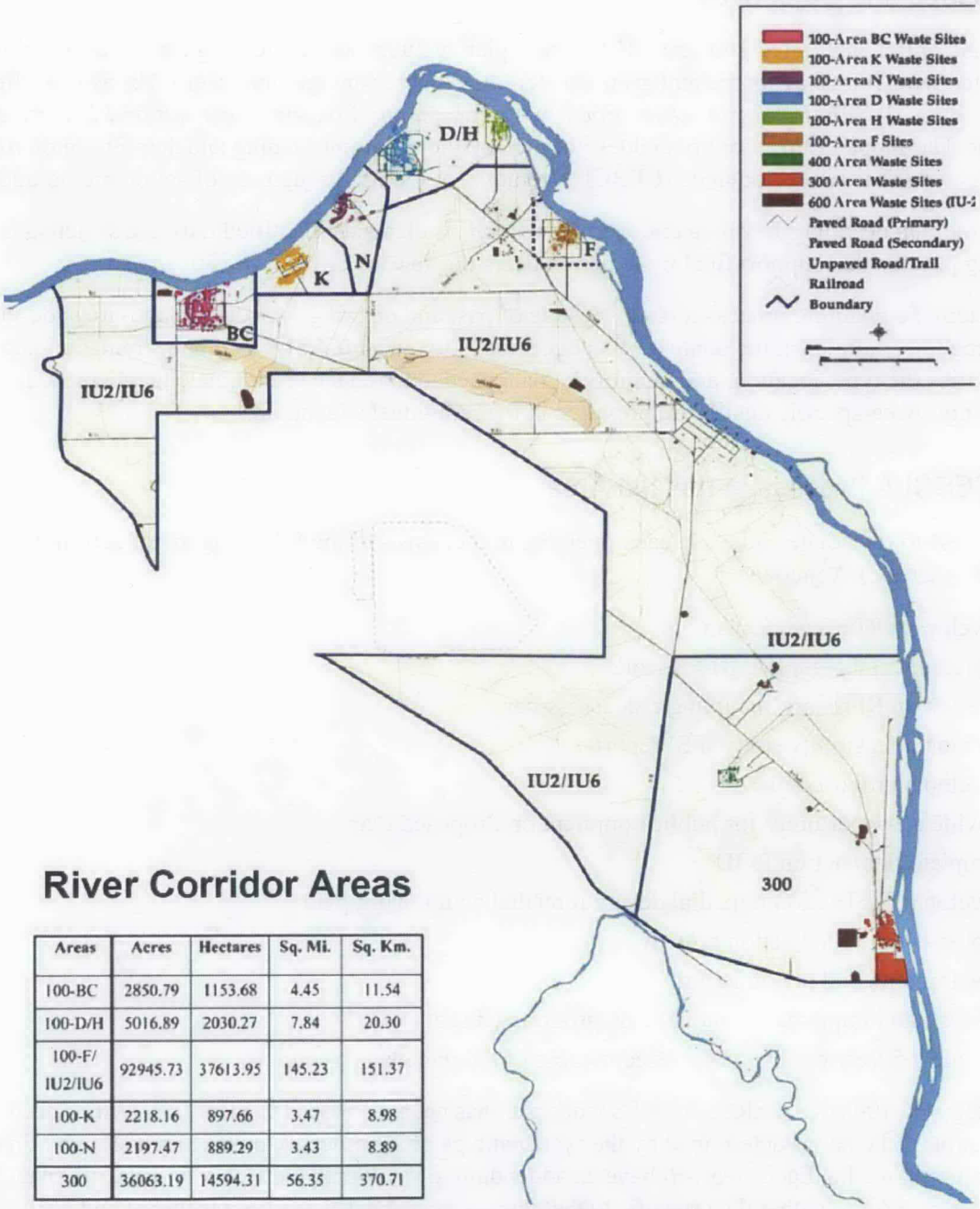
- Addendum 1: 100-DR-1, 100-DR-2, 100-HR-2, 100-HR-3 Operable Units
- Addendum 2: 100-KR-1, 100-KR-2, 100-KR-4 Operable Units
- Addendum 3: 100-BC-1, 100-BC-2, 100-BC-5 Operable Units
- Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, 100-IU-6 Operable Units
- Addendum 5: 100-NR-1, 100-NR-2 Operable Units

Figure 1-1 illustrates the relationship between the work plan and each addendum. Figure 1-2 shows the boundaries of the 100 and 300 Areas of the River Corridor.



ARAR applicable or relevant and appropriate requirement
CERCLA *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC contaminant of potential concern
RCRA *Resource Conservation and Recovery Act of 1976*

Figure 1-1. Relationship Between the Work Plan and Addenda



River Corridor Areas

Areas	Acres	Hectares	Sq. Mi.	Sq. Km.
100-BC	2850.79	1153.68	4.45	11.54
100-D/H	5016.89	2030.27	7.84	20.30
100-F/ IU2/IU6	92945.73	37613.95	145.23	151.37
100-K	2218.16	897.66	3.47	8.98
100-N	2197.47	889.29	3.43	8.89
300	36063.19	14594.31	56.35	370.71

Figure 1-2. River Corridor Boundaries

This work plan is prepared in accordance with the following guidance documents:

- EPA/540/G-89/004, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final, OSWER Directive 9355.3-01
- DOE/EH-94007658, Remedial Investigation/Feasibility Study (RI/FS) Process, Elements and Technical Guidance
- EPA/240/B-06/001, Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4

1.1 Scope and Objectives

The scope of this integrated 100 Area RI/FS work plan includes waste sites (e.g., trenches, pipelines) associated with 100 Area source and groundwater OUs. Source and groundwater OUs, as identified in Ecology et al., 1989b, *Hanford Federal Facility Agreement and Consent Order Action Plan*, are evaluated together. The scope of this work plan does not include the decommissioning and demolition of 100 Area buildings, which is addressed under CERCLA removal authority through use of action memoranda.

This work plan describes key data collection and analysis elements identified during a systematic planning process that support final remediation decisions in each of the five 100 Areas.

The systematic planning process includes results of past and ongoing remediation activities; describes the remaining uncertainties in the context of a conceptual site model (CSM)[4] to support remedial decisions; and justifies the type, location, and quantity of data needed to reduce or eliminate the identified uncertainty. Area-specific details are provided in the individual addendum.

1.2 CERCLA Process in the 100 Area

The process to remediate and close each operable unit consists of the following major activities, as defined by CERCLA guidance:

- Develop an RI/FS work plan
- Implement and complete RI/FS work
- Develop an RI report, including risk assessment
- Develop a feasibility study (FS) report
- Develop a proposed plan
- Provide an opportunity for public comment on Proposed Plan
- Complete final action ROD
- Develop a final action remedial design/remedial action work plan
- Implement the final action remedy
- Develop remedial action report
- Develop and implement a monitoring program (if required)
- Provide a 5-year review of the effectiveness of the remedy (if required)

This integrated 100 Area CERCLA RI/FS work plan has been developed to identify activities needed to gather additional data (as determined by the systematic planning process) to make an integrated final decision for all media. Each area will have an addendum to the overall CERCLA RI/FS work plan, which will include a SAP to gather data specific to that area. After the data have been gathered and analyzed, and the CSM has been updated, an FS will be performed for each area to identify and evaluate alternatives. A proposed plan that contains a summary of the investigation and evaluation and includes the preferred remedial alternative will be issued to the public for review and comment for each area encompassing the operable units within that area. After completion of this review and comment cycle, a final action ROD for

[4] A conceptual site model is a set of hypotheses and assumptions about the physical characteristics (e.g., media properties) and phenomena (e.g., model of fluid flow) that describe and postulate the behavior of contamination. The conceptual site model describes contaminant sources and receptors, and the interactions linking them. CSM is used to identify uncertainties and provide a framework to identify data and information needed to resolve each uncertainty. Conceptual site models evolve as new data and information are developed.

each area will be developed and approved by the Tri-Parties. The remedies then will be implemented. Should the remedies leave contamination in place, monitoring requirements will be identified in the monitoring program. The completed remedy that does not achieve unlimited use/unrestricted exposure is subject to a reviews every 5-years to verify long-term effectiveness and protection.

1.2.1 Integration with Ongoing Cleanup Activities

A feature of each area is the ongoing implementation of interim action RODs, CERCLA removal actions, RCRA corrective actions, treatability tests, and other activities (Section 1.4) to remediate contaminated areas or to develop more effective methods that advance remediation.

Implementation of these interim action ROD activities is generating information that allows an improved understanding of site complexity, supports refinement of the CSM, and documents the effectiveness of the remedial actions.

Cleanup of waste sites in accordance with the interim action RODs and focused FSs is ongoing and expected to continue until final action RODs are in place. As remedial actions under interim action RODs are completed, verification sampling and laboratory analyses are performed to document the extent to which remedial action goals (RAGs) established under the interim action RODs have been met. This information will be essential to supporting final action RODs.

There are many buildings and structures in the 100 Area. The buildings and structures are evaluated for removal, usually using a CERCLA removal action. Once these structures are demolished and decommissioned under CERCLA non-time-critical removal actions, samples of the residual soil may be collected for analysis. If the analytical results indicate that the area is contaminated, the area is considered a potential waste site. The area is then evaluated, and a remedy is selected in accordance with the interim action ROD.

Characterization data and information developed through implementation of remedial actions under interim action RODs and this work plan will be coordinated to reach a final action ROD. To support a final action remedy at each operable unit, the current remedial actions under interim action RODs for the 100 Area OUs will continue. While these remedial actions are underway, data will be generated to support final action decision making through the CERCLA process.

The 100 Area integrated RI/FS process will be concluded with a data summary for all media (i.e., surface soil, vadose zone, groundwater, and surface water) documented in the RI report, and evaluated through alternative analyses in the FS. The final action remedy selection completes the RI/FS process. Under CERCLA, 5-year reviews continue to be required to evaluate the effectiveness of remedial actions.

1.2.2 Past and Ongoing Risk Assessments

Past and ongoing risk assessments support the development of the final action RODs for the 100 Area operable units. Risk assessment supports development of preliminary remediation goals (PRGs) used to determine the need for a remedial action. Under this final action ROD process, the risk assessment process and results of the various risk assessments (completed or ongoing) will be evaluated and summarized to help make informed risk management decisions for each operable unit. Sources of information for risk characterization supporting the final action RI/FS include the following:

- Data collected during implementation of an interim action ROD
- Data packages developed as part of completion of a soil removal action
- Sampling conducted specifically for assessment of human health and ecological risk

- New and historical characterization activities
- New and historical groundwater monitoring activities

Past risk assessments include the qualitative risk assessment (QRA) supporting the interim action RODs and the River Corridor Baseline Risk Assessment (RCBRA), which were performed to evaluate protection of human health and the environment, including ecological receptors. Further details about these risk assessment activities, as well as the ongoing RIs for Hanford Site releases to the Columbia River, are provided in Chapter 4.0 of this work plan.

1.2.3 CERCLA Implementation History

In 1989, representatives from Ecology, EPA, and DOE signed the Tri-Party Agreement (Ecology et al., 1989a), which created a cohesive regulatory framework, schedule, and adjudication process to administer environmental remediation activities at the Hanford Site for both CERCLA response action and RCRA corrective action activities.

The Tri-Party Agreement (Ecology et al., 1989a) is composed of a Legal Agreement, an Action Plan, and several appendices. The Legal Agreement, Part 3, describes the legal requirements under which CERCLA will be applied. The Action Plan contains a description of the CERCLA remedial action process and its application at the Hanford Site. Specifically, Section 7 of the Action Plan describes the steps in the CERCLA process to address inactive waste sites and associated groundwater contamination. Section 8 describes the use of the CERCLA response action process to disposition inactive key facilities that have a potential to release CERCLA hazardous substances.

Appendices A and B to the Tri-Party Agreement Action Plan (Ecology et al., 1989b) also provide important context for implementing CERCLA at the Hanford Site. Appendix C of the Action Plan provides a list of all known past-practice waste sites to be addressed under CERCLA or RCRA corrective action and their grouping to form OUs. These OUs are groups of past-practice waste sites that can be characterized, assessed, and remediated as a group. In addition to source OUs, several Hanford Site groundwater contaminant plumes have been defined as groundwater OUs. Each OU is assigned to either EPA or Ecology as the lead regulatory agency. Appendix D of the Tri-Party Agreement (Ecology et al., 1989a) provides a list of milestones and schedules for implementing various CERCLA investigations and actions.

The 100 Areas have been subdivided into 18 OUs, including 13 source and 5 groundwater OUs, for the purpose of implementing the CERCLA process. Table 1-1 lists the OUs. Interim action RI/FS work plans were developed starting in early 1990.

Table 1-1. 100 Area Operable Units

Areas	Operable Units	Reactors
100-BC	100-BC-1 OU, 100-BC-2 OU, 100-BC-5 Groundwater OU	B Reactor C Reactor
100-D/H	100-DR-1 OU, 100-DR-2 OU, 100-HR-1 OU, 100-HR-2 OU, 100-HR-3 Groundwater OU	D Reactor DR Reactor H Reactor
100-F/IU-2/IU-6	100-FR-1 OU, 100-FR-2 OU, 100-FR-3 Groundwater OU, 100-IU-2 OU, 100-IU-6 OU	F Reactor
100-K	100-KR-1 OU, 100-KR-2 OU, 100-KR-4 Groundwater OU	KE Reactor KW Reactor
100-N	100-NR-1 OU, 100-NR-2 Groundwater OU	N Reactor

OU = operable unit

For each reactor area, interim action RI/FS work plans were prepared initially for a source OU containing liquid waste sites that constitute primary sources of groundwater contamination and the corresponding groundwater OU. Once the RI/FS process was underway for these OUs, additional interim action RI/FS work plans were prepared to investigate burial ground and other less-significant waste-site-based OUs.

For those OUs with the "isolated unit" designation, an approach and plan was developed (DOE/RL-95-108, *Approach and Plan for Cleanup Actions in the 100-IU-2 and 100-IU-6 Operable Units of the Hanford Site*, Rev. 0). This plan was a "focus package" that presented plans and schedules for addressing waste sites. Waste sites in these OUs were addressed through a combination of CERCLA removal and remedial actions.

The "key facilities" (as identified in Section 8 of the Tri-Party Agreement [Ecology et al., 1989a]) in the 100 Area include the 105-B, 105-C, 105-D, 105-DR, 105-F, 105-H, 105-KE, 105-KW, and 105-N Reactor Buildings. The CERCLA removal actions have been used to disposition these key facilities (with the exception of the B Reactor, which is a designated National Historic Landmark) into a safe and stable configuration known as "interim safe storage (ISS)," pending final decommissioning in the future.

For other 100 Area facilities, the CERCLA removal action process has been used for decommissioning. These facilities are smaller and far less complex than the key facilities subject to the requirements of Section 8 of the Tri-Party Agreement (Ecology et al., 1989a).

As a result of enacting the Tri-Party Agreement (Ecology et al., 1989a), several expedited response and interim remedial actions were implemented. Table 1-2 lists the decisions for remedial actions that have been issued for the 100 Area. The responses/actions resulting from the interim action RODs addressing contaminated soil consist principally of excavating contaminated soil for treatment (as required) and disposal. The responses for contaminated groundwater are designed as interim actions to keep selected principal threat contaminants from reaching the Columbia River. The action memorandums directed the efforts to place the reactors in ISS condition.

Table 1-2. List of Decisions for the 100 Area

ROD Fiscal Year	ROD Type	Operable Units Affected	ROD Number	Internet Link
2009	ESD	100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, 200-CW-3	See note 1	http://www5.hanford.gov/arpir/?content=findpage&AKey=0908240150.
2007	ESD	Source units in the 100 Areas	See note 2	http://www5.hanford.gov/arpir/?content=findpage&AKey=DA06144408.
2005	AMD	100-KR-2	See note 3	http://yosemite.epa.gov/R10/CLEANUP.NSF/9f3c21896330b4898825687b007a0f33/af62704e19f69e868825652c007e9288/$FILE/K%20Basins%20ROD%20Amendment%209June2005%20-Final.pdf.

Table 1-2. List of Decisions for the 100 Area

ROD Fiscal Year	ROD Type	Operable Units Affected	ROD Number	Internet Link
2004	ESD	Source units in the 100 Areas	See note 4	http://www5.hanford.gov/arpir/?content=findpage&AKey=D4855290/
2003	ESD	100-NR-1 and 100-NR-2	EPA/ESD/R10-03/605	http://www.epa.gov/superfund/sites/rods/fulltext/e1003605.pdf.
2003	ESD	100-HR-3	EPA/ESD/R10-03/606	http://www.epa.gov/superfund/sites/rods/fulltext/e1003606.pdf.
2000	ROD	100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 (100 Area Burial Grounds)	EPA/ROD/R10-00/121	http://www.epa.gov/superfund/sites/rods/fulltext/r1000121.pdf.
2000	ESD	100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 (100 Area Remaining Sites)	EPA/ESD/R10-00/045	http://www.epa.gov/superfund/sites/rods/fulltext/e1000045.pdf.
2000	ROD	100-NR-1	EPA/ROD/R10-00/120	http://www.epa.gov/superfund/sites/rods/fulltext/r1000120.pdf.
2000	AMD	100-HR-3	EPA/AMD/R10-00/122	http://www.epa.gov/superfund/sites/rods/fulltext/a1000122.pdf.
1999	ROD	100-NR-1 and 100-NR-2	EPA/ROD/R10-99/112	http://www.epa.gov/superfund/sites/rods/fulltext/r1099112.pdf.
1999	ROD	100-KR-2	EPA/ROD/R10-99/059	http://www.epa.gov/superfund/sites/rods/fulltext/r1099059.pdf.
1999	ROD	100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3	EPA/ROD/R10-99/039	http://www.epa.gov/superfund/sites/rods/fulltext/r1099039.pdf.
1997	AMD	100-BC-1, 100-DR-1, and 100-HR-1	EPA/AMD/R10-97/044	http://www.epa.gov/superfund/sites/rods/fulltext/a1097044.pdf.
1996	ROD	100-HR-3 and 100-KR-4	EPA/ROD/R10-96/134	http://www.epa.gov/superfund/sites/rods/fulltext/r1096134.pdf.
1996	ROD	100-IU-1, 100-IU-3, 100-4, and 100-IU-5	EPA/ROD/R10-96/151	http://www.epa.gov/superfund/sites/rods/fulltext/r1096151.pdf.
1995	ROD	100-BC-1, 100-DR-1 and 100-HR-1	EPA/ROD/R10-95/126	http://www.epa.gov/superfund/sites/rods/fulltext/r1095126.pdf.

Table 1-2. List of Decisions for the 100 Area

ROD Fiscal Year	ROD Type	Operable Units Affected	ROD Number	Internet Link

Notes:

Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision, August 2009. No document number has been issued.

Explanation of Significant Difference for the Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units (100 Area Burial Grounds), October 2007. No document number has been issued.

June 2005 ROD amendment (no document number) was issued for the K Basins and is not included as part of the 100 Areas RI/FS Work Plan scope.

Explanation of Significant Differences for 100 Area Remaining Sites Interim Remedial Action Record of Decision, February 2004. No document number has been issued.

Source: "Record of Decision System (RODS) Hanford 100-Area (USDOE)," EPA, 2009a

AMD = Amendment

EPA = U.S. Environmental Protection Agency

ESD = explanation of significant difference

RI/FS = Remedial Investigation/Feasibility Study

ROD = record of decision

TBD = to be determined

Appendix A of this work plan provides a summary of the CERCLA process implementation to date for 100 Area source and groundwater OUs. Figure 1-3 provides a timeline of 100 Area CERCLA decisions. For source OUs, the cleanup strategy for the remedial action remedy under the interim action RODs was removal, treatment (as required), and disposal (RTD) of contaminated soil from liquid waste disposal sites responsible for groundwater contamination. Additional cleanup decisions and ROD amendments were implemented in subsequent years to address additional waste sites and radioactive waste burial grounds in other OUs.

Figure 1-3 also provides a chronology of groundwater OU decisions. The 100 Area groundwater OU decisions addressed contaminants that represent a principal threat through the groundwater pathway. Hexavalent chromium (CrVI) and Strontium-90 (Sr-90) were identified as principal threats to the Columbia River and aquatic receptors. Actions to mitigate the impacts of CrVI were initiated in the 100-HR-3 and 100-KR-4 Groundwater OUs. In the 100-NR-2 OU, actions were undertaken to reduce the amount of Sr-90 entering the river through riverbank springs.

Each of these decisions resulted in interim action remedial activities (e.g., pump-and-treat systems, waste site excavation, facility demolition, reactor ISS, groundwater treatability studies) that were designed to mitigate potential risks, protect groundwater, and protect the Columbia River.

All but one of the RODs *(EPA Superfund Record of Decision: Hanford 100-Area [USDOE] EPA ID: WA3890090076, OU 21 Benton County, WA*, EPA/ROD/R10-96/151) issued for the 100 Area are interim action RODs. The process to incorporate these remedial actions into the final action CERCLA process for the 100 Area is illustrated in Figure 1-4. The interim action ROD remedial activities have provided further data for use, and also identified additional uncertainties to address during the final action RI/FS process.

1.2.4 Regulatory Path Forward for the Hanford Site

The 1993 NEPA *Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (58 FR 48509) documents DOE's decision of ISS followed by one-piece removal to a Central Plateau disposal facility. N Reactor was not included in the environmental impact statement (EIS) as it was not available for decommissioning at the time of the *National Environmental Policy Act of 1969* (NEPA) EIS and would be addressed by a subsequent NEPA or CERCLA decision process. In August 2005, an Engineering Evaluation (DOE/RL-2005-45, *Surplus Reactor Final Disposition Engineering Evaluation*, Rev. 0) evaluated the NEPA ROD decision and determined that the NEPA alternatives remained viable. B Reactor has been designated as a National Historic Landmark and will be placed in a configuration consistent with that use for the foreseeable future. For all reactors except B, ISS actions, selected through the CERCLA removal action process, are designed to prevent deterioration and release of contamination from the reactors for up to 75 years.

The NEPA ROD for the reactors also indicated DOE's intent to complete these reactor-decommissioning actions consistent with the proposed cleanup schedule for CERCLA remedial actions. DOE will evaluate the coordination of the final decommissioning actions with the completion of remaining actions in each area within the CERCLA RI/FS report for each area (Table 1-3). DOE will also evaluate, in those RI/FS reports, remedial alternatives for waste sites in close proximity to the reactors: i.e., waste sites that underlie or are so close to the reactors that they cannot be remediated by remove-treat-dispose prior to final reactor decommissioning.

Final reactor decommissioning actions could be established through either a NEPA ROD and implemented through DOE's *Atomic Energy Act of 1954* (AEA) authority, or through a CERCLA decision and action. Until reactor removal is complete, DOE will continue to conduct routine maintenance, surveillance, and radiological monitoring activities to ensure continued protection of human health and the environment during the interim storage period. Actions needed to address potential environmental releases associated with reactor footprints before reactors are removed will be specified in the CERCLA decision. The RI/FS for each area will include a discussion and analysis of both the options for reactor removal and a strategy for coordinating reactor removal activities with other cleanup activities in the CERCLA final action ROD.

Table 1-3. Hanford Reactor Status and Final Disposition

Reactor	Current Status*	Area	Final Disposition
B	National Historic Landmark 2008	100-BC	ROD for Decommissioning of Eight Surplus Production Reactors EIS (58 FR 48509).
C	ISS since 1998		
D	ISS since 2004	100-D/H	
DR	ISS since 2002		
H	ISS since 2005		

Table 1-3. Hanford Reactor Status and Final Disposition

Reactor	Current Status*	Area	Final Disposition
F	ISS since 2003	100-F/IU-2/IU-6	
KE	ISS to be completed	100-K	
KW	ISS to be completed		
N	ISS to be completed	100-N	Final disposition will be addressed by NEPA or CERCLA decision.

* ISS decisions made through CERCLA removal action authority.

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

EIS = environmental impact statement

ISS = interim safe storage

NEPA = *National Environmental Policy Act*

ROD = Record of decision

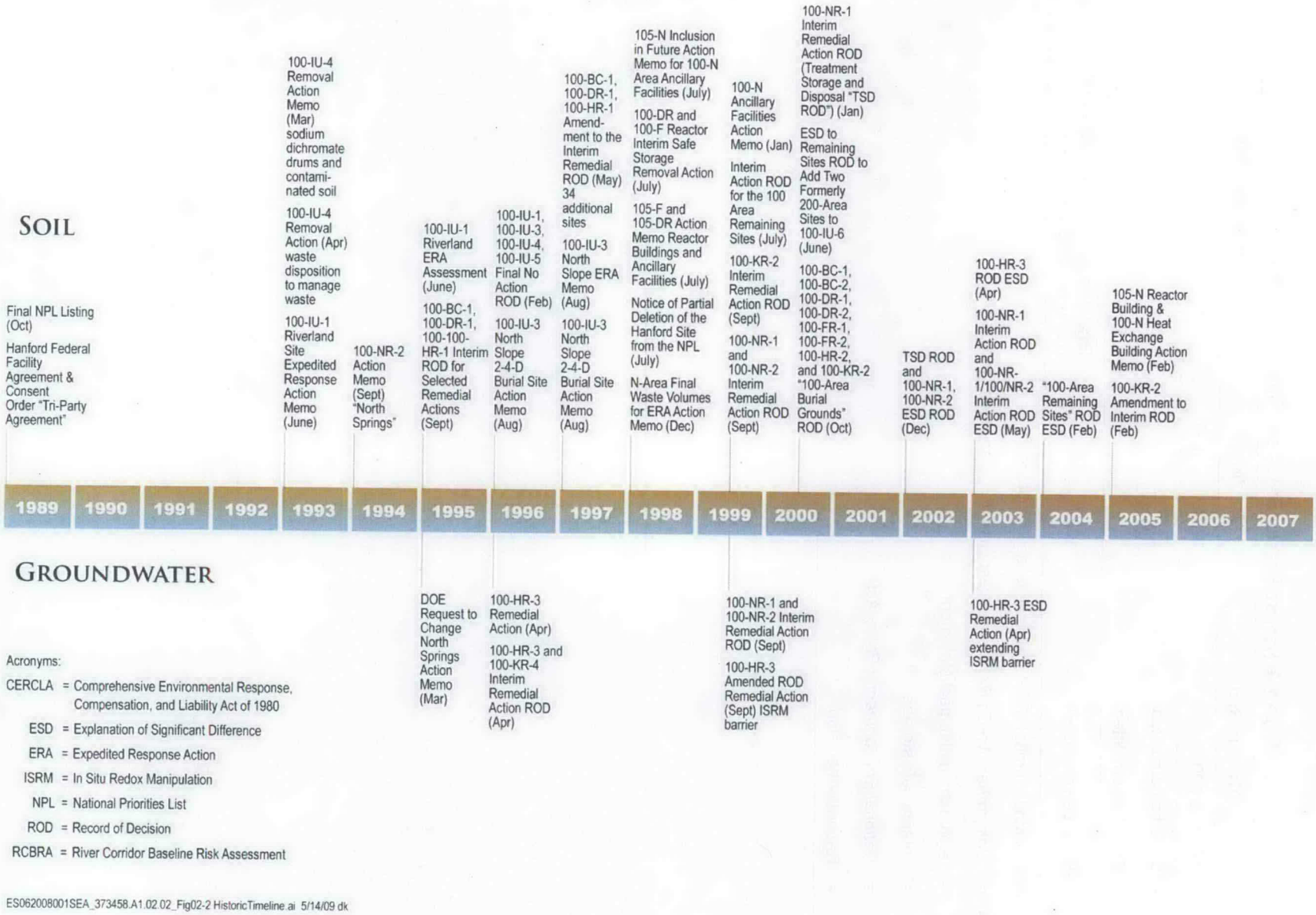


Figure 1-3. Historic Timeline of CERCLA Decisions

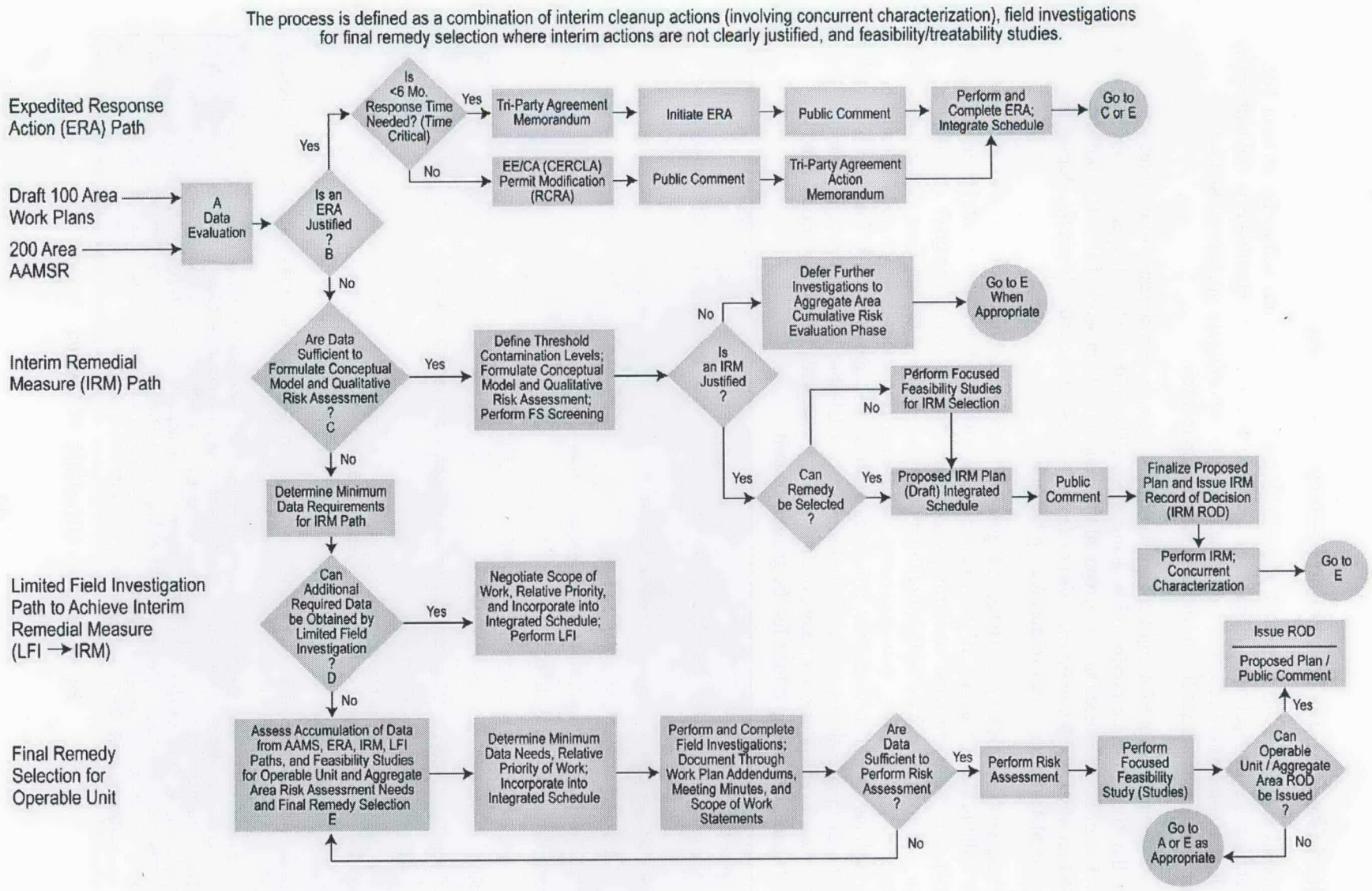


Figure 1-4. Hanford Site Past-Practice Remedial Investigation/Feasibility Study Process

1.3 Hanford Site Cleanup Completion Framework – Summary

The key elements of Hanford Site Cleanup Completion framework are summarized in this section. The framework defines the principal components of cleanup – River Corridor, Central Plateau, and tank waste – and provides the context for individual cleanup actions by establishing the approaches and key principles for those decisions needed to complete the cleanup mission.

The DOE, in cooperation with EPA and Ecology, is developing a strategy to achieve final cleanup decisions for the River Corridor portion of the Hanford Site. The DOE, Richland Operations Office (RL) and DOE, Office of River Protection have prepared the completion framework (DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework*) to describe that strategy and to begin developing the approach to complete the remainder of the cleanup mission.

The overarching goals for cleanup are stated in Figure 1-5. These goals embody more than 20 years of consultation with the Tribal Nations, 17 years of consultation with the Hanford Natural Resource Trustees (Trustees) and dialogue between the Tri-Parties, stakeholders, and the public. The goals consider key values captured in forums such as the Hanford Future Site Uses Working Group, Tank Waste Task Force, Hanford Summits, Tribal Nation values statements, and Hanford Advisory Board (HAB) Exposure Scenario Workshops, as well as more than 200 pieces of advice issued by the HAB. These goals provide a set of principles that guide all aspects of Hanford Site cleanup. Cleanup activities at various areas of the site support the achievement of one or more of these goals. These goals help set priorities to apply resources and sequence cleanup efforts for the greatest benefit.

Goal 1: Protect the Columbia River.

Goal 2: Restore groundwater to its beneficial use* to protect human health, the environment, and the Columbia River.

Goal 3: Clean up River Corridor waste sites and facilities to:

- Protect groundwater and the Columbia River
- Shrink the active cleanup footprint to the Central Plateau
- Support anticipated future land uses

Goal 4: Clean up Central Plateau waste sites, tank farms, and facilities to:

- Protect groundwater and the Columbia River
- Minimize the footprint of areas requiring long-term waste management activities
- Support anticipated future land uses

Goal 5: Safely manage and transfer legacy materials scheduled for offsite disposition including special nuclear material (including plutonium), spent nuclear fuel, transuranic waste, and immobilized high-level waste.

Goal 6: Consolidate waste treatment, storage, and disposal (TSD) operations on the Central Plateau.

Goal 7: Develop and implement institutional controls and long-term stewardship activities that ensure protection of human health and the environment after cleanup activities are completed.

* EPA expects to return usable groundwaters to their beneficial uses wherever practical, within a period that is reasonable given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practical, EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater and evaluate further risk reduction" 40 CFR 300.430(a)(1)(iii)(F). The state requirements, RCRA and MTCA (WAC 173-340), establish that groundwater cleanup levels shall be based on the estimates of the highest beneficial use. For most sites, the use of groundwater as a source of drinking water is the beneficial use requiring the highest quality of groundwater. [WAC 173-303-64620(4), WAC 173-340-720(1)(a), WAC 173-303-610(2)(b)(i)].

Figure 1-5. Overarching Goals for Cleanup

These goals recognize that the Columbia River (Figure 1-6) is a critical resource for the people and ecology of the Pacific Northwest. As one of the largest rivers in North America, its waters support a multitude of uses that are vital to the economic and environmental well being of the region. Cleanup actions must protect this river.

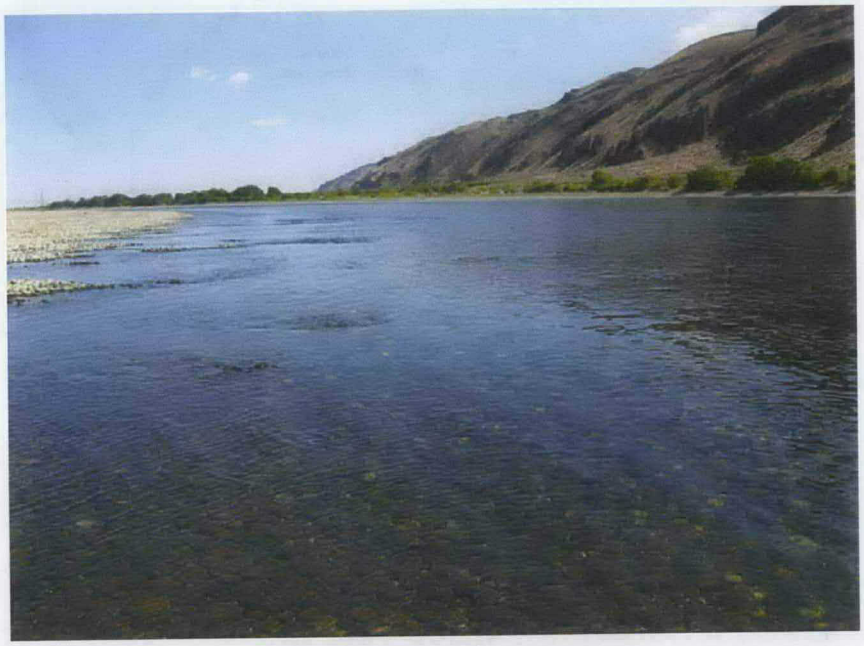


Figure 1-6. Columbia River

The Hanford Site cleanup consists of three major components: (1) River Corridor, (2) Central Plateau, and (3) tank waste (note that the tank waste component is contained within the Central Plateau). Each component of cleanup is in itself a complex and challenging undertaking involving multiple projects and contractors and requiring many years and billions of dollars to complete. These components are shown in Figure 1-7.

River Corridor Cleanup. The River Corridor includes more than 518 km^2 (200 mi^2) of the Hanford Site as shown in Figure 1-7. The River Corridor portion of the Hanford Site includes the 100 and 300 Areas along the south shore of the Columbia River. The 100 Area contains nine retired plutonium production reactors, numerous support facilities, solid and liquid waste disposal sites, and contaminated groundwater. The 300 Area, located north of the city of Richland, contains fuel fabrication facilities, nuclear research and development facilities, associated solid and liquid waste disposal sites, and contaminated groundwater. For the purposes of this completion strategy and ensuring that cleanup actions address all threats to human and environmental health, the River Corridor includes the contiguous areas that extend from the 100 Area and 300 Area to the Central Plateau.

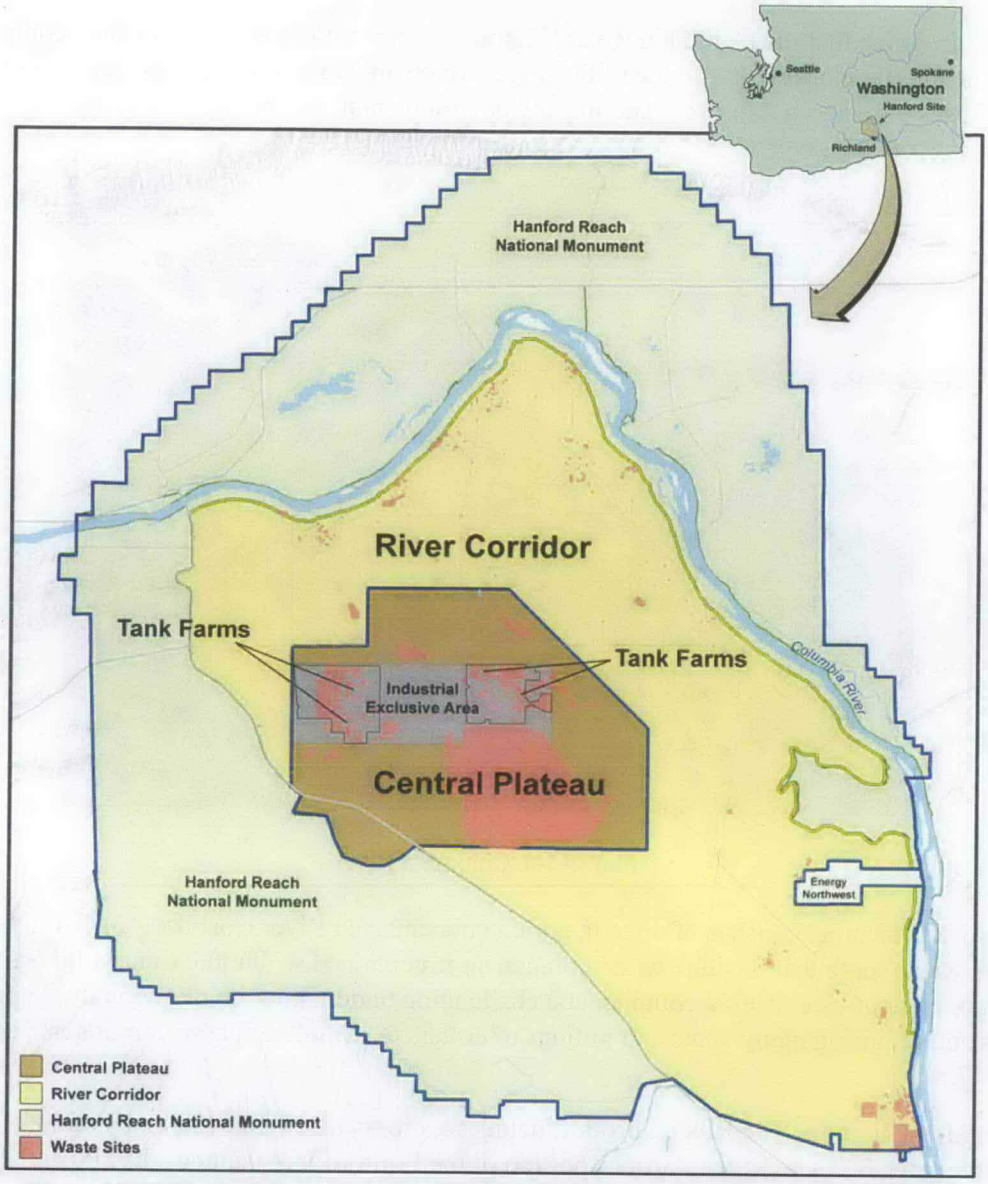


Figure 1-7. Principal Components of Hanford's Cleanup Completion Framework: River Corridor, Central Plateau, and Tank Waste

For sites in the River Corridor, remedial actions are expected to restore groundwater to drinking water standards and to ensure that the aquatic life in the Columbia River is protected by achieving ambient water quality standards where there are ecological receptors, including the hyporheic zone. It is intended that these objectives be achieved, unless technically impracticable, within a reasonable time frame. In those instances where remedial action objectives (RAOs) are not achievable in a reasonable time frame or are determined to be technically impracticable, programs will be implemented to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction opportunities as new technologies become available. River Corridor cleanup work also removes sources of contamination that are close to the Columbia River to the Central Plateau for final disposal or to other disposal facilities as appropriate. The intent is to shrink the footprint of active cleanup to within the 194 km^2 (75 mi^2) area of the Central Plateau by removing excess facilities and remediating waste sites. Cleanup actions will support anticipated future land uses.

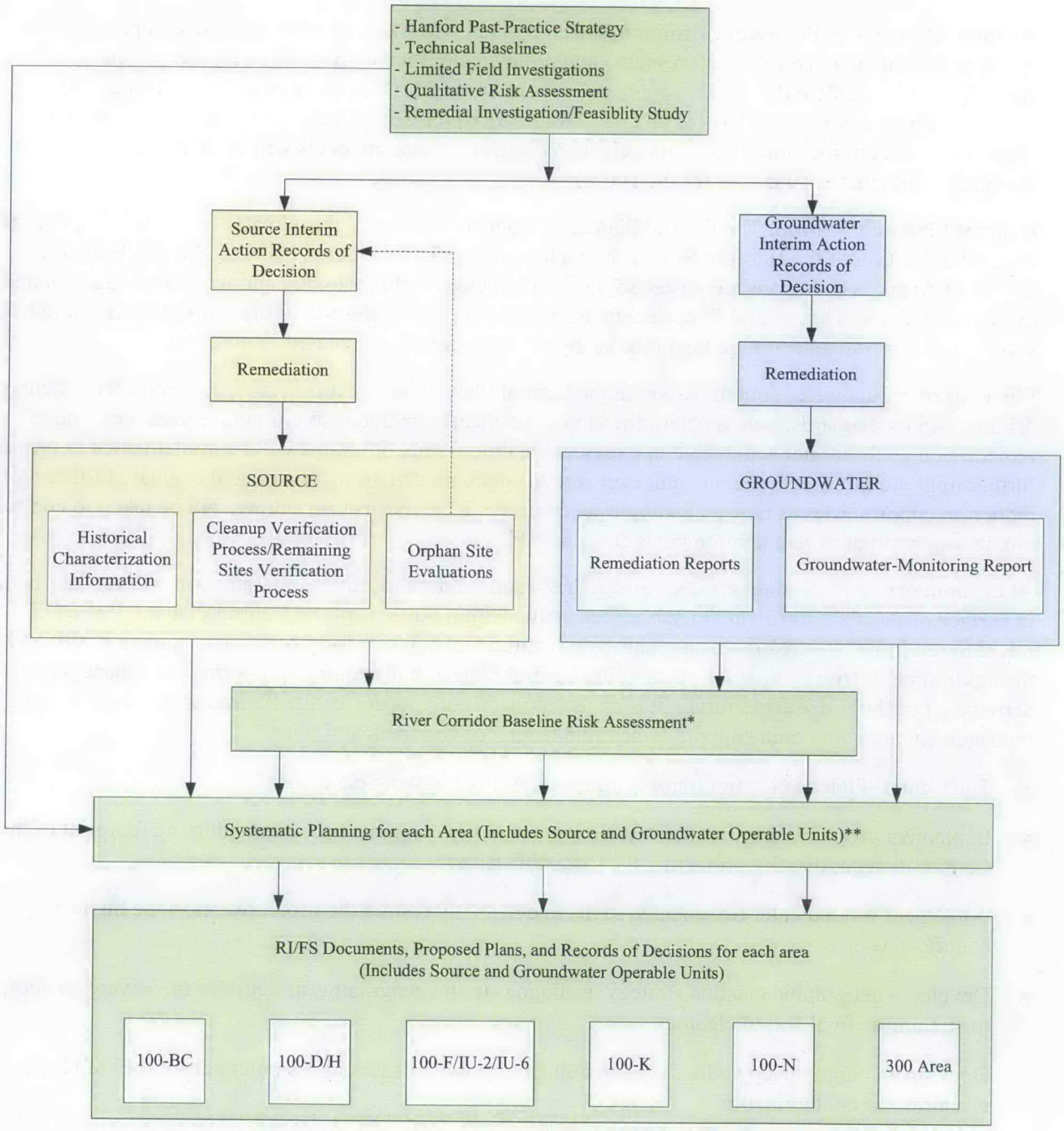
To complete cleanup, the River Corridor has been divided into six geographic areas encompassing all operable units to achieve final action source and groundwater remedy decisions. Figure 1-8 illustrates how DOE will complete RI/FSs for source and groundwater OUs. These final action decisions will provide comprehensive coverage for all areas within the River Corridor and will incorporate interim action cleanup activities into final action cleanup decisions. Cleanup levels will be achieved that support reasonably anticipated land uses for the 100 Area.

Central Plateau Cleanup. The Central Plateau component includes approximately 194 km^2 (75 mi^2) in the central portion of the Hanford Site as shown in Figure 1-7. This region contains the 200 East and 200 West Areas, which have been used primarily for nuclear fuel processing and waste management and disposal activities. The Central Plateau contains processing and support facilities, tank systems, liquid and solid waste disposal and storage facilities, utility systems, and contaminated groundwater.

For areas of groundwater contamination in the Central Plateau, the goal is to restore the aquifer to achieve drinking water standards, unless determined to be technically impracticable. In those instances where remediation goals are not achievable in a reasonable time frame, programs will be implemented to prevent further migration of the plume, prevent exposure to contaminated groundwater, and evaluate further risk reduction opportunities as new technologies become available. Near-term actions will be taken to control plume migration until remediation goals are achieved.

At the completion of cleanup efforts, residual hazardous and radioactive contamination will remain, both in surface disposal facilities and in subsurface media within portions of the Central Plateau. It is DOE's intent to minimize the area requiring long-term institutional controls for protection of human health and the environment. However, some areas of the Central Plateau will require long-term waste management activities. For the foreseeable future, it is expected that a core portion of the Plateau will remain a waste management area but could support compatible federal government activities.

- The Central Plateau cleanup framework includes the following elements:
- Implement groundwater treatment systems to contain contaminant plumes within the footprint of the Central Plateau, thereby protecting the Columbia River.
- Implement groundwater treatment systems to eventually restore the groundwater to the highest beneficial use.
- Develop a geographic cleanup strategy, analogous to the geographic strategy for the River Corridor, to streamline final action cleanup.
- Develop and apply deep vadose zone treatment technologies to address potential sources of future groundwater contamination.
- Remediate the outer portion of the Central Plateau to further reduce the active cleanup footprint of the Hanford Site.
- Remediate the inner portion of the Plateau to minimize the area requiring long-term waste management activities.
- Implement cleanup decisions to support anticipated future land use.
- Regularly evaluate new and improved cleanup technologies to assess their potential to improve cleanup effectiveness and to allow for greater footprint reduction.



* Ecological evaluations were performed at 20 sites, human health evaluations were performed at 164 sites and groundwater evaluations were based on samples from 320 groundwater monitoring wells between 1998 and 2008.
** Information from completed treatability tests was also used during the systematic planning process.

Figure 1-8. Strategy for Alignment of Records of Decision for the River Corridor

Tank Waste Cleanup. Within the Central Plateau, the efforts of the Tank Waste component are responsible for retrieving and treating the Hanford Site's tank waste and for closing or remediating tank farms (Figure 1-7) to protect the groundwater on the Central Plateau, thereby protecting the Columbia River. The tank farms include 177 underground storage tanks (149 single-shell tanks and 28 double-shell

tanks) containing approximately 200 million L (53 million gal.) of chemically hazardous radioactive waste from past nuclear processing operations. Sixty-seven of the Hanford Site tanks are confirmed or presumed to have leaked up to 3,780,000 L (1 million gal.) of contamination into the ground.

The tank waste cleanup strategy includes the following elements:

- Complete construction of the Waste Treatment Plant.
- Provide sufficient treatment capacity to enable mission completion.
- Begin treatment and immobilization of tank waste to enable tank retrieval to proceed at a rate that supports treatment capacity.
- Store tank waste safely until it is retrieved for treatment.
- Implement remedies that protect the groundwater and environment from past tank farm releases – in conjunction with surrounding waste sites and groundwater OUs.
- Complete closure of tank farms in coordination with, and consistent with, the Central Plateau cleanup completion strategy.

Long-Term Stewardship and Legacy Management. Following the implementation of site cleanup actions, there will be disposal facilities and other areas that will necessitate long-term management activities. Natural resource restoration activities and long-term stewardship activities will be required for portions of the Hanford Site to ensure protection of human health and the environment. If the completion of cleanup will not result in the total restoration of all natural resources injured by a release, the United States is required to resolve natural resource damage liability.

The DOE is committed to maintaining the protection of human health and the environment and to meeting its long-term, post-cleanup obligations in a safe and cost-effective manner. The completion of cleanup and the transition to long-term stewardship are approaching. Therefore, actions are being considered and taken today to minimize natural resource concerns and ensure long-term stewardship considerations are incorporated into the cleanup decisions.

1.4 100 Area Remediation Overview

Environmental remediation under CERCLA was first initiated on the Hanford Site in 1996 and continues today. Since that time, DOE has taken actions to characterize groundwater plumes and their potential sources, evaluate alternative treatment methods, and remediate groundwater and soil. All these activities provide data and information to support the development of work plans. Table 1-4 provides a list and brief summary of selected activities and investigations that have been conducted to date in the 100 Area. Further details on these activities are provided in Chapter 3.0.

Table 1-4. Examples of Activities Providing Information and Data to Support Development of Remedial Investigation/Feasibility Study Work Plans (Through December 2008)

Activity Name	Accomplishments/Investigations
Facility D4 Actions	Over 300 structures have been demolished in the 100 Area. In addition, five 100 Area reactors have been placed in ISS.
Waste Site Remediation Program	Remediation in accordance with the interim action RODs occurred at more than 155 waste sites, including 78 of 82 high-priority liquid waste sites*, which have been backfilled with clean soil. Approximately, a total of 8 million tonnes (9 million tons) of contaminated soil have been disposed at the ERDF.
Spent Nuclear Fuel and Related Sludge Removal Actions	Approximately 2,100 tonnes (2,300 tons) of spent nuclear fuel and up to 30 cubic meters (40 cubic yards) of sludge, 9.1 million liters (2.4 million gal.) of water, and hundreds of tons of debris and fuel racks (solid waste) were removed from two basins that are located less than a quarter-mile from the Columbia River.
Orphan Site Evaluation Program	Orphan site evaluations have been completed across 25 percent of the River Corridor. Most of the remaining area is within the 100-F/IU-2/IU-6 "inter areas." Over 14,190 ha (35,058 ac) have been assessed through the orphan site evaluations to identify new waste sites.
River Corridor Baseline Risk Assessment	The assessment provided an analysis of human health and ecological risk in the River Corridor.
Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River	This plan described efforts to collect data for an evaluation of the nature and extent of contamination and current risk to humans, animals, and plants exposed to Hanford Site related contaminants. Samples of pore water, sediment, surface water, fish, and island soil collected in 2008 and 2009.
100-K, 100-D, 100-H, and 100-N Areas Pump-And-Treat Systems	The 100-K, 100-D, and 100-H large pump-and-treat systems have treated over 7.6 billion L (2 billion gal.) of groundwater and removed nearly one ton of CrVI from the aquifer. The 100-N Pump-and-Treat system has removed 1.8 curies of Sr-90 and is currently in cold standby.
Remediation Process Optimization	This process provides a systematic evaluation and enhancement of the current site remediation actions to foster improved cleanup performance and reduce cost.
Groundwater Monitoring	All HEIS groundwater monitoring data available through December 2008 from all groundwater monitoring wells constructed in the River Corridor will be evaluated.
Aquifer Tube Sampling	More than 400 aquifer tubes have been installed at the Hanford Site since 1997. These aquifer tubes are sampled to provide data on the nature and extent of contaminants in groundwater at locations adjacent to the Columbia River.
Biostimulation Test	Molasses was injected at the 100-D Area biostimulation treatability test site to nourish bacteria that can reduce CrVI to trivalent chromium, which is less toxic and less mobile than CrVI.
Electrocoagulation Test	New technology enabled cost-effective remediation of CrVI contaminated groundwater.
In Situ Redox Manipulation	By injecting non-toxic chemicals into an aquifer, ISRM can successfully immobilize contaminants to aquifer sediments, or reduce contaminants to a less toxic form (e.g., reduce CrVI to trivalent chromium).
Fortifying ISRM Barrier with Iron	Maintaining the ISRM barrier depends on the presence of naturally occurring iron. Studies have shown that fortifying the barrier with more iron offers a sustainable long-term repair.

Table 1-4. Examples of Activities Providing Information and Data to Support Development of Remedial Investigation/Feasibility Study Work Plans (Through December 2008)

Activity Name	Accomplishments/Investigations
Apatite Barrier Installation	The barrier removes Sr-90 from groundwater and allows it to radioactively decay in the soil by binding Sr-90 from the groundwater into the apatite mineral matrix.
Petroleum Hydrocarbon Remediation at 100-N Area	Installed boreholes and wells for ongoing monitoring, natural attenuation, and bioremediation of groundwater and vadose zone.
Polysulfide Injection	New technology was tested to reduce CrVI within groundwater.
Phytoremediation Field Demonstration	Phytoremediation, using the Coyote willow (a common plant that grows along the banks of the Columbia River), can be used to extract Sr-90 from the groundwater prior to its migration to the Columbia River.

* High priority waste sites are identified in limited field investigation (LFI) reports and interim action RODs that pose risk(s) through one or more pathways sufficient to recommend streamlined action via an interim action remedial measure.

CrVI = hexavalent chromium

D4 = deactivation, decontamination, decommissioning, and demolition

ERDF = Environmental Restoration Disposal Facility

HEIS = Hanford Environmental Information System

ISRM = In situ redox manipulation

ISS = interim safe storage

ROD = record of decision

Sr-90 = strontium-90

1.5 Systematic Planning

The EPA *Policy and Program Requirements for the Mandatory Agency-Wide Quality System* (CIO 2105.0) requires that a process be used in a systematic fashion for projects involving environmental data. EPA recommends a data quality objective (DQO) process for a systematic planning tool. The systematic planning process used for the 100 Area RI/FS work plan consisted of the following steps:

1. For the 100-D, 100-H, 100-K, and 300 Area, interviews were conducted with interested parties including DOE, EPA, Ecology, Tribal Nations, Natural Resource Trustees, and stakeholders to generate a list of concerns to guide development of project components.

2. Presentation plates of CSM components were developed to identify principal study questions, supporting information, and resulting data gaps requiring further evaluation.

3. Work sessions were held with the Tri-Parties to present, discuss, and collect comments on the plates. These comments primarily took the form of uncertainties that were further evaluated in smaller agency and contractor groups (uncertainty teams).

4. Input from both the working sessions and uncertainty teams supported updating of the CSM plates, which included both principal study questions and data gaps. A process of collecting and responding to regulator comments was conducted.

Upon the completion of the CSM plates, the data needs and proposed sampling approaches were developed and outlined in the 100 Area addenda. This development utilized the CSM plates, outcomes of the working sessions, outcomes of the uncertainty teams, and existing data.

A summary table (provided in Chapter 4.0 of the addenda) is included to link proposed sampling to each data need.

Tribal Nations, Trustees, and stakeholders were informed of progress via traditional mechanisms, such as the Hanford Advisory Board's River and Plateau Committee and the Natural Resource Trustee Council.

2 Background and Setting

This chapter provides a brief overview of the Hanford Site 100 Area, identifies the areas, and describes the environmental setting of the 100 Area.

2.1 100 Area Overview

The 100 Area is located in the northern portion of the Hanford Site, along the southern shore of the Columbia River (Figure 2-1). The Hanford Site, managed by DOE, encompasses approximately 1,517 km^2 (586 mi^2) in the Pasco Basin of south-central Washington State. The Hanford Site was selected for plutonium production in 1942 as part of the Manhattan Project because of the availability of water from the Columbia River and access to power from Bonneville and Grand Coulee Dams.

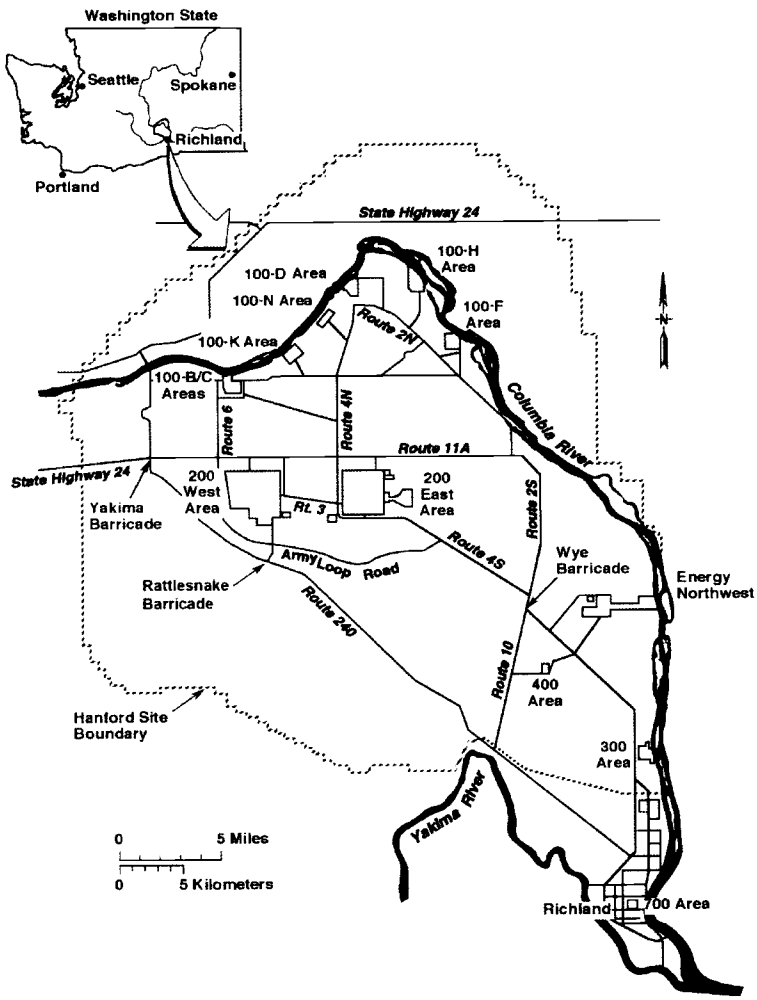


Figure 2-1. Location of the Hanford Site and the 100 Areas

Between 1943 and 1964, nine plutonium (Pu) production reactors were built along the Columbia River in six areas: the 100-B/C, 100-K, 100-N, 100-D, 100-H, and 100-F (Table 2-1). Operations began with the B Reactor, followed in chronological order by D, F, H, DR (built as a replacement for D Reactor), C, KW and KE, and N Reactors. Only the N Reactor was constructed with a closed loop coolant circuit and a secondary use of steam production for power generation at the Hanford Generating Plant.

Table 2-1. Construction and Operational Periods for 100 Area Reactors

Reactor	Construction Start	Operations Start	Operations Stop
B	Aug 1943	Sep 1944	Feb 1968
D	Nov 1943	Dec 1944	Jun 1967
F	Dec 1943	Feb 1945	Jun 1965
DR	Dec 1947	Oct 1950	Dec 1964
H	Mar 1948	Oct 1949	Apr 1965
C	Jun 1951	Nov 1952	Apr 1969
KW	Nov 1952	Dec 1954	Feb 1970
KE	Jan 1953	Feb 1955	Jan 1971
N	May 1959	Mar 1964	Jan 1987

Production of special nuclear materials (principally Pu-239 and tritium) was the primary function of the reactors. All the reactors have been retired from service. Each area consists of OUs for liquid and solid waste disposal (called source OUs), as well as an OU for groundwater related contamination (DOE/RL-92-11, *100 Area Feasibility Study, Phases 1 and 2*). The reactors are located in their corresponding areas (e.g., 100-B/C Area contains B Reactor and C Reactor). Table 1-1 identifies the source and groundwater OUs contained in a particular area.

Liquid wastes from reactor operations and associated facilities were released to the soil column and the Columbia River. Solid wastes were disposed in burial grounds associated with the facilities. Wastes released to or buried within the environment created sources of contamination, such as liquid waste sites (ponds, trenches, cribs, and French drains), burial grounds and numerous miscellaneous small waste sites scattered throughout the river corridor.

- **Ponds**: Unlined, high volume, surface liquid waste sites, designed primarily as percolation sites to receive low concentration waste streams (Figure 2-2). Pond depths ranged from 1 to 9 m (3.28 to 29.5 ft), and their surface areas typically were more than 2,600 m^2 (27,934 ft^2).

Figure 2-2. 100-D Area Ponds (1992)

- **Trenches**: Shallow, narrow, unlined surface liquid waste sites of variable length that received limited quantities of sludge and/or liquid wastes (cooling water, contaminated water and sludge, sodium dichromate, fuel rupture effluent, and decontamination solutions [i.e., citric acid, nitric acid, and solvents]). Trenches typically were 15 to 40 m (50 to 130 ft) long, 3 to 5 m (10 to 16.5 ft) wide, and 2 to 6 m (6 to 20 ft) deep.

- **Cribs**: Subsurface liquid waste disposal sites for percolating wastewater into the ground without exposure to the atmosphere. The "cribs" typically were 3 by 3 by 3 m (10 by 10 by 10 ft) boxes, shored with wooden railroad ties, and filled with gravel. Early waste management practices used cribs to receive low-level radioactive waste for disposal and to provide a physical barrier against surface exposure. Cribs received contaminated water and sludge, contaminated process tube effluent, fuel storage effluent, spent laboratory solutions, and potassium borate solutions.

- **French drains**: Subsurface liquid waste disposal sites designed to percolate wastewater into the ground without exposure to the atmosphere; usually constructed with a 1 m (3-ft) diameter, open or gravel filled pipe placed vertically to less than 5 m (less than 16 ft) below ground surface. French drains typically received low-level radioactive waste for disposal.

- **Solid waste burial grounds**: Areas used for near surface disposal of solid waste containing hazardous substances (radioactive and nonradioactive), and received construction debris (e.g., steel, concrete, and wood) from reactor modifications, contaminated construction equipment, contaminated soil, irradiated reactor parts, thimbles, gun barrels, potential spent fuel, and low level radioactive combustible material (WHC-EP-0087, *Estimates of Solid Waste Buried in 100 Area Burial Grounds*; RL-REA-2247, *Historical Events – Reactors and Fuels Fabrication*). Figure 2-3 shows the 118-H-1 Burial Ground during excavation.

Figure 2-3. 118-H-1 Burial Ground Excavation (2007)

Wastes unintentionally released to the environment created sources of contamination referred to as unplanned release sites. In general, an unplanned release site is the result of an unintentional airborne, liquid, or solid release of contaminants to the environment. Waste sites in this group typically were caused by liquid waste spills.

- **Retention basins**: Large, open, reinforced concrete structures designed to temporarily hold cooling water from reactor operations, then discharged to the Columbia River after cooling and decay of short-lived radioactive contaminants. Although retention basins are sometimes considered liquid waste sites because they leaked substantially to the surrounding soil column, they were not designed to percolate liquids into the soil column.
- **Pipelines**: Closed transfer lines to, between, and from facilities or structures that periodically leaked or were compromised and released contaminants to the environment.
- **Spills/leaks**: Waste sites that were generated via broken valves to or on mobile tanks, trucks, or transfer lines, and the sites are generally small. Figure 2-4 depicts an unplanned release site.

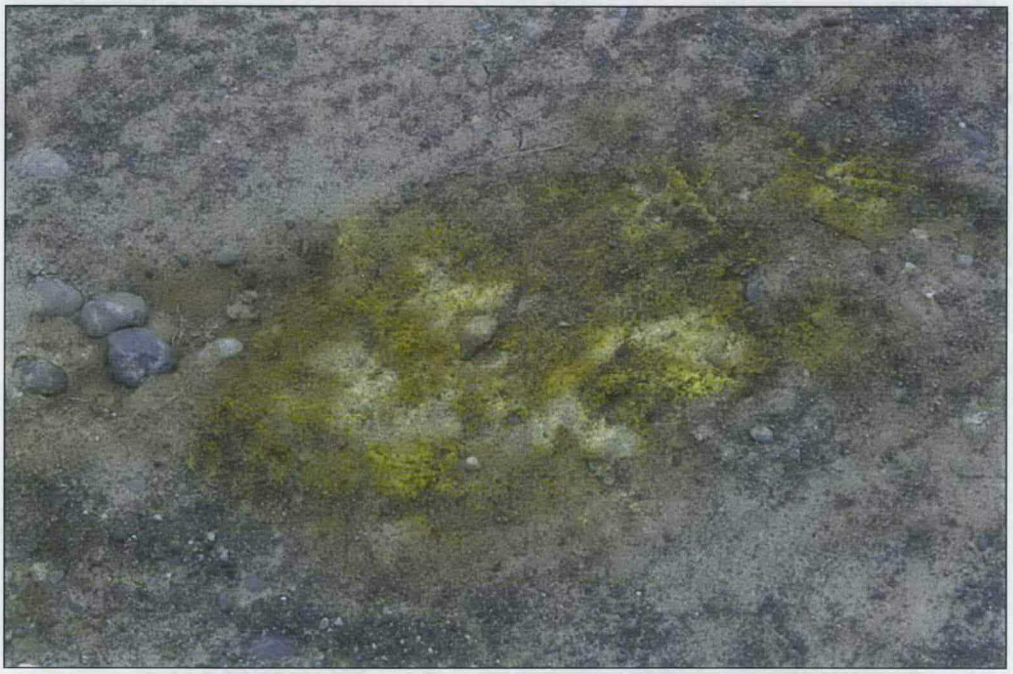


Figure 2-4. Chromium Soil Contamination Near Well 100-D-12

Waste sites are identified in the official Hanford Waste Information Data System (WIDS) database, which is the source for information of known and suspected waste sites. Waste sites are defined as any location that may require action to mitigate a potential environmental impact (RL-TPA-90-0001, *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14). Within WIDS, waste sites and suspected waste sites are assigned a classification/reclassification category to designate the status of a site. The types of waste site classification/reclassification status are accepted, consolidated, not accepted, interim closed out, closed out, no action, and discovery. These terms are defined in RL-TPA-90-0001, TPA-MP-14, as follows:

- **Discovery**: An initial classification status indicating evidence of a potential waste site; assessment not yet complete. This is the classification of a newly discovered WIDS site.
- **Not accepted**: A classification status indicating an assessment was made that a WIDS site is not a waste management unit and is not within the scope of the Tri-Party Agreement Action Plan, Section 3.1. This classification requires lead regulatory agency approval.
- **Accepted**: A classification status indicating an assessment has been made that a WIDS site is a waste management unit as defined in the Tri-Party Agreement Action Plan, Section 3.1.
- **Consolidated**: A reclassification status indicating that a WIDS site is a duplicate of, physically located within, or adjacent to another WIDS site and will be dispositioned as part of the other WIDS site. Note: A consolidated WIDS site has no future updates in WIDS after reclassification. All updates are limited to the WIDS site with which it was consolidated.
- **No action**: A reclassification status indicating a waste site does not require any further remedial action under RCRA Corrective Action, CERCLA, or other cleanup standards based on an assessment of quantitative data collected for the waste site.
- **Interim closed out**: A reclassification status indicating due to actions taken, a waste management unit meets cleanup standards specified in an interim action ROD or action memorandum but for which a final action ROD has not been issued.
- **Closed out**: A reclassification status indicating that due to actions taken, a waste management unit meets applicable cleanup standards or closure requirements. (Note: Many remediation waste sites were identified as "Closed Out" based on a previous classification scheme. Since all the associated RODs are interim action RODs, these waste sites are considered "Interim Closed Out" based on current definitions.)
- **Rejected**: A reclassification status indicating a waste site does not require remediation under RCRA Corrective Action, CERCLA, or other cleanup standards based on qualitative information such as a review of historical records, photographs, drawings, walkdowns, ground penetrating radar scans, and shallow test pits. Such investigations do not include quantitative measurements.

Table 2-2 presents the numbers of waste sites by their classification/reclassification within each area. The status of waste site classification/reclassification fluctuates as wastes sites are closed, discovered, etc. More up-to-date details on waste sites' status will be made available in the area-specific addenda.

Table 2-2. Waste Site Status (as of 2009)

Waste Site Classification	Sites
100-BC Area	
Accepted	13
Discovery	7
Closed out	2
Interim closed out	58
Not accepted/Rejected	19
No action	17

Table 2-2. Waste Site Status (as of 2009)

Waste Site Classification	Sites
Waste site total:	**116**
100-D/H Area	
Accepted	102
Discovery	21
Closed out	5
Interim closed out	64
Not accepted	29
No action	5
Waste site total:	**226**
100-F/IU-2/IU-6 Area	
Accepted	40
Discovery	43
Closed out	1
Interim closed out	69
Not accepted	74
No action	26
Waste site total:	**253**
100-K Area	
Accepted	96
Discovery	14
Closed out	1
Interim closed out	12
Not accepted	26
No action	0
Waste site total:	**149**
100-N Area	
Accepted	89
Discovery	3
Closed out	1
Interim closed out	15
Not accepted	35
No action	1
Waste site total:	**144**
TOTAL WASTE SITES	**888**

2.2 Descriptions

Because of changing data collection needs, decision logic, and current understanding of 100 Area conditions, the various remedial activities will be conducted by area rather than by individual OU. Coordinated decisions for contiguous source and groundwater OUs will be made to achieve final action cleanup decisions for given portions of the 100 Area. Figure 1-2 shows the River Corridor boundaries and Table 1-1 provides information on each of the operable units within the 100 Area.

2.3 Environmental Setting

The Hanford Site occupies a small portion of the Columbia River drainage system in the Pasco Basin of south-central Washington State. The area is relatively low relief, which resulted from river and stream sedimentation filling the valleys and basins in the Pasco Basin. Hanford Site elevations range from approximately 100 m (330 ft) to nearly 1,100 m (3,600 ft) above sea level (DOE/RL-91-50, *Environmental Monitoring Plan United States Department of Energy Richland Operations Office*). The 100 Area reactors and associated facilities are on steep bluffs overlooking the river. The bluff heights range from 9.2 m (30 ft) at the 100-B/C Area to approximately 21 m (70 ft) at the 100-N Area.

2.3.1 Meteorology

The Hanford Site is characterized by a semi-arid, shrub steppe climate, and is the driest and warmest portion of the Columbia Basin. The Hanford Site's large size and complex topography can accommodate substantial spatial variations in wind, temperature, precipitation, and other meteorological parameters, which are further affected by mountain barriers (PNNL-6415, *Hanford Site National Environmental Policy Act [NEPA] Characterization*). The Cascade Range, to the west, creates a rain shadow effect on the Hanford Site climate, while the Rocky Mountains and ranges in southern British Columbia protect it from the more severe polar air masses from Canada (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*).

Surface winds blow predominantly from the northwest during winter and summer and from the southwest during spring and fall. In the 100 Area and along the Columbia River, local winds are strongly influenced by near river topography (PNNL-6415). Average monthly wind speeds are the lowest during winter, averaging 10 to 11 km/h (6 to 7 mi/h), and highest during summer, averaging 14 to 16 km/h (8 to 10 mi/h). High-speed surface winds in the summer from the southwest can generate regional dust storms that sometimes lead to onsite work terminations.

Climatic data are monitored at the Hanford Meteorological Station and 28 monitoring locations throughout the Hanford Site and local area (PNNL, 2008, "Hanford Meteorological Station (HMS), Monthly and Annual Temperatures [°F]"). From 1946 through 2004, the recorded maximum temperature was 45°C (113°F) during July 2002 and August 1961, and the recorded minimum temperature was 30.6°C (–23°F) during February 1950 (PNNL-6415). The monthly average temperature from 1946 through 2004, ranged from a low of –0.24°C (31.7°F) in January to a high of 24.6°C (76.3°F) in July. The monthly and annual minimum temperatures and the monthly and annual maximum temperatures are shown in Tables 2-3 and 2-4). The annual average relative humidity is 54 percent (PNNL-6415).

Table 2-3. Monthly and Annual Minimum Temperatures from 1945 through 2004

1945-2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average (°F)	7	12	21	29	35	44	49	49	39	27	17	9	28
Lowest (°F)	-22	-23	6	21	28	37	39	41	30	7	-13	-14	-23
Highest (°F)	24	29	32	37	48	52	58	56	48	34	28	23	58

Note: Data from PNNL, 2008, "Hanford Meteorological Station (HMS), Monthly and Annual Temperatures (°F)"

Table 2-4. Monthly and Annual Maximum Temperatures from 1945 through 2004

1945-2004	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average (°F)	57	62	70	81	93	99	105	103	95	81	65	57	81
Lowest (°F)	36	46	63	71	81	86	96	96	86	73	57	39	36
Highest (°F)	72	72	83	94	104	111	113	113	106	89	76	69	113

Note: Data from PNNL, 2008 "Hanford Meteorological Station (HMS), Monthly and Annual Temperatures (°F)"

Annual precipitation measurements historically recorded at the Hanford Site have varied from approximately 8.7 to 28.8 cm/year (3.4 to 11.3 in/year) since 1947, with an average of 19.5 cm/year (7.7 in/year). Most precipitation occurs during late autumn and winter, with more than half of the annual amount occurring from November through February. Snowfall accounts for approximately 38 percent of precipitation from December through February (PNNL-6415). Winter monthly average snowfall ranges from 0.8 to 13.5 cm (0.3 to 5.3 in.) (March and January, respectively).

2.3.2 Geologic Setting

The Hanford Site lies within the Pasco Basin, a sub-basin of the Columbia River Basin. The Columbia River Basin comprises much of eastern Washington and northeastern Oregon and is framed by the Cascade Mountains to the west and the Rocky Mountains to the east.

The Columbia River Basalt Group consists mainly of continental basalts derived approximately 6 to 17 million years ago from north to northwest-trending fissures in eastern Washington, north-central and northeastern Oregon, and western Idaho. The Columbia River Basalt Group underlies the sedimentary deposits in the Pasco Basin, as shown in the generalized stratigraphic column in Figure 2-5. These suprabasalt sediments are laterally extensive Neogene deposits of the Ringold Formation and the Hanford formation, an informal designation (PNNL-14202, *Mineralogical and Bulk-Rock Geochemical Signatures of Ringold and Hanford Formation Sediments*). The sediments play a major role in contaminant transport in the subsurface environment.

This section of the work plan focuses on the following suprabasalt sediments from oldest to youngest:

- Ringold Formation (coarse- to fine-grained sediment)
- Hanford formation (coarse- to fine-grained sediment)
- Holocene surficial deposits (aeolian sediment)

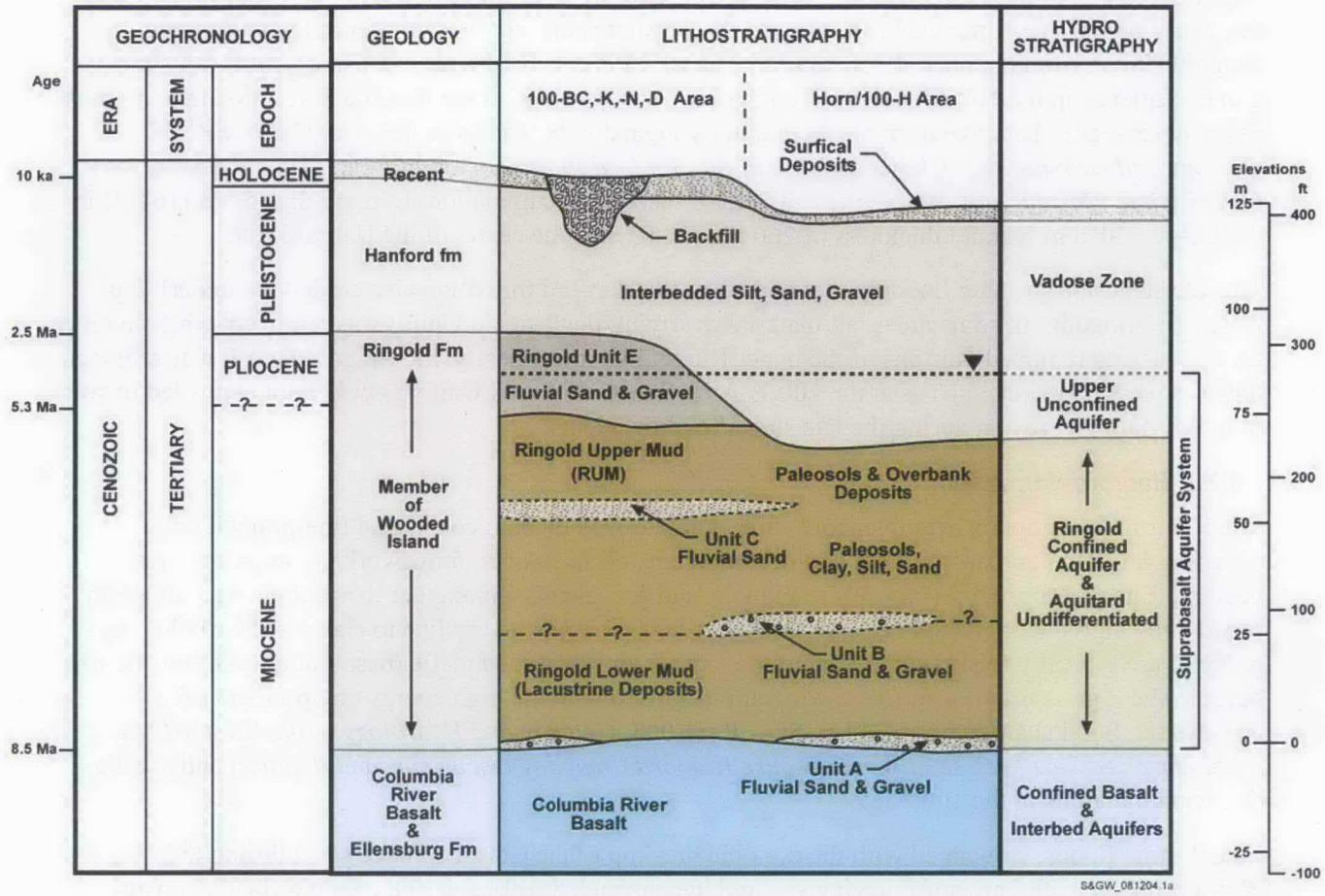


Figure 2-5. Generalized Hydrogeology of the 100 Area

2.3.2.1 Ringold Formation

The Ringold Formation[5] consists of six lithofacies units distinguished by grain size laboratory data and borehole geophysical responses (WHC-SA-0740-FP, *Sedimentology and Stratigraphy of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington*):

- Mud
- Mud and sand
- Sand
- Sand and gravel
- Gravel
- Cobble and boulder

5 The Ringold Formation initially was described as five, laterally traceable lithostratigraphic units of an interstratified sequence of unconsolidated clay, silt, sand, and granule to cobble gravel (DOE/RW-0164, *Consultation Draft Site Characterization Plan: Reference Repository Location, Hanford Site, Washington*; RHO-BWI-ST-4, *Geologic Studies of the Columbia Plateau: A Status Report*.

The Ringold Upper Mud (RUM) Unit forms the base of the unconfined aquifer at the Hanford Site and acts as an aquitard (less permeable sediment) that separates the confined aquifer in the underlying Ringold Unit A from the unconfined aquifer. The RUM is covered by the extensive Unit E sand and gravel sequence in the 100 Area. Unit E comprises those portions of the Ringold Formation that are most easily observed or that have been most commonly logged in boreholes or test pits (USGS-PP-717, *Geology and Groundwater Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington*). Where present, Unit E displays accumulations of more than 50 m (164 ft) in thickness, with a maximum thickness of 260 m (820 ft) near the center of the Hanford Site.

The late stage catastrophic flooding that deposited the Hanford formation also eroded the underlying Ringold Formation. In some areas, all material overlying the Ringold Unit E was removed, while in other areas, scouring removed portions of the upper Ringold Unit E. Locally, the Ringold Unit E was removed down to the RUM Unit, such as at the 100-H Area. The Cold Creek Unit was either not deposited or was removed through erosion during the late stage flooding events.

2.3.2.2 Hanford Formation

The Hanford formation is heterogeneous. It is characterized by both coarse and fine-grained units including large to very large cobble boulder fragments/clasts in open framework gravel in massive bedding. The grains are typically sub-round to round gravel and sub-angular to round in the sand grain faction; the high-energy depositional environment did not deposit very fine to clay sized particles. The particles are typically felsic (granite, quartzite, gneiss, or schist) and mafic (basalt or andesite) in all size ranges. These gravels are open framework and identified with the high-energy environment of cataclysmic flood channel ways (WHC-SD-ER-TI-003, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*) and are the dominant materials in the 100 Area.

Cataclysmic floods, associated with the periodic breakup of the Cordilleran ice sheet during the Pleistocene, are well known for having scoured the channeled scablands and creating flood deposits behind hydraulic constrictions at Wallula Gap. Up to 100 m (330 ft) of fine to coarse-grained flood deposits incrementally accumulated as the Hanford formation at the Hanford Site (Bjornstad et al., 2001, "Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State"). These deposits make up the most extensive and voluminous part of the Hanford formation and are less common in the 100 Area.

2.3.2.3 Holocene Surficial Deposits

Holocene surficial deposits are composed of silt, sand, and gravel that were deposited by a mix of Aeolian and alluvial processes. No thicker than approximately 5 m (16 ft), these deposits are observed as a thin veneer across much of the Hanford Site, where the surface has not been disturbed or altered by construction.

2.3.3 Hydrogeology

The groundwater flow system beneath the Hanford Site remains a primary pathway for some contaminants to migrate from source areas, and for some contaminants to discharge to the Columbia River. Hydrogeologic characterization for the100 Area requires an understanding of the properties and behavior of the vadose zone, groundwater, and surface water sources, interfaces, and interactions. The Pasco Basin supports a multiple aquifer system corresponding to the upper Columbia River Basalt Group and the suprabasalt sediments (WHC-SD-ER-TI-003).

Evidence suggests that the most significant recharge events are associated with rapid melts of large snowpacks, (PNNL-14744, *Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*). While evapotranspiration and transpiration account for most of the remaining precipitation loss (net infiltration is less than 5 mm per year [PNNL-16688, *Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas*]), some precipitation infiltrates into the soil and eventually recharges the groundwater flow system. The amount of recharge varies spatially, based primarily on soil texture, vegetation type, and vegetation coverage (PNL-10285, *Estimated Recharge Rates at the Hanford Site*). Recharge also varies temporally with the majority occurring in the winter and spring.

A significant source of recharge is from infrastructure losses (e.g., leaking water lines, leaking water storage structures) as water migrates through more permeable backfill materials placed along piping trenches and around buried storage tanks, or placed in remediated excavation areas. Additional infiltration occurs as the result of water used for dust suppression during source remediation activities.

2.3.3.1 Vadose Zone Transport

Contaminant transport through the vadose zone may occur in multiple types of phases over intermittent periods. Contaminant materials may enter the soil periodically in rainwater solution, be precipitated within the upper portions of the soil as solids, deposited as airborne particulate, be transported in the subsurface by biomechanical transport mechanisms (burrowing animals), or be part of an infrastructure loss (leaks and spills).

Vadose zone moisture content changes with location, along with changes in soil matrix potential, and the corresponding anisotropy (ratio of horizontal to vertical hydraulic conductivity) varies in unsaturated flow. Thus, as saturation decreases, anisotropy increases, resulting in a dominance of lateral flow. This condition is unlike saturated flow where, with no changes in saturation (saturation is constant), anisotropy is a constant (saturation dependent anisotropy). Extensive moisture content data have been collected that show evidence for variable anisotropy for unsaturated media.

2.3.3.2 Saturated Zone Transport

Groundwater flow through aquifers beneath the Hanford Site is a major mechanism for transporting radioactive and hazardous wastes constituents discharged to various locations on the Site since 1944 (PNNL-14058, *Prototype Database and User's Guide of Saturated Zone Hydraulic Properties for the Hanford Site*). Radioactive and hazardous contaminants have been identified within the unconfined and confined aquifer systems (PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*) that are mainly derived from high-volume wastewater discharges during nuclear materials production. Additional wastes and waste constituents present in surface facilities and the vadose zone have the potential to be continuing sources of contamination to the unconfined aquifer. Remediation of the sources in the vadose zone and the aquifer are necessary to limit impact to human health and the environment (PNNL-14058).

Within the saturated zone (aquifer), transport is usually less complex than transport through the vadose zone. Groundwater contaminant transport is a function of confined or unconfined conditions, as well as groundwater flow parameters.

2.3.3.3 Groundwater Flow

The hydraulic properties that most affect groundwater flow are hydraulic conductivity, specific storage, and aquifer thickness. For unconfined aquifers, both the storativity associated with aquifer response and the specific yield (calculated during extraction well testing or aquifer dewatering) are important. Effective porosity is an additional parameter in determining groundwater flow velocity and rates of contaminant transport (PNNL-14058).

In combination with the previous parameters, information such as boundary conditions and hydraulic gradient provide a description of the groundwater flow system. Aquifer thickness is most commonly determined from a combination of borehole geophysics and geologic logging during well drilling.

Groundwater discharges from the uppermost aquifer to the Columbia River via the riverbed, and to a lesser extent via riverbank springs. Rates of flow are typically several tenths of a meter per day (0.5 to 1.0 ft/day) (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project*). In the 100 Area, groundwater movement is primarily perpendicular to the shoreline, with a minor component of alongshore flow.

2.3.3.4 Groundwater and River Water Interaction

Intermingling groundwater and river water in the zone of interaction and locations of groundwater discharges into the river channel are key issues to understanding the rate and magnitude of contaminants potentially entering the Columbia River. Discharge into the river environment may occur across the riparian zone as seeps and within the river channel substrate. Riverbank seepage creates a potential human health risk through exposure to contaminants and the introduction of contaminants to the food chain. Upwelling of groundwater into the channel substrate poses a potential risk to aquatic organisms that may create an introduction of contaminants to the food chain.

Groundwater flow (especially near the river), is strongly influenced by river stage, which is directly controlled by the upstream Priest Rapids Dam. The rise and fall of river stage creates a dynamic zone of interaction between groundwater and river water, and it influences flow patterns, transport rates, contaminant concentrations, and attenuation rates within the system (PNNL-13674). Columbia River elevations have varied up to 4.6 m (15 ft) over the course of one year and have varied by as much as 2.7 m (9 ft) in a single day (PNL-9437, *Monitoring Groundwater and River Interaction Along the Hanford Reach of the Columbia River*).

In the 100 Area, there are cases, such as for CrVI, when the ambient water quality criteria (AWQC) is more stringent than the drinking water standard. The aquatic receptor exposure point of concern is within the river substrate at depths up to 18 inches (46 centimeters), where embryonic salmon and fry would be present during parts of the year. Under the interim action RODs, it is considered impractical to routinely monitor the river substrate; therefore, groundwater has been monitored at near-river on-shore locations above the common high river mark. To account for dilution within the aquifer between the monitoring location on-shore and the aquatic receptor exposure point of concern within the river substrate, a preliminary dilution factor of 1:1 was selected based on the available data at the time the interim RODs were written (i.e., under the interim RODs, 20 µg/L CrVI in on-shore near-river well points is considered equivalent to 10 µg/L CrVI in the river substrate). Groundwater sampling has been conducted in the fall when river levels are low and dilution by river water at the compliance monitoring point is minimal (reference 100-HR-3 and 100-KR-4 ROD). However, for final action RODs, the appropriate method for determining compliance with AWQC for CrVI in the 100 Areas has not yet been determined.

Groundwater upwelling data collected using the Trident Probe[6] as part of the remediation investigation for Hanford Site releases to the Columbia River may be a source of information for this evaluation (Section 3.6.4).

Physical, chemical, and biological processes occur within the zone of interaction that potentially alter the characteristics of approaching groundwater. Data suggest physical processes are the primary influences on contaminant concentrations and fluxes where groundwater discharges into the free flowing river. Chemical processes may render contaminants less mobile as they adsorb to sediments or precipitate.

An expert panel of scientists was convened in April 2008 to review existing information and provide observations and suggestions to improve the current understanding of groundwater-surface water interactions in the 100 Area, primarily focusing on 100-D Area. The panel was asked to recommend any improvements on current approaches and methods used to understand interactions between the groundwater and the Columbia River, evaluate the current monitoring network and data collection methods, and evaluate the role played by modeling. The panel produced a report (SGW-39305, *Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area*) containing their observations and suggestions for enhancing understanding of these interactions.

2.3.3.5 Surface Water Hydrology

The Columbia River has played a major role in the depositional and erosional processes that helped produce the sedimentary and geologic features across the Hanford Site. The river is noted for its very low suspended load, its low nutrient content, and an absence of microbial contaminants (DOE/RW-0164).

Columbia River flows typically peak from April through June during spring run-off from regional and high elevation snowmelt, and flows are lowest from September through October. Significant spring run-off rates can occur from the melting of larger than normal snowpacks. Fluctuations of daily discharge rates from upstream dams cause river depths to change rapidly. As a result of fluctuation in discharges, the depth of the river varies significantly over time (PNL-10698, *Hanford Site Ground-Water Monitoring for 1994*). Hanford Reach river width can vary from approximately 300 to 1,000 m (1,000 to 3,300 ft). Varying with flow rate, river width fluctuations cause repeated wetting and drying of the shoreline area (PNNL-6415).

Along the 100 Area is the only remaining, free flowing portion of the Columbia River in the United States (Figure 2-6). This stretch of the river is referred to as the "Hanford Reach," and it extends from Priest Rapids Dam to the headwaters of Lake Wallula. In May 2000, the Hanford Reach was incorporated into the 70,820 ha (175,000-ac) Hanford Reach National Monument (PNNL-13125, *Evaluation of the Potential for Agricultural Development at the Hanford Site*). River flows here are managed mainly for generating power, controlling floods, and promoting salmon egg and embryo survival.

2.3.3.6 Columbia Riverbank Seeps

Riverbank seep discharges to the river are visible during low river stage. Conversely, during high river stage, the seeps are submerged as river water infiltrates the riverbanks and forms either a layered system or a mixture during interaction with approaching groundwater. Data from the seeps and along the riverbank indicate the riverbank storage water composition oscillates dramatically from nearly completely river water during high river stage to primarily groundwater during low river stage (PNNL-13674). Figure 2-7 shows an illustrated model of river bank seepage.

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[6] The Trident Probe has a patent pending for Coastal Monitoring Associates.

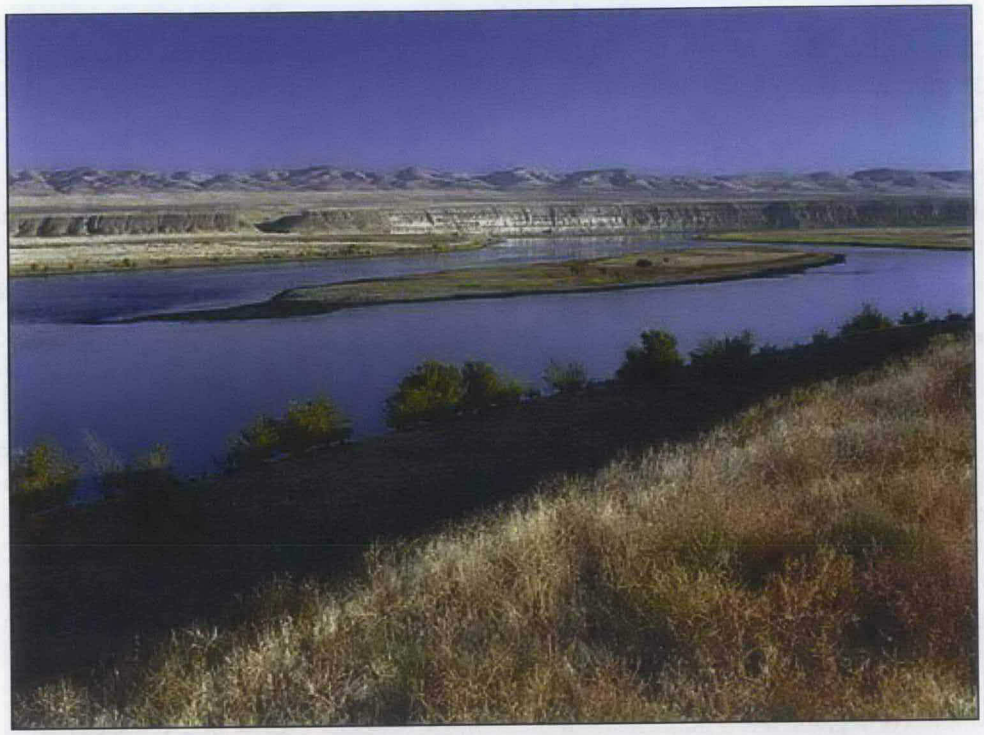
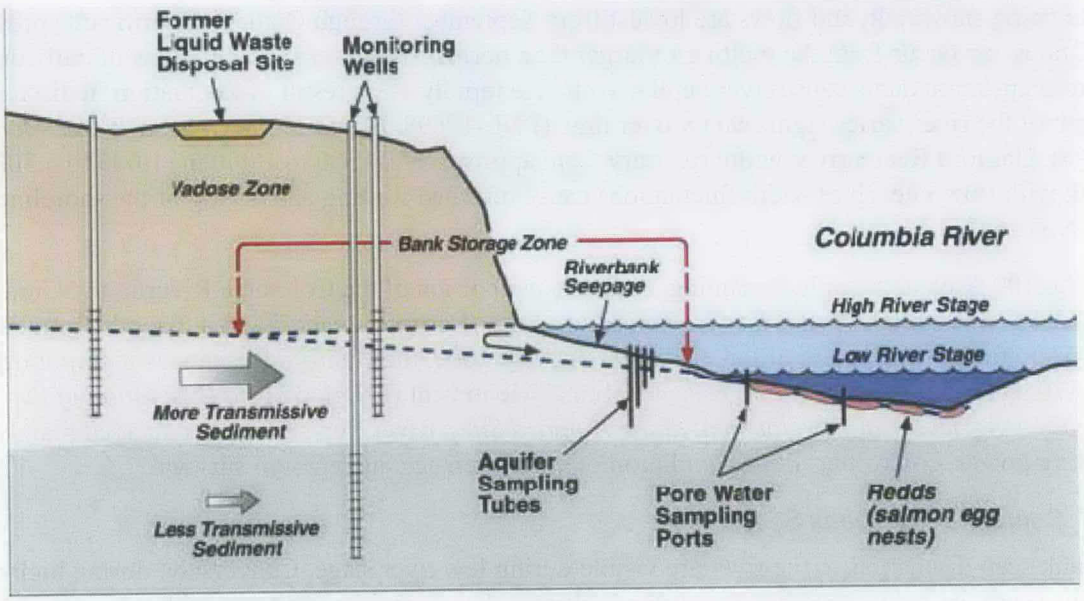


Figure 2-6. 100 Areas – The Last Free Flowing Portion of the Columbia River



Modified from PNNL-13674

Figure 2-7. Illustration of River Bank Seepage

Riverbank seeps are contaminated when in hydrologic contact with contaminated groundwater, and they create potential pathways for groundwater contamination to enter the river (PNL-5289, *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River*). Potential mixing of river water with groundwater may produce lower contaminant concentrations in the seep discharges than can be found in upgradient groundwater. These lower contaminant concentrations may be attributed to the bank storage phenomenon, where infiltrated river water stored in the riverbank during high river stage returns to the river via seeps during spring flow, low river stage (PNNL-17603, *Hanford Site Environmental Report for Calendar Year 2007*).

The areas of groundwater discharges along the riverbank are in the vicinities of the 100-N Area, the former Hanford townsite, and the 300 Area. During operations, seeps and springs were often observed to emerge as hydrological conditions near the river changed. These changes in hydrology and their consequent impacts on current conditions are discussed in detail in the individual addenda. However, the current estimated flow volumes for groundwater along the entire Hanford Site are very small (3.00E+08 ft^3/yr; PNL-10285) compared to those of the receiving river waters (3.71E+12 ft^3/yr; estimated from PNNL-6415). Groundwater monitoring in the unconfined aquifer is the most effective method for determining potential groundwater discharges to the river. However, because most of the seeps are accessible only during low river conditions, year-round routine access is not possible (PNL-5289).

2.3.3.7 Flooding

The greatest influence on river stage is attributed to the seasonal melting of the regional and higher elevation winter snowpack, mainly from April to June. When combined with above normal precipitation, peak flow occurs. While the river has produced large, episodic floods in the past, the construction of multiple dams on the Columbia River has considerably reduced the likelihood of future large-scale flooding (DOE/EIS-0113, *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes: Hanford Site Richland, Washington*). Hourly to daily release rates of the Priest Rapids Dam further manage river stage to control the potential for flooding from the Columbia River at the Hanford Site. Real-time data are available at: http://waterdata.usgs.gov/usa/nwis/uv?site_no=12472800.

2.3.3.8 Non-Riverine Surface Water

A groundwater mound created by the Gable Mountain Pond (Waste Site 216-A-25) may have had some contact with groundwater in the 100-KR-4 Groundwater OU. In addition, an encroachment of tritium and other contaminants from the 200 Area to the 100-BC Area may have occurred. Other than the retention basins and naturally occurring ponds previously described, no other naturally occurring surface water bodies are noted at the Hanford Site.

2.3.4 Environmental Resources

Environmental resources are widespread across the Hanford Site, with significant cultural and historical heritage resources established from the riverfront environment to the ridge tops (DOE/EIS-0119F, *Addendum [Final Environmental Impact Statement]: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*). The Hanford Reach National Monument was formed to place high priority on shrub-steppe community habitat maintenance and enhancement for native species throughout the Monument. The State of Washington has designated shrub-steppe communities as priority habitat because of their significance to a number of wildlife species and the scarcity of this habitat type. In addition, the U.S. Department of the Interior has identified native shrub and grassland steppe in Washington and Oregon as an endangered ecosystem.

2.3.4.1 Flora

Native pre-settlement vegetation consisted primarily of shrubs, perennial bunchgrasses, a variety of forbs, and a living soil crust composed of lichens, moss, and algae. Much of the native flora in the 100 Area has been disturbed by agricultural and livestock practices from Euro-American settlement in the early 20th Century and later by Hanford Site construction, operation, and post-operation activities, resulting in the introduction of non-native plant species. Large tracts of land adjacent to the 100-K Area and the other reactor areas that were farmed are now dominated by stands of cheatgrass (*Bromus tectorum*). Despite these "old fields," many places on the Hanford Site are relatively free of non-native species and are extensive enough to retain characteristic populations of shrub-steppe plants and animals. Unaffected areas support desert shrubs and drought resistant grasses and forbs. The predominant plant community in the 100 Area is sagebrush/Sandberg's bluegrass/cheatgrass. Other shrub communities are dominated by bitterbrush, hopsage, and rabbitbrush (PNNL-6415). A relatively narrow riparian zone supports grasses, sedges, and scattered deciduous shrubs and trees such as willow, mulberry, and Siberian elm along the banks of the river.

There are no plant species on the Hanford Site that are currently listed as threatened or endangered under the *Endangered Species Act of 1973*. However, two species of plants are candidates for federal protection: Umtanum desert buckwheat (*Eriogonum codium*), which occurs in several small, highly localized populations on Umtanum Ridge, and the White Bluffs bladderpod (*Lesquerella tuplashensis*), which occurs on White Bluffs. Additional plant species are listed as threatened or endangered by Washington State. Several of these, including the awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and persistent sepal yellowcress (*Rorippa columbiae*), are restricted to wetlands in the riparian zone of the Columbia River (PNNL-6415). Table 2-5 lists the threatened or endangered plant species.

Table 2-5. Threatened or Endangered Plant Species

Plants	Scientific Name	State
Awned halfchaff sedge	*Lipocarpha (= Hemicarpha) aristulata*	Threatened
Desert dodder	*Cuscuta denticulata*	Threatened
Geyer's milkvetch	*Astragalus geyeri*	Threatened
Grand redstem	*Ammannia robusta*	Threatened
Loeflingia	*Loeflingia squarrosa var. squarrosa*	Threatened
Great Basin gilia	*Gilia leptomeria*	Threatened
Lowland toothcup	*Rotala ramosior*	Threatened
Persistent sepal yellowcress	*Rorippa columbiae*	Endangered
Rosy pussypaws	*Calyptridium roseum*	Threatened
Umtanum desert buckwheat	*Eriogonum codium*	Endangered
White Bluffs bladderpod	*Lesquerella tuplashensis*	Threatened
White eatonella	*Eatonella nivea*	Threatened

Notes:

Reference: PNNL-17603, *Hanford Site Environmental Report for Calendar year 2007, September*

2.3.4.2 Fauna

The shrub and grassland habitat of the Hanford Site supports many groups of terrestrial wildlife. Species include large animals like Rocky Mountain elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*); predators such as coyote (*Canis latrans*), bobcat (*Lynx rufus*), and badger (*Taxidea taxus*); and herbivores including deer mice (*Peromyscus maniculatus*), harvest mice (*Riethrodontonomys megalotis*), ground squirrels (*Spermophilus* spp.), voles (*Lemmiscus curtatus*, *Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus*). The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus*). Many of the rodent species and some predators (badgers) construct burrows on the Site. Other non-burrowing animals including cottontails (*Sylvilagus nutalli*), jackrabbits, snakes, and burrowing owls (*Athene cunicularia*) may use abandoned burrows of other animals.

The height of the steep bluffs along the river in the 100 Area and the location of most of the facilities back from the edge of the bluff minimize the line-of-sight effect that human activity might otherwise have on eagles and other nesting birds (DOE/RL-94-150, *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington*). In addition, few trees remain close to the reactor areas, which further limit the potential of line-of-sight effects. However, the trees immediately upriver of the 100-K Area are an exception, and roosting eagles can be seen in these trees from the west end of the 100-K Area.

Human occupancy at the Hanford Site has had great effect on wildlife populations. To support agricultural development, wildlife species (i.e., mule deer and coyote) were believed to threaten crops and livestock and were targeted for population reduction. On the other hand, trees planted for use as windbreak by early settlers have since survived to provide much needed nesting and perch sites for raptors and some waterfowl (Rickard et al., 1982, "The Non-Fisheries Biological Resources of the Hanford Reach of the Columbia River"). Seasonal populations of Canada geese and other birds forage in the riparian zones and old (cultivated) fields, which are now dominated by cheatgrass (Eberhardt et al., 1989, "Survival of Juvenile Canada Geese During the Rearing Period").

The aquatic ecosystem is an accessory to the Columbia River. This aquatic ecosystem supports a large and diverse community of plankton, benthic invertebrates, fish, and other communities. Organisms in these communities in turn provide food sources to other species.

Important game species that inhabit the Columbia River are Chinook salmon, steelhead, Coho salmon, sockeye salmon, smallmouth bass, largemouth bass, sturgeon, walleye, yellow perch, and channel catfish. Most importantly, the river supports a healthy population of fall spawning Chinook salmon, whose spawned out carcasses attract bald eagles in the fall and winter. Fall Chinook spawning areas are described in DOE/EIS-0113 and PNNL-6415.

2.3.4.3 Critical Habitats

Two species of federal endangered fish, the Upper Columbia River spring run Chinook salmon and 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 (Figure 2-8) spawning has been observed near mid-channel gravel bars in the Hanford Reach, from the downstream edge of the 100-BC Area, to Wooded Island, downstream of Energy Northwest (DOE/RL-2000-27, *Threatened & Endangered Species Management Plan: Salmon and Steelhead*). 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*, Vol. 1).

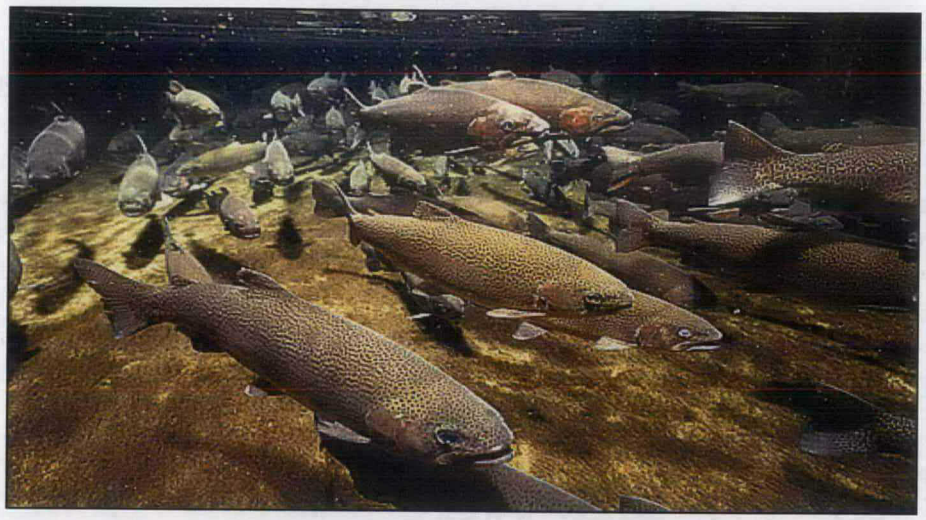


Figure 2-8. Columbia River Steelhead

DOE employs the following protective measures for endangered salmon and steelhead:

- Water diversions meet state screening criteria or appropriate administrative controls. Discharges meet National Pollutant Discharge Elimination System permit requirements. Removal of native riparian or emergent vegetation is minimized. Where possible construction projects will not simplify shoreline structures, final construction will produce banks at a 3:1 slope.
- Silt loaded surface runoff will be minimized along the shoreline, and disruptive activities in the river or on the shoreline will be avoided from April to November.

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. In addition, DOE has decided to continue to protect nest and roost sites on the Hanford Site under DOE/RL-94-150. This plan is currently under revision to account for the de-listing of the bald eagle. Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 m (874 yd) to 400 m (437 yd).

The bald eagle is a regular winter resident and forages on dead salmon and waterfowl along the Columbia River. Hanford Site bald eagle habitat includes perch sites, night roosts, foraging areas, and nesting areas that can occur anywhere along the Columbia River. Continued eagle-use pattern observations at the Hanford Site will help protect nesting sites or primary roosts through updating DOE/RL-94-150 and adjusting protection levels, as warranted.

While bald eagles do not currently nest successfully at the Hanford Site, past and attempted nest sites exist (PNNL-6415). Nest sites are built in groves of trees (e.g., black locust, white poplar, and Siberian elm) along the Hanford Reach. Buffer zones around primary night roosts and nest sites have been established in consultation with the U.S. Fish and Wildlife Service (USFWS). While the night-roost locations are consistent from year to year, the nesting sites have varied and are readjusted in consultation with the USFWS each year. Maps of current bald eagle nesting sites are not publicly available because of the birds' sensitivity of disturbance.

The Washington State Department of Fish and Wildlife has declared protection of roosting trees for bald eagle habitat and foraging areas (WAC 232-12-292, "Bald Eagle Protection Rules").

2.3.4.4 Land Use Characteristics

Land uses at the Hanford Site are strictly controlled to preserve public health and safety and to support national security. Federal control is asserted throughout Hanford Site planning processes for Site development. Typical local land uses around the Hanford Site include irrigated and dry land farming, livestock grazing, and urban and industrial development. Industrial development typically supports either agriculture or energy production (DOE/RL-98-10, *Hanford Cultural Resources Management Plan*). The land around the reactor areas is buffered from development by land use restrictions imposed at the 78,914 ha (195,000-ac) Hanford Reach National Monument.

2.3.4.5 Beneficial Water Use Characteristics

Ecology requires that groundwater be restored to its "highest beneficial use," which is defined as the beneficial use requiring the highest quality. For water, Ecology has determined that at most sites, the use of groundwater as a drinking water source is the beneficial use of a resource generally requiring the highest quality in the resource (WAC 173-303-64620, WAC 173-340-720(1)(a), WAC 173-303-610(2)(b)(i)). Beneficial use may include discharged surface water, and cleanup levels will need to protect aquatic life in the Columbia River.

Ecology requires that surface water cleanup levels be based on the "highest beneficial use" and the reasonable maximum exposure expected to occur under both current and potential future site conditions. The highest beneficial use is determined in accordance with WAC 173-340-730 (1)(a), "Surface Water Cleanup Standards." Institutional controls will be in place until such time that cleanup standards are achieved.

Water users withdraw water in the Hanford Reach for offsite irrigation, for use at the Washington Public Power Supply System Nuclear Project 2, and for Hanford Site water use (PNNL-16623, *Hanford Site Environmental Report for Calendar Year 2006*). In addition, the Columbia River is used extensively for recreation, including fishing, hunting, boating, sailing, waterskiing, diving, and swimming. The Columbia River also supplies water for public and domestic use, irrigation, barge transportation, and industry, and supports wildlife habitat (DOE/RL-2005-40). Ecology requires that surface water cleanup levels be based on the "highest beneficial use" and the reasonable maximum exposure expected to occur under both current and potential future site conditions. The highest beneficial use is determined in accordance with WAC 173-340-730 (1)(a).

2.3.4.6 Sensitive Environments

Potential remedial activities would protect the Columbia River's beneficial uses and maintain it as a recreational resource, drinking and irrigation water resources, and habitat for waterfowl, fish, and transitory endangered and threatened wildlife. Because of critical bald eagle habitat, many areas of the Hanford Site may be declared a federal sensitive environment (40 CFR 300, Appendix A, "The Hazard Ranking System").

2.3.5 Human Resources

The Hanford Site contains some of the most important archaeological sites in the region. Many of these sites are listed on the National Register of Historic Places in accordance with 36 CFR 60, "National Register of Historic Places." In addition, other natural resources and sacred sites important to the present cultures of the regional Tribal Nations are preserved at the Hanford Site (PNL-9785, *Data Compendium for the Columbia River Comprehensive Impact Assessment*). Long-term (i.e., more than 50 years)

restricted access has minimized looting and vandalism of historic, cultural, and archaeological sites. Furthermore, hydroelectric and agricultural development have not destroyed these culturally significance sites, as has been experienced elsewhere in the Columbia River Basin.

While rapid Hanford Site development did not accommodate protection of important Native American locations, current and future Hanford Site planners, onsite construction activity directors, and Tribal Nations leaders work together for the protection of important Native American locations.

2.3.5.1 Cultural Resources

The cultural resources of the Hanford Site area are important to many people interested in their historic preservation. The National Register of Historic Places criteria (DOE/RL-97-02, *National Register of Historic Places Multiple Property Documentation Form Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington*) offer three convenient categories for chronicling historic, archaeological, and traditional cultural properties of the Hanford Site:

- Pre-historic era (10,000 years before present to common era 1805; pre-Lewis and Clark)
- Homestead and townsite era (1805 to 1945)
- Manhattan Project and Cold War era (post-1945 to 1990)

These categories are represented across the Hanford Site.

RL has undertaken a comprehensive preservation planning effort for the Hanford Site that is ongoing. The results of these efforts have implemented protective programs for conserving cultural resources (DOE/RL-96-77, *Programmatic Agreement Among the U.S. Department of Energy, Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site, Washington*; DOE/RL-97-02; DOE/RL-98-10). Cultural resource surveys are routinely conducted as part of site evaluation and preparation prior to excavation to protect culturally sensitive areas. The results of these surveys are used in the site selection process and applied in the various sampling and analysis plans. Additionally, the creation of the Hanford Reach National Monument (DOI, 2008, *Hanford Reach National Monument, Final Comprehensive Conservation Plan & EIS August 2008;* 73 FR 72519, "Hanford Reach National Monument; Adams, Benton, Franklin and Grant Counties, WA") provides an additional means for the preservation and maintenance of the wide range of cultural resources present along the river.

2.3.5.2 Archaeological Resources

Because the Hanford Site was closed to the public for over 50 years, Hanford Site archeological resources have been particularly well preserved compared to locations elsewhere in the mid-Columbia River Basin. A high density of archaeological resources at the Hanford Site is associated with the legacy of the Native American and early settler cultural settings. The locales are identified in terms of function based on surface evidence, features, artifacts, or a combination of these (DOE/RL-97-02). Many of these sites are located along the 100 Area near the Columbia River.

Artifacts discovered across the Hanford Site provide evidence on Site occupational characteristics, use durations and periods, and multiple land use (e.g., ceremonial and religious sites, and burial grounds). Evidence of older archaeological uses ranges from abundant deer and mountain sheep bones, projectile points, scatterings of fire-cracked rock, rock flakes, and net weights, and high densities of shell fragments that date as far back as 2,500 to 4,500 years ago (PNL-8143, *Fiscal Year 1991 Report on Archaeological Surveys of the 100 Areas, Hanford Site, Washington*). Even older artifacts have been discovered that date to the period from 4,500 to 11,000 years before present (Lohse, 1985, "Rufus Woods Lake Projectile

Point Chronology"; PNL-8143; BHI-01556, *Archaeological Excavation Report for Extraction Well C3662 in Support of the 100-KR-4 Pump-and-Treat Project*).

Historic era sites of archaeological importance include locations such as the Hanford Irrigation Canal, the remains of the Haven Railroad Station, many homesteads, the Hanford and White Bluffs townsites, docks, and other relatively recent documented facilities and features.

2.3.5.3 Traditional Cultural Places

Hanford Site cultural resources are diverse, ranging from early prehistoric times to the Atomic Age. Native American archaeological sites are associated with prehistoric and ethnographic villages and activities, as well as sacred and ceremonial areas such as mountains and rivers, where food and medicinal plants were gathered and are dispersed across the landscape (PNNL-14237, *U.S. Department of Energy's Hanford Cultural Resources Laboratory Oral History and Ethnography Task Annual Report*).

Many sites and natural features along the Columbia River are regarded as sacred or important to the cultural heritage of members of the Confederated Tribes of the Umatilla Indian Reservation, Yakama Indian Nation, the Nez Perce Tribe, and the Wanapum People. Nearby features culturally important to Tribal Nations members include Rattlesnake Mountain, Gable Mountain, Gable Butte, and Goose Egg Hill.

Data collection and remedy selection in the RI/FS process will be guided by preserving these locations for exercising customary cultural resource rights. Similar to other areas across the Hanford Site, disturbance maps and reports have been prepared for many areas. The locations and potential impacts to these resources are reviewed by Tribal Nations leaders before site activities begin (DOE/RL-98-10).

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3 Historical Information

Since the early 1990s when interim action cleanup began in earnest in the River Corridor, DOE has accomplished major goals in the investigation and remediation of contaminated sites. More than 35,000 environmental samples, (including more than 20,700 groundwater 5,900 surface water, 1,400 sediment, and 7,000 biota samples) have been collected to provide key risk assessment information that will be further augmented by current human health and ecological risk assessments. In addition, 200 to 363 wells per year have been sampled from 1992 to 2008. These studies have been undertaken to determine the nature and extent of the contamination, support risk assessment activities, and identify opportunities for early cleanup actions at NPL sites for the River Corridor. More than 300 structures have been demolished, along with ISS of five plutonium production reactors; over 155 waste sites have been remediated and 78 of 82 high-priority sites cleaned up; and over 5,500 ha (13,600 ac) evaluated to identify newly discovered waste sites. Over 7.6 billion L (2 billion gal.) of groundwater has been treated and nearly 907 kg (1 ton) of CrVI removed from the aquifer.

This chapter summarizes previous investigations, remediation, and risk assessment activities conducted to support sound interim action cleanup decisions and to refine the CSMs. DOE has thoroughly examined a number of sources of information. Information collected in previous investigations has been combined with the information gathered during the implementation of interim remedial actions and removal actions to provide an understanding of the nature and extent of contamination at each area (Figure 3-1). Results from these activities have differentiated between contaminated and uncontaminated areas throughout the River Corridor.

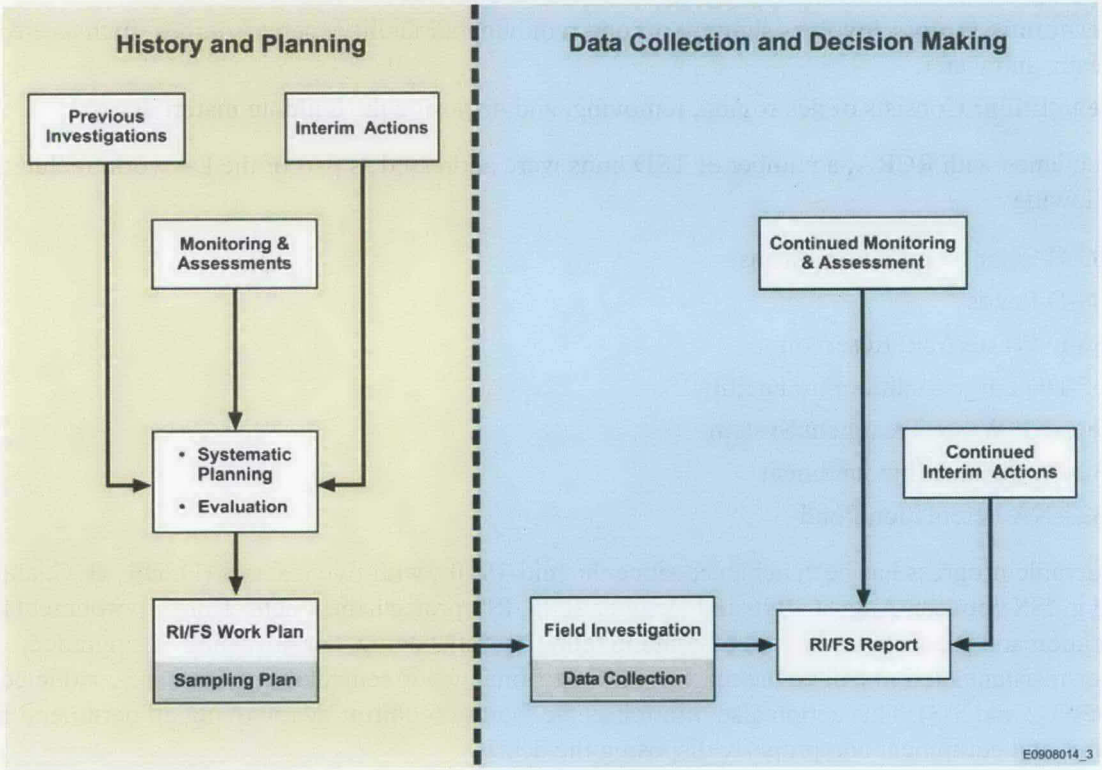


Figure 3-1. Information Sources for Development of the Remedial Investigation/Feasibility Study

Early cleanup actions have helped sharpen the focus of data collection efforts in recent years to fine tune remedial actions. Efforts to understand the nature and extent of contamination beyond the areas adjacent to reactors have been extensive and have demonstrated that the focus of early actions on waste sites associated with reactor areas has been instrumental in addressing the highest priority environmental risks.

This work plan and addenda propose collection of additional information that is needed to support final action cleanup decisions. When combined with historical data, data collected during continued implementation of interim action RODs, routine site monitoring activities, and specific studies to assess the potential applicability of treatment technologies, this information will be integrated in the RI/FS report to support final action cleanup decisions for sites in the River Corridor (Figure 3-1).

3.1 Facility Deactivation, Decontamination, Decommissioning, and Demolition Actions

Since 1995, more than 300 structures (including several treatment, storage, and disposal [TSD] units) have been demolished in the 100 Area. These actions have cleared the way for remedial action at underlying waste sites and provided opportunity for the discovery of new waste sites.

The removal of a contaminated facility involves the following sequenced deactivation, decontamination, decommissioning, and demolition (D4) steps:

- **Deactivation:** Involves halting the operations or processes of the facility. For example, in one of the early efforts in 1992, corroding radioactive fuel was removed during the 100-K Basin deactivation.
- **Decontamination:** Includes removing and stabilizing radioactive and hazardous materials.
- **Decommissioning:** Involves shutting off and removing all facility energy sources, such as electricity, steam, and water.
- **Demolition:** Consists of destroying, removing, and disposing the building materials.

In compliance with RCRA, a number of TSD units were addressed as part of the D4 work, including the following:

- 183-H Solar Evaporation Basins
- 100-D Ponds
- 186-D Waste Acid Reservoir
- 105-DR Large Sodium Fire Facility
- 1706-KE Waste Treatment System
- 1324-N Surface Impoundment
- 1324-NA Percolation Pond

Considerable progress has been achieved since the mid-1990s, with five reactors (D, DR, H, C, and F) placed in ISS between August 1996 and October 2005. ISS protects the reactor from environmental degradation and prevents the spread of contamination by "cocooning," or providing an upgraded, weather-resistant shell to isolate the reactor core until final action remedial activities are conducted (Figures 3-2 and 3-3). This action also minimizes the facility footprint by removing all peripheral reactor buildings and equipment and properly disposing the debris.

Figure 3-2. C Reactor in 1992 before Cocooning

Figure 3-3. C Reactor as it Looks Today

3.2 Previous Investigation

Previous investigations and characterization activities conducted to support sound interim action cleanup decisions and to refine CSMs included the following:

- Technical baseline reports summarized existing process and contamination information.
- Limited field investigations (LFIs) were conducted to collect additional characterization data and support QRAs.
- Focused FSs were prepared to select interim remedial actions.

The following sections describe these reports.

3.2.1 Technical Baselines

Technical baseline reports were prepared for each operating area and provided DOE, regulatory agencies, and contractors with a "baseline" of technical information related to operational processes and resulting contaminated waste sites. A report was created for each River Corridor operating area (Table 3-1). The information in the reports was based on the evaluation of numerous Hanford Site reports, drawings, and photographs supplemented by site inspections and employee interviews. No intrusive field investigation or sampling was conducted during development of the technical baseline reports.

Table 3-1. Technical Baseline Reports

Report Title	Document Number
100-B Area Technical Baseline Report	WHC-SD-EN-TI-220
100-D Area Technical Baseline Report	WHC-SD-EN-TI-181
100-F Reactor Site Technical Baseline Report Including Operable Units 100-FR-1 and 100-FR-2	BHI-00031
100-H Area Technical Baseline Report	BHI-00127
100-IU-6 Operable Unit Technical Baseline Report	BHI-00146
100-K Area Technical Baseline Report	WHC-SD-EN-TI-239
100-N Area Technical Baseline Report	WHC-SD-EN-TI-251
300-FF-2 Operable Unit Technical Baseline Report	BHI-00012
White Bluffs, 100-IU-2 Operable Unit Technical Baseline Report	BHI-00448

Each 100 Area technical baseline report, with the exception 100-IU-2 and 100-IU-6, describes the industrial process history, which was similar from one area to another. Industrial processes were not conducted in the 100-IU-2 and 100-IU-6 Areas. There were variations in terms of years of operation and intensity of use, as well as containment failure events, process improvements, or research activities unique to a given area. The reports also describe the types of waste streams that resulted from the operations, with estimated volumes and suspected contaminants. The reports contain maps and photographs of the facilities cited in the reports and information on the environmental monitoring sampling conducted for each area. A detailed description is provided for each waste site within an area, describing known contamination and condition as of the time the report was written.

Work plan documents summarized and supplemented the technical baseline information for conducting field investigations. Table 3-2 lists the work plan documents for the River Corridor OUs.

Table 3-2. River Corridor Source and Groundwater OU Work Plan Reports

Report Title	Document Number
Remedial Investigation/Feasibility Study Work Plan for the 100-BC-1 Operable Unit, Hanford Site, Richland, Washington	DOE/RL/90-07
Remedial Investigation/Feasibility Study Work Plan for the 100-BC-2 Operable Unit	DOE/RL-91-07
Remedial Investigation/Feasibility Study Work Plan for 100-BC-5 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-90-08
Remedial Investigation/Feasibility Study Work Plan for the 100-KR-1 Operable Unit	DOE/RL-90-20
Remedial Investigation/Feasibility Study Work Plan for 100-KR-4 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-90-21
RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit	DOE/RL-90-22
RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-2 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-91-46
RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-DR-1 Operable Unit, Hanford Site, Richland, Washington	DOE/RL/89-09
RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-1 Operable Unit Hanford Site, Richland, Washington	DOE/RL-88-35
RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-2 Operable Unit	DOE/RL-93-20
RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-3 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-88-36
Remedial Investigation/Feasibility Study Work Plan for the 100-FR-1 Operable Unit	DOE/RL-90-33
Remedial Investigation/Feasibility Study Work Plan for the 100-FR-3 Operable Unit, Hanford Site, Richland, Washington	DOE/RL-91-53

Additional work plan documents supplementing the technical baseline information include the future RCBRA report and the DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to Columbia River*.

3.2.2 Limited Field Investigations and Qualitative Risk Assessments

The LFIs completed for the 100 Area OUs consisted of historical data compilation, nonintrusive investigations (e.g., geophysics), intrusive investigations (e.g., boreholes), and the 100 Area aggregate studies (i.e., ecological, river water, and sediment sampling). In addition, the LFIs provide information regarding historical sampling and analysis, which is useful in developing soil (deeper than the 4.6 m [15 ft] point-of-compliance depth) target analyte lists for further investigation.

The LFI reports completed for the 100 Area consisted of historical data compilation, nonintrusive investigations (e.g., geophysics), intrusive investigations (e.g., boreholes), and the 100 Area aggregate studies (i.e., ecological, river water, and sediment sampling) (DOE/RL-88-36, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-3 Operable Unit, Hanford Site, Richland, Washington*). The LFI reports completed for River Corridor waste sites are listed in Table 3-3.

Table 3-3. Limited Field Investigation Reports

Report Title	Document Number
Limited Field Investigation Report for the 100-BC-1 Operable Unit	DOE/RL-93-06
Limited Field Investigation Report for the 100-BC-2 Operable Unit	DOE/RL-94-42
Limited Field Investigation Report for 100-BC-5 Operable Unit	DOE/RL-93-37
Limited Field Investigation Report for the 100-KR-1 Operable Unit	DOE/RL-93-78
Limited Field Investigation Report for 100-KR-4 Operable Unit	DOE/RL-93-79
Limited Field Investigation Report for 100-NR-2 Operable Unit	DOE/RL-93-81
Limited Field Investigation/Qualitative Risk Assessment for the 100-DR-1 Operable Unit, Appendix D of *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-DR-2 Operable Unit*	DOE/RL-93-46
Limited Field Investigation Report for the 100-DR-2 Operable Unit	DOE/RL-94-73
Limited Field Investigation Report for the 100-HR-1 Operable Unit	DOE/RL-93-51
Limited Field Investigation Report for the 100-HR-2 Operable Unit	DOE/RL-94-53
Limited Field Investigation Report for 100-HR-3 Operable Unit	DOE/RL-93-43
Limited Field Investigation Report for the 100-FR-1 Operable Unit	DOE/RL-93-82
Limited Field Investigation Report for 100-FR-3-Operable Unit	DOE/RL-93-83
100-FR-3 Groundwater Soil Gas Supplemental Limited Field Investigation Report	DOE/RL-95-99

The LFIs recommended sites for interim remedial action and categorized them as high or low priority. High-priority sites were considered to have the highest potential to contribute to contamination of groundwater and the Columbia River. The reports also provided a preliminary summary of site characterization studies and identified contaminant-specific and location-specific applicable or relevant and appropriate requirements (ARARs). The data collection activities associated with the LFIs supplemented existing information (such as the compilation of waste site investigation results in UNI-946, *Radiological Characterization of the Retired 100 Areas*) to support formulation of conceptual models, as well as performance of QRA for each area.

The QRAs, listed in Table 3-4, included consideration of whether contaminant concentrations pose an unacceptable risk that warrants remedial action. This information is used as the basis for remedial actions completed to date as well as current and future remedial actions identified in the interim action RODs.

Table 3-4. Qualitative Risk Assessment Reports

Report Title	Document Number
Qualitative Risk Assessment for the 100-BC-1 Source Operable Unit	WHC-SD-EN-RA-003
Qualitative Risk Assessment for the 100-KR-1 Source Operable Unit	WHC-SD-EN-RA-009
Qualitative Risk Assessment for the 100-NR-1 Source Operable Unit	BHI-00054
Qualitative Risk Assessment for the 100-DR-1 Source Operable Unit	WHC-SD-EN-RA-005

Table 3-4. Qualitative Risk Assessment Reports

Report Title	Document Number
Qualitative Risk Assessment for the 100-HR-1 Source Operable Unit	WHC-SD-EN-RA-004
Qualitative Risk Assessment for the 100-FR-1 Source Operable Unit	BHI-00053

The high-priority sites were evaluated using the following criteria to help identify those recommended for remedial actions:

- Magnitude of risk identified in the QRA
- Exceedance of a chemical-specific ARAR
- Potential to contaminate groundwater
- Insufficient information for conceptual model
- Multiple exposure pathways
- Expected natural attenuation and radioactive decay

QRAs were performed for the high-priority sites in each OU. Conservative assumptions, such as highest reported contaminant levels from either the LFI or historical data from UNI-946, were used in the QRAs. The QRA provides estimates of human health risks, assuming frequent use and occasional use, and includes considerations such as the attenuation of external dose provided by layers of clean gravel fill that overlie many sites. The QRAs identify the human health risk to be primarily from external exposure to the radionuclides cobalt-60, cesium-137, europium-152, and europium-154. The QRAs were used to establish the basis for action for all waste sites identified in the River Corridor.

3.2.3 Focused Feasibility Studies

The purpose of the focused FSs performed in the 100 Area was to support selection of interim remedial actions for sites within the OUs. DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study Report*, provided the decision makers with the information they require from the investigation activities for selection of remedial actions. Focused FSs developed site profiles for the high-priority waste sites (as identified in the LFI reports) and made comparative analyses of the remedial action alternatives.

3.3 Monitoring and Assessment

During implementation of interim actions, other investigations and monitoring have been conducted to evaluate contamination and continue refinement of information within the 100 Area. These investigation and monitoring activities include the following:

- Environmental monitoring and surveys
- Air emissions evaluations
- Routine groundwater monitoring and remedy effectiveness monitoring
- Environmental Radiation Monitoring and Assessment Program

The following sections describe these activities.

In addition to monitoring and assessment activities, an inventory of known and potential waste sites has been maintained in the WIDS database since the early 1980s. The process of evaluating old land-based and aerial photographs, historical documentation, and area walkdowns has continued as part of many subsequent projects. The WIDS waste site list has grown to contain more than 2,800 sites. The list contains sites within the areas where plutonium production and research operations occurred and in areas of lower intensity use outside the operational boundaries. Even locations such as known borrow pits are tracked and evaluated for their potential to have received wastes in the past. Sites are not removed from WIDS after they are cleaned up, but the classification status and information concerning each site are updated.

In 2004, a longer term study called the orphan sites evaluations began. Extensive review of historical records, field walkdowns, interviews with current and former Hanford Site employees, and geophysical investigations are being conducted in the 100 and 300 Areas operations areas and surrounding lands. This process is anticipated to continue in the coming years for the remaining operations areas and the areas between the reactor areas. New waste sites identified during the orphan sites evaluation process typically include pipelines, dry wells associated with buildings, and dump sites/debris piles/landfills from former decontamination and demolition activities. These new sites are being added to the WIDS database for disposition under the proper remedial authority. Section 3.4.2 of this document provides more details.

3.3.1 Environmental Monitoring and Surveys

Much investigative work has been focused along the Columbia River because of the potential risk of exposure to people and the environment. DOE has completed routine radiological surveys of the river shore (PNL-3127, *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and* the *Snake River Confluence*), as well as sampling of the riverbank springs and sediment (DOE/RL-92-12, *Sampling and Analysis of 100 Areas Springs*; WHC-SD-EN-TI-198, *100 Area Columbia River Sediment Sampling*; PNNL-13230, *Hanford Site Environmental Report for Calendar Year 1999 [Including Some Historical and Early 2000 Information*]). The annual environmental monitoring reports also document and evaluate surveillance sampling of many media on and off the Hanford Site (e.g., vegetation, terrestrial and aquatic wildlife, air, soil, and water) to quantify potential contaminant concentrations and to assess their environmental and human health significance.

Aerial radiological surveys were completed (EGG-10617-1062, *An Aerial Radiological Survey of the Hanford Site and Surrounding Area*) to define areas of radioactive contamination. The EGG-10617-1062 survey covered the Hanford Site and the banks of the Columbia River downriver to McNary Dam. The radiation levels over more than 95 percent of the site were reported to be due to normal levels of background radiation. Areas of elevated radionuclide activity outside of operational areas have been investigated and are identified in WIDS. Several slough areas along the Columbia River also showed elevated radioactivity; these areas were sampled and the radionuclide content shown to be only slightly above background (WHC-SD-EN-TI-198). This sampling also confirmed that the sensitivity of the aerial radiological survey equipment used was sufficient to detect low levels of radioactivity.

3.3.2 Air Emissions Evaluations

In 2005, an evaluation of the releases on the Hanford Site from air emissions stacks located in the 100 and 300 Areas was made (DOE/RL-2005-49, *RCBRA Stack Air Emissions Deposition Scoping Document*) using previous background soil sampling work, radiological surveys, and an evaluation of the materials (radionuclides and metals) emitted and their amounts. The report concluded that there were no

locations of elevated radioactivity or metals in the 100, 300, or associated 600 Areas due to aerial deposition, other than those discrete areas already identified as waste sites in WIDS. This information was considered along with soil sampling results to evaluate the sites selected as reference or comparison sites for the baseline risk assessment.

3.3.3 Groundwater Monitoring

DOE monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the AEA, RCRA, CERCLA, and the *Washington Administrative Code*. In fiscal year 2006, workers sampled 778 wells and 247 shoreline aquifer tubes to determine the distribution and movement of contaminants. A total of 307 of those wells are located in the 100 Area. An annual summary report is published to integrate information from multiple sources. PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, discussed emerging issues, groundwater flow, groundwater monitoring and remediation, shoreline monitoring, well installation, maintenance and monitoring, vadose zone, and continued monitoring.

3.3.4 Environmental Radiation Monitoring and Assessment Program

The Washington State Department of Health (DOH), Division of Environmental Health has an oversight program to independently verify the quality of the DOE monitoring programs at the Hanford Site. The DOH performs this oversight by conducting split, co-located, and independent sampling at locations having the potential to release radionuclides to the environment or locations that may be impacted by such releases. DOH uses the oversight data to assess impacts to the public and to address public concerns related to radiation at the Hanford Site. The DOH publishes an annual Hanford Site environmental oversight program summary report.

3.4 Interim Actions

Interim actions for the 100 Areas were established in the 1990s. These actions were for both waste site and groundwater remediation. These interim actions and orphan site evaluations are discussed in the following sections.

3.4.1 Interim Action Waste Site Remediation

The earliest interim action ROD (EPA/ROD/R10-95/126, *EPA Superfund Record of Decision: Hanford 100-Area (USDOE) EPA ID: WA3890090076, OU 01, Benton County, WA*) established for the 100 Area covers interim actions in the 100-B/C-1, 100-DR-1, and 100-HR-1 OUs. DOE/RL-94-61 identified six general response actions that could have been applied to waste sites in these OUs. The six response actions (alternatives) evaluated for interim action remediation were:

1. No action
2. Institutional Controls
3. Containment
4. In Situ Treatment
5. Remove/Dispose
6. Remove/Treat/Dispose

Before the evaluation, a future unrestricted land use goal for the 100 Area lands was established. Because some of the evaluated actions would have imposed limitations on land use, and/or failed to meet other NCP criteria, the first five alternatives were rejected as a result of the evaluation process.

The selected remedy was the RTD for liquid radioactive effluent disposal site cleanup. The RTD activities included the following:

- Removing and stockpiling uncontaminated overburden for re-use as fill material. This includes dust suppression during excavation, transportation, and disposal.
- Treating soil through soil washing or thermal desorption before transport to the Environmental Restoration Disposal Facility (ERDF).
- Field screening contaminant levels during remediation.
- Adhering to site-specific soil excavation and management factors to determine the extent of remediation:
  - For soil contamination less than 4.6 m (15 ft), RAOs must be met at the achievement of residential *Model Toxics Control Act* (WAC 173-340) Method B levels and the 15 mrem/year residential dose level, and support protection of groundwater and the Columbia River.
  - For soil contamination that extends 4.6 m (15 ft) bgs and deeper, protection of groundwater and the Columbia River must be achieved. Additional factors may be considered, such as decay risks of short-lived radionuclides, protection of human health and the environment, remediation and monitoring costs, ERDF capacity, worker safety, presence of ecological and cultural resources, use of institutional controls, and compliance with maximum contaminate levels (MCLs) for groundwater protection and AWQC for river protection.
- Backfilling and revegetating at remediated sites.
- Implementing institutional controls and long-term monitoring, as needed.
- Conducting 5-year reviews.

For over a decade, large-scale cleanup at the Hanford Site has focused on liquid waste sites, which are the sites believed to have the greatest influence on groundwater quality. By 2004, 78 of the 82 high-priority liquid waste sites identified in the 100 Area had been cleaned up and work had begun on solid waste burial grounds and remaining miscellaneous waste sites as guided by interim action RODs. The remaining miscellaneous waste sites include the sodium dichromate handling, mixing, and distribution systems that may have contributed to groundwater contamination. The four remaining high-priority liquid waste sites are in the 100-K Area and are not accessible due to ongoing operations. Over 155 waste sites have been remediated in the 100 Area through cleanup actions that removed 8 million tonnes (9 million tons) of contaminated soil and debris. Twenty-six of the 45 burial grounds have been cleaned up/evaluated to date, with the remainder scheduled to be completed by the end of calendar year 2010. Figure 3-4 shows contaminated soil removed from the 100-D Area.

Figure 3-4. Contaminated Soil Removed from 100-D Area

The primary interim cleanup actions for waste sites involve removing soil, underground pipes (as shown in Figure 3-5), and debris that could endanger human health, groundwater, or the environment. Removal of soil and debris continues until field observations and data indicate that cleanup levels specified in the interim action RODs have been meet. Every remediated waste site then undergoes verification sampling and analysis as part of the cleanup verification package (CVP). Some waste sites also require an intermediate step called confirmation sampling. These sites are sampled and evaluated using designs that are approved by DOE and the lead regulators to determine if remediation is required. After DOE and the involved regulatory agency agree that remediation goals for the site have been achieved, the waste site is backfilled (as applicable) and reclassified to an interim closed out or no action status, and revegetated.

Figure 3-5. Pipe Removal from a Chromium-Contaminated Waste Site

3.4.2 Waste Site Identification

Past and present activities provide confidence that waste site locations in the River Corridor are known and processes have been established to address new discoveries when identified. Waste site identification activities in the River Corridor fall into two categories: systematic and observational. Various systematic programs have been conducted at different times, while observation-based identification activities can happen at any time and will continue into the future.

One of the key systematic processes used to identify waste sites was conducted between 1985 and 1988. Reviews of technical baseline reports, historical waste disposal records, occurrence reports, site investigation observations, release discoveries, and employee interviews were used to identify, organize, and rank sites with respect to potential environmental impacts. The results from this process provided information to support the addition of the 100 and 300 Areas to the NPL and subsequent listing of waste sites in Appendix C of the Tri-Party Agreement in 1989 (Ecology et al., 1989a). The RAOs for these waste sites were established in the CERCLA interim action RODs in 1996, which have guided cleanup actions in the River Corridor.

Supplementing past systematic efforts that led to identification of source waste sites in the existing RODs, a series of investigations to identify new potential waste sites in the River Corridor was initiated in 2004. The investigations, called "orphan site evaluations," are a systematic approach to review land parcels in the River Corridor to increase confidence that waste disposal or releases requiring characterization and cleanup within a given land parcel of the Corridor have been identified. Information collected through

these evaluations also supports elements of the CERCLA Section 120(h)(4) requirements for review and identification of uncontaminated property at federal facilities. The progress of orphan site evaluations in the River Corridor through August 2009 is shown in Figure 3-6.

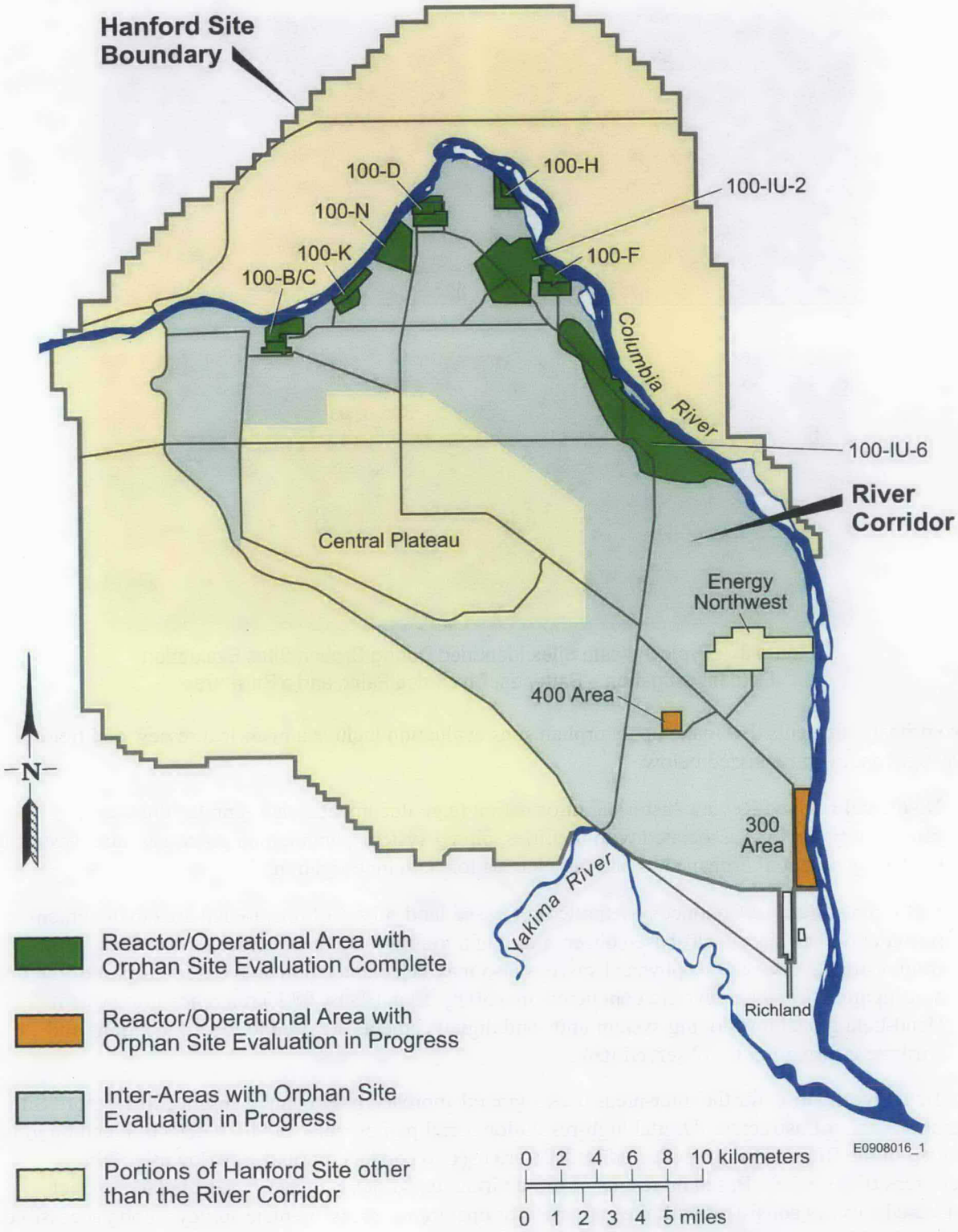


Figure 3-6. Orphan Site Evaluation Areas (through August 2009)

Results of the evaluations are reviewed with participation from the lead regulatory agency and are summarized in an orphan site evaluation report. New waste sites identified through this process (Figure 3-7) typically are added to the scope of one of the source OU RODs through issuance of an Explanation of Significant Difference (ESD).

Figure 3-7. Typical Waste Sites Identified During Orphan Sites Evaluation Field Investigation – Batteries, Discarded Paint, and a Burn Area

Two primary elements that make up an orphan sites evaluation include a historical review and field investigation, as summarized below.

- **Historical review:** Review historical information (e.g., documents, photographs, drawings, geophysical surveys) associated with facilities, piping systems, operational processes, and waste sites to identify potential orphan sites and target areas for field investigation.
- **Field investigation:** Conduct systematic foot-based land survey of operational area to document potential orphan sites (field-based observation) and to follow up on potential orphan sites identified from historical review. Geophysical surveys also may be conducted in target areas as part of the field investigation. Land surveys are conducted on a 30 by 30 m (98 by 98 ft) reference grid system. Hand-held global positioning system units and digital cameras are used to record locations and attribute information for observed items.

The field investigation for the inter-areas uses a graded approach based on the absence of Hanford Site operations and infrastructure. Digital high-resolution aerial photographs and light detection and ranging imagery of the River Corridor collected in 2008 are used to conduct "virtual walkdowns" of the inter-areas (Figure 3-8). Based on results of these virtual walkdowns, areas are selected to conduct foot-based surveys consistent with the approach for operational areas. Vehicle surveys along accessible roads and utility easements also are part of the field investigation for the inter-areas.

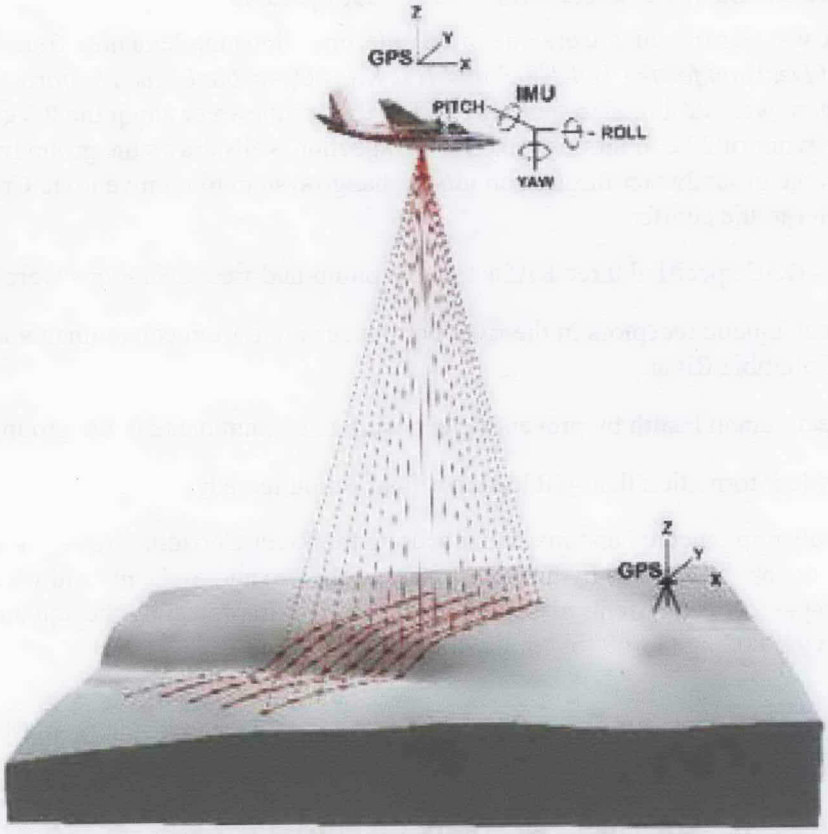


Figure 3-8. Schematic of Light Detection and Ranging Imagery Data Collection Using Fixed-Wing Aircraft

Following completion of the orphan sites evaluation for a given area, new waste sites identified by the process typically are "plugged-in" to an appropriate ROD for subsequent characterization and determination of the need for cleanup. If one or more of the new waste sites does not meet the criteria for "plug-in" under the provisions of an existing ROD, the Tri-Parties will determine the approach to establish the regulatory framework for selection of cleanup actions under an appropriate decision document.

In addition to the systematic processes that have been conducted in the River Corridor to identify waste sites, observation-based discoveries can lead to identification of new waste sites (often referred to as discovery sites). Demolition and removal of retired facilities, cleanup of existing waste sites, and routine monitoring or area management activities provide new opportunities for discovery of potential waste sites. These discoveries can occur at any time and may be identified by any individual. Observation-based discoveries that become waste sites typically are added to the scope of existing RODs in the same way as sites identified through systematic processes. The opportunities for these type discoveries will continue throughout cleanup of the river corridor, including activities conducted after final action RODs are issued (e.g., CERCLA 5-year reviews).

3.4.3 Groundwater Remediation

The interim actions for groundwater in the 100 Area are pump-and-treat systems. Three areas have operations pump-and-treat systems. The systems and remediation process optimization are discussed in the following sections.

3.4.3.1 100-K, 100-D, and 100-H Areas Pump-and-Treat Systems

The pump-and-treat systems, which were one of the interim actions implemented from EPA et al., 1996, *Interim Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington*, were designed to remedy CrVI in the groundwater along the River Corridor. The current system network of 27 extraction wells and 11 injection wells draws the groundwater from the aquifer, processes the groundwater through an ion-exchange system to remove toxic CrVI, and returns the treated groundwater to the aquifer.

The interim action ROD specified three RAOs that the pump-and-treat operations were to achieve:

- **RAO 1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- **RAO 2:** Protect human health by preventing exposure to contaminants in the groundwater.
- **RAO 3:** Provide information that will lead to a final action remedy.

Institutional controls implemented and maintained along the River Corridor already have been successful in protecting human health (RAO 2) by limiting access to the site and to the groundwater. As shown in Table 3-5, the pump-and-treat systems also have made progress in protecting the aquatic receptors (RAO 1) by removing 802 kg (1,769 lbs) of CrVI in the past decade.

Table 3-5. Status (2008) of the Pump-and-Treat Systems in the 100-K, 100-D, and 100-H Areas

System	Startup	Groundwater Treated Since Startup – December 2007 (million gal)	CrVI Removed Since Startup – December 2007 (lb)	Design Capacity (gal/min)	Current Average Process Flow (gal/min)	Number of Extraction Wells	Number of Injection Wells
100-HR-3	June 1997	845	717	300	167	10	3
100-DR-5	July 2004	60	392	50	38	4	1
100-KR-4	October 1997	1,054	614	300	252	9	5
100-KW	January 2007	45	46	100	97	4	2
Totals		**2,004**	**1,769**	**750**	**554**	**27**	**11**

The pump-and-treat systems continue to operate in the 100-K, 100-D, and 100-H Areas but are in the process of receiving upgrades to achieve the protection of the aquatic receptors objective. Plans to increase their capacity and area of influence are moving forward through a continuous improvement technique called "remedial process optimization." The four systems are being evaluated to determine what improvements and expansions might be needed to make them operate more efficiently, increase the area of influence, and increase the mass removal of CrVI. The present and planned remedial process optimization improvements and expansions of the pump-and-treat network (Table 3-6), in conjunction with other remedial actions, will accelerate achievement of the protection of the aquatic receptors objective.

Table 3-6. Ongoing and Planned Optimization and Expansion of the Pump-and-Treat-Systems in the 100-K, 100-D, and 100-H Areas

System	Scheduled Start	Additional Design Capacity (gal/min)	Number of Additional (New) Extraction Wells	Number of Additional (New) Injection Wells
HR-3 Optimization	November 2008, complete acceptance testing in April 2010	0*	~0	~0
HR-3 Expansion	November 2008, complete acceptance testing in May 2011	100	5	2
DX	November 2008, complete acceptance testing in May 2011	600	28	14
KX	Current, turnover to operations February 2009	400	10	8
KX/KR-4 realignment, Phase I	December 2008, complete acceptance testing in May 2009	~150	3	0
KX/KR-4 realignment, Phase II	February 2009, complete acceptance testing in January 2010	~50	1	2
KW expansion	October 2008, complete acceptance testing in May 2009	100	4	2
Totals by December 2011		**~1,400**	**~51**	**~28**

Notes:

The values shown are approximate based on current information and may change as further design of the systems and systems improvements occur.

*Existing wells will be used to increase the throughput of the 100-HR-3 Pump-and-Treat Facility up to its design capacity of 1,136 L/min (300 gal/min).

~ = approximately

In addition to supporting system efficiencies, the evaluation of the pump-and-treat systems and their effectiveness will contribute to the FS. This evaluation will provide input for the final action remedy, thus meeting RAO 3. Although pump-and-treat systems are in place, in some areas when used alone, they may not be able to remove enough CrVI to achieve cleanup goals. Other technologies are being considered to supplement the pump-and-treat systems.

3.4.3.2 Remediation Process Optimization

Remediation process optimization (RPO) leads to the formulation of remedial action alternatives that have a higher likelihood of achieving cleanup at reduced cost. By implementing a systematic evaluation and enhancing the current site remediation actions, remedial process optimization can foster help with cleanup performance and streamline cost. To determine how remedial actions could be improved, RL initiated a remedial process optimization effort for the 100-D/H Area in 2008 that is continuing into 2009. The RPO process will also occur at the 100-K Area.

The 100-D Area encompasses the operating areas of two former DOE production reactors (D and DR Reactors). While these reactors were operational, large volumes of river water were treated with sodium dichromate (to inhibit corrosion of the reactor piping) for use as coolant for the reactors. After a single pass through the reactor and before being discharged back to the river, the coolant water was sent to unlined retention basins to cool and allow short-lived radioactive isotopes to decay. This process created both contaminated vadose zone soils and large areas of contaminated groundwater. In addition, planned and inadvertent discharges of concentrated sodium dichromate stock solution led to "hot spots" of elevated levels of CrVI in the vadose zone and groundwater.

Despite the natural flushing of the aquifer that has occurred since the reactors were taken off-line and the installation and operation of treatment systems at the 100-D Area, elevated concentrations of CrVI have persisted in the groundwater in this area. The persistence of the CrVI plume, including localized "hot spot" areas containing substantially elevated concentrations, provides evidence that residual CrVI continues to provide a source of ongoing contamination.

The current remediation approaches for the plumes leverage a number of mechanisms. The initial treatment system, known as the 100-HR-3 system, extracts contaminated groundwater using four extraction wells that are located in the northeastern portion of the 100-D Area (Figure 3-9).

Between 2000 and 2003, the 100-HR-3 system was augmented by the phased installation of the passive in situ redox manipulation (ISRM) treatment zone (as previously discussed). Augmentation of the ISRM barrier is being considered because the degree of upgradient CrVI contamination is greater than previously believed.

Active treatment in the 100-D Area was expanded in 2004 with the addition of a second ion-exchange pump-and-treat system, the DR-5 System. The DR-5 system was designed to capture CrVI contamination located further south in the 100-D Area plume (and upgradient of the ISRM). Four groundwater extraction wells currently operate as part of the DR-5 System.

During 2008 and early 2009, the remedial process optimization team identified actions necessary to reduce cost and improve performance of existing remedial systems. The team also identified and evaluated promising new technologies (e.g., bioremediation) for CrVI remediation. The remedial process optimization results culminated in the development of a two-step, or "phased," approach for implementing proposed remedial alternatives to the 100-D Area, 100-H Area, and the "Horn" Area:

- **Phase 1:** Involved leaving existing institutional controls in place and continuing RTD and pump-and-treat operations. The RTD and pump-and-treat operations will be expanded to increase their coverage of the contaminated groundwater plume.
- **Phase 2:** Continues current actions, with the addition of the option to conduct in situ bioremediation or chemical remediation to accelerate remediation of soil and groundwater alternatives at the 100-D Area, 100-H Area, and the Horn Area as follows:

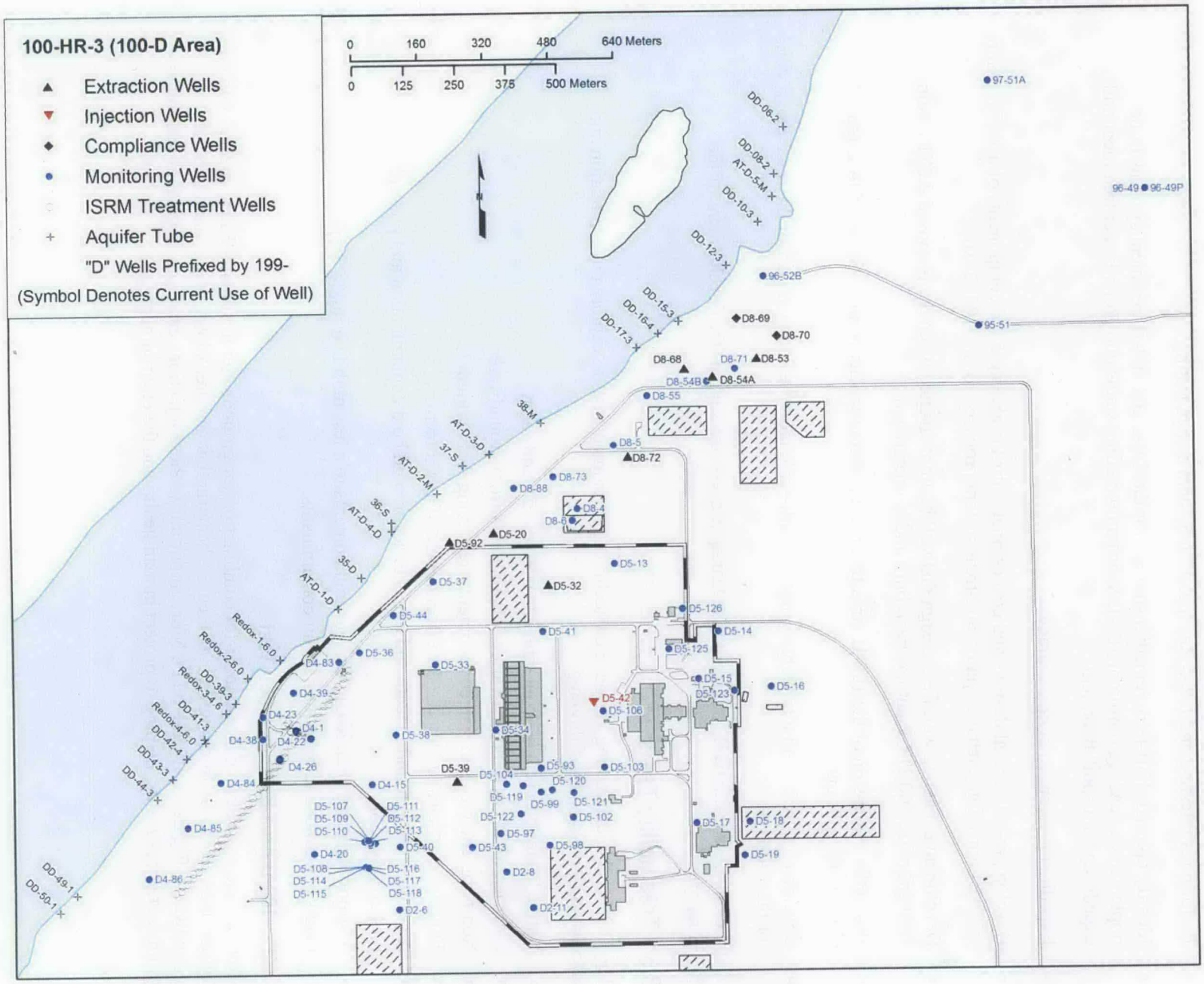


Figure 3-9. 100-D Area Treatment System Infrastructure

Specific work proposed through the remedial process optimization included the following multiple elements.

- Perform resin testing and DR-5 Regeneration System design testing.
- Identify optimal short-term remedial strategy for the DR-5 and 100-H treatment systems to be implemented pending startup of 100-DX system including status quo groundwater treatment and expediting "hot spot" treatment.
- Expedite the river protection strategy.
- Develop pre-conceptual designs and cost estimates for the aboveground components of a 2,271 L/min (600 gal/min), ion-exchange pump-and-treat system proposed for the 100-D Area.
- Develop an expanded well field design that will be implemented when the proposed 2,271 L/min (600 gal/min), 100-DX Plant has been built and is operational.
- Design the expansion of the 100-H Area treatment system capacity from 1,136 to 1,514 L/min (300 to 400 gal/min).
- Develop and implement a treatability test of a full-scale bioremediation as part of the remedial system for the 100-D Area.

These elements substantively augment the cleanup process and support the development of the RI/FS reports.

3.5 Treatability Tests

The DOE is also conducting various new technology treatment tests to explore the application and effectiveness of using the following:

- Native bacteria to remove contaminants from the groundwater.
- Electrical fields to remove a variety of pollutants from groundwater.
- Non-toxic chemicals to trap contaminants, rendering them immobile.
- Tiny iron particles to increase the effectiveness of a treatment.
- A stable mineral found in teeth and bones to adsorb and hold contamination and prevent further migration.
- A strong reducing chemical to change contaminants to a less mobile or toxic form.
- Plants to extract and/or sequester soil contaminants.

3.5.1 100-D Area Biostimulation Test

Molasses and vegetable oil are a powerful combination for groundwater treatment. When injected into the aquifer, these common food ingredients feed the bacteria that can breakdown contaminants in the groundwater (Figures 3-10 and 3-11). More importantly, these injections can work in tandem with other groundwater treatments, helping to protect human health and the environment.

Figure 3-10. Molasses Injected at 100-D Area Biostimulation Treatability Test Site to Nourish Contamination-Destroying Bacteria

Figure 3-11. Molasses from Large Tanker Truck Injected into Well that Delivers it to Contaminated Groundwater

Referred to as "in situ biostimulation," the technology has been used commercially at many contaminated sites. Whether it could be used at the Hanford Site to augment other remedial technologies was a question that a treatability study in the 100-D Area was designed to answer, and the results indicate that in situ biostimulation is a treatment option.

The study focused on determining whether in situ biostimulation could work at the 100-D Area in conjunction with the existing ISRM barrier, which was installed to reduce the amount of CrVI entering the Columbia River. The longevity of the ISRM barrier is currently being threatened by high levels of nitrate and dissolved oxygen in the groundwater. If the two technologies prove compatible, the in situ biostimulation could serve as an inexpensive method for supplementing the ISRM reduction of CrVI. Moreover, in situ biostimulation could increase the life of the ISRM barrier by decreasing the

concentrations of CrVI, nitrate, and dissolved oxygen flowing into the ISRM barrier. In addition to these advantages, biostimulation can be designed to treat groundwater species over relatively long timeframes, via slow-release substrates, buildup of biomass, and/or relatively inexpensive reinjection of substrates.

Two phases of field testing for a biostimulation barrier were performed to examine two commercially available approaches: one approach using molasses (a soluble substrate), and the second approach using emulsified vegetable oil (an immiscible substrate). The first phase was initiated in September 2007 with the injection of molasses into the aquifer through a single injection well at the 100-D Area testing location. The injected molasses successfully formed a treatment zone about 30 m (100 ft) in diameter, and the treatment zone has effectively been treating nitrate and CrVI over the past 15 months of monitoring.

The molasses test provides information needed to assess biostimulation in terms of effectiveness, implementability, and cost, and the early results look promising. Implementation of the barrier was accomplished, thereby meeting the test goals for injecting the molasses and obtaining a treatment barrier of the targeted size. Data on equipment and operational requirements were obtained so full-scale costs can be estimated. However, continued monitoring is needed to establish the period of treatment provided by the initial molasses injection in order to estimate the reinjection frequency for use in full-scale cost estimates.

In August 2008, the second phase of field testing began with the injection of emulsified vegetable oil into the aquifer via a single injection well near the molasses test location. The emulsified vegetable oil was successfully injected to form a treatment zone about 15 m (50 ft) in diameter. The treatment zone has effectively been treating nitrate, and CrVI. Continued monitoring is expected to provide information needed to assess the effectiveness, implementability, and cost of this biostimulation approach. As was the case for the molasses test, implementation of the barrier was accomplished, thereby meeting the test goals for injecting the emulsified vegetable oil and obtaining a treatment barrier of the targeted size. Again, data on equipment and operational requirements were obtained so full-scale costs can be estimated. The information from continued monitoring will help establish the period of treatment provided by the initial injection so the reinjection frequency can be estimated and used in full-scale cost estimates.

A separate, but similar, smaller-scale field test of biostimulation was conducted at the 100-H Area. In this test, a commercial polylactate compound was injected into the aquifer. The injection formed a treatment zone for nitrate, oxygen, and CrVI that has been sustained near the injection well for about 3 years.

The studies show that biostimulation, by adding safe and relatively inexpensive organic compounds to the aquifer, can induce the bacteria in the 100-D Area groundwater to treat nitrate, dissolved oxygen, and CrVI. Similar success in testing biostimulation at the 100-H Area suggests that biostimulation is likely viable broadly within the 100 Areas groundwater. The results also demonstrate that biostimulation can function as a supplemental technology for groundwater remedies already treating CrVI in the 100-D Area. Using simple food sources, biostimulation applies natural processes to groundwater contamination. Combined with other treatment technologies, biostimulation can be part of the solution to treat the aquifer to protect the Columbia River.

3.5.2 Treatability Test of Ex Situ Electrocoagulation to Remove CrVI from Groundwater in the 100-D Area

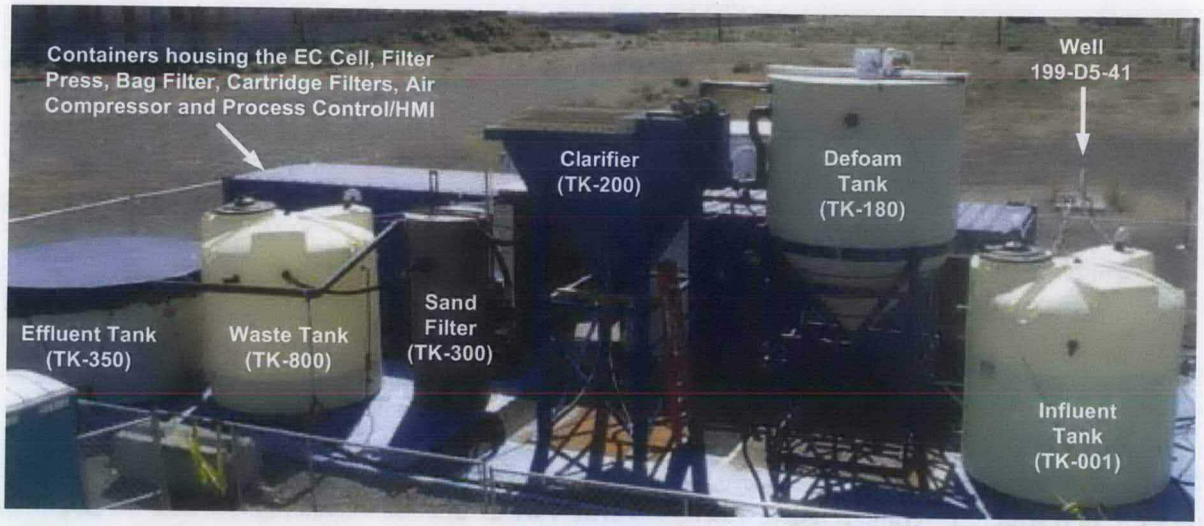
In 2007, ex situ electrocoagulation (i.e., a water treatment process known to be able to remove a variety of suspended solid and dissolved pollutants from aqueous solutions) joined the ranks of new technologies being tested to remediate CrVI-contaminated groundwater in the 100 Area. With the potential to increase efficiency and reduce costs, compared to the present ion-exchange treatment, electrocoagulation showed promise as a treatment that could augment existing technologies.

In electrocoagulation, an electric field is applied to metal plates, which release ions into the water. To remove oxidized species like CrVI, iron plates typically are used. The iron ions reduce CrVI to an iron-chromium hydroxide, which then can be removed from the water. The 2007 treatability test allowed evaluation of the practicality of using this technology to expand the pump-and-treat system at the 100-D Area. The following test objectives focused on gaining information for that evaluation:

- Determine the operability, robustness, and treatment efficiency of an electrocoagulation system
- Characterize volume and composition of waste for proper waste classification
- Obtain design data for scaling the process from a 189 L/min (50 gal/min) to a 1,893 L/min (500 gal/min) system.

The treatment system included the electrocoagulation unit (Figure 3-12) and the water treatment system, and these components are shown in Figure 3-13. The electrocoagulation unit contained multiple charged plates through which the contaminated water passes. The water treatment system removed the precipitates and reoxygenated the water. Components of the water treatment system included a clarifier, filters, and a filter press to dewater the sludge.

Figure 3-12. Electrocoagulation Unit (Electrode Plates Exposed)



EC = electrocoagulation
HMI = human-machine interface

Figure 3-13. Overview Photo of the Installed Electrocoagulation Treatability Test System

The performance objective for the treatability study was to determine the efficiency (effectiveness) of CrVI removal from the groundwater, with a desired concentration of less than or equal to 20 µg/L CrVI in the effluent before injection back into the aquifer. The test consisted of a startup phase from May 3 to July 20, 2007; a continuous testing phase from July 23 to October 12, 2007; and a final testing phase using groundwater augmented with higher concentrations of CrVI on October 16 and 17, 2007. Over the course of the test period, the test system treated 10.3 million L (2.8 million gal.) of groundwater.

The data evaluation at the conclusion of the test suggests that electrocoagulation could be an effective supplement to existing pump-and-treat approaches, but cost and operational factors do not favor the use of this technology. While the evaluations are discussed in detail in DOE/RL-2008-13, *Treatability Test Report for the Removal of Chromium from Groundwater at 100-D Area Using Electrocoagulation,* the main conclusions can be summarized as follows:

- **Chromium removal:** CrVI levels met the performance objective (less than or equal to 20 µg/L) in over 90 percent of the samples (Figure 3-14), although often the groundwater had to be passed through the treatment system more than once to achieve the objective. The electrocoagulation unit sometimes met the performance objective with a single pass through the system. All effluent CrVI samples during the batch testing with high influent CrVI concentrations (approximately 2,000 µg/L) met the performance objective.

- **Waste stream:** All solid-phase secondary waste streams exhibited levels below the limits for the toxicity characteristic and within the limits for the corrosivity characteristic.

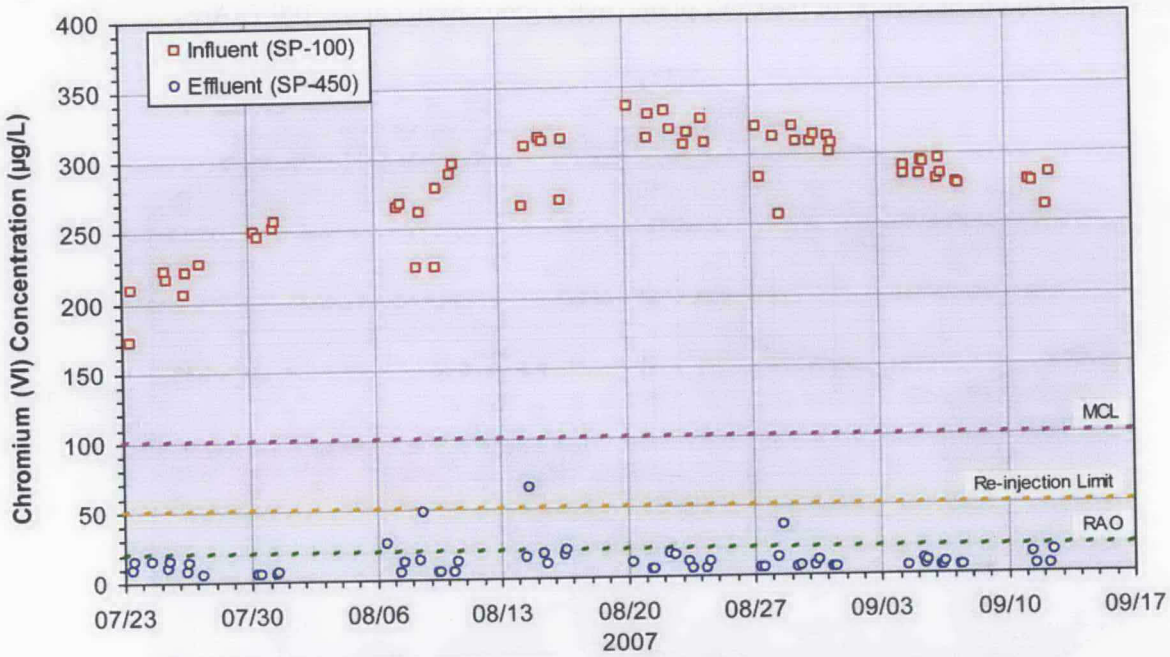


Figure 3-14. CrVI Influent and Effluent Concentrations Obtained During the Electrocoagulation Test

- **Operational reliability:** For the continuous operations testing period, the system could not operate unless it was attended. An extensive period of startup and adjustment preceded continuous operations but was unsuccessful in providing a suitable and robust operating condition. Primary operational reliability problems were related to the sensitivity of the solid separation process to operational conditions, so a robust operating procedure (e.g., chemical dosage) was not identified during the treatability test. Poor solids separation and high effluent iron concentrations also led to operational difficulties associated with injection well fouling. This was key information, as the application of the electrocoagulation technology with reinjection of the treated water into the aquifer via a well is a rigorous performance requirement for the technology. The technology is typically reliable and robust for operations in industrial settings where effluent standards are higher, the effluent can be discharged to the sewer rather than injected to a well, and influent CrVI concentrations are higher.

- **Treatment cost:** Including all capital cost elements, the estimated cost of treatment was \$0.21/L (\$0.78/gal). Neglecting capital costs, the operations cost is \$0.07/L (\$0.28/gal). This compares unfavorably to an average cost of \$0.005/L (\$0.02/gal) for the current treatment system at the 100-HR-3 OU.

In summary, the treatability study data suggest that electrocoagulation has the potential to meet the performance goal for use as the aboveground component of a pump-and-treat system at the Hanford Site. However, system operation during the test was problematic and costs were significantly higher than current treatment methods. Thus, evaluation of this technology should consider recommendations from the treatability test and potential implementability issues.

3.5.3 100-D Area In Situ Redox Manipulation

By injecting non-toxic chemicals into an aquifer, the ISRM groundwater remediation technology can successfully immobilize contaminants (Figure 3-15). Whether ISRM could be an effective method for remediating CrVI plumes at the Hanford Site has been a topic of research since 1994. After multiple

studies and an initial treatability test showed the technology sound, ISRM was selected as the remedy of choice for the southern portion of the CrVI plume in the groundwater at the 100-D Area.

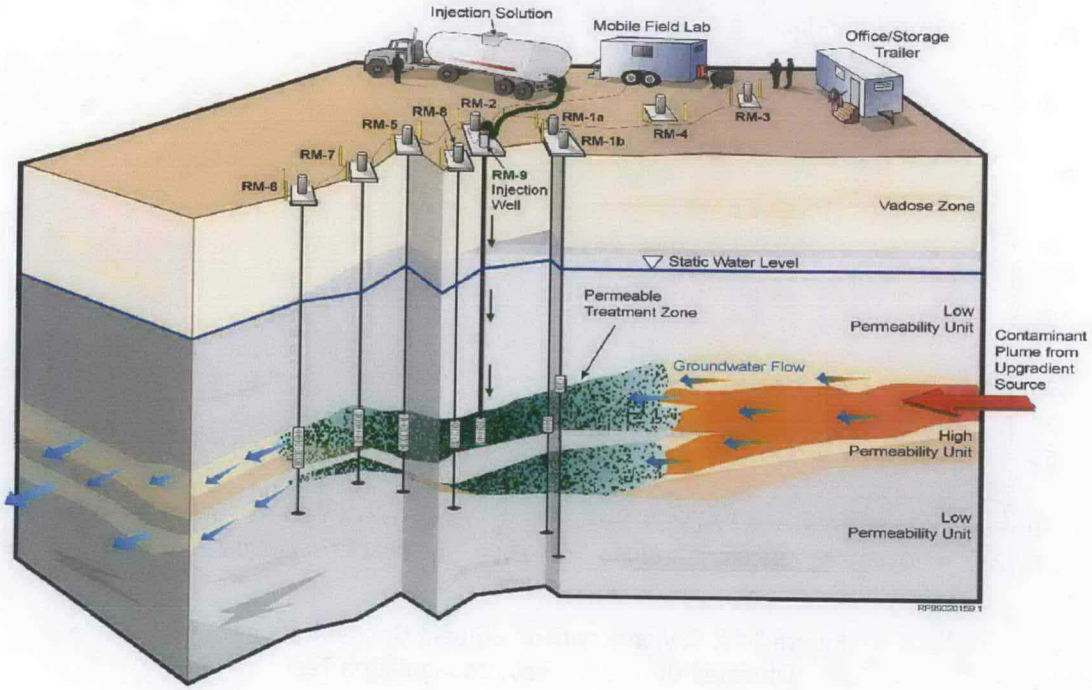


Figure 3-15. Illustration of how ISRM Works to Protect the Columbia River from Sodium Dichromate Contamination

Some of the CrVI plumes now affect the Columbia River. Although a pump-and-treat system is in place at the 100-D Area, used alone it is unlikely to be able to remove enough CrVI to achieve cleanup goals within a reasonable time limit. Conventional particulate permeable barriers that have been successful in other applications cannot be easily installed at the 100-D Area because of the depths involved. The ISRM technology provides the at-depth capability to support cleanup by using chemical processes to reduce the contamination.

In the first step of ISRM operations, sodium dithionite (a non-toxic chemical) is injected into the aquifer through a conventional 15.2 cm (6 in.) groundwater well. As the sodium dithionite disperses through the aquifer, it interacts with naturally occurring ferric iron in the aquifer sediments. Reacting to the sodium dithionite, ferric iron is reduced to ferrous iron. The reduced iron clings to sediment surfaces, becoming incorporated in the clay structure of the aquifer and producing a stationary, yet permeable, barrier to contamination. This barrier then acts as an in situ treatment zone. As contaminated groundwater passes through the barrier, the reduced iron interacts with the CrVI, converting it to a less-toxic form, and then trapping it in the sediments. Depending on contaminant concentrations, the barrier can be designed to operate passively for decades.

When the ISRM technology performed successfully during a 2-year treatability test in the 100-D Area, DOE and the regulatory agencies decided to fully deploy the technology by expanding the original test barrier. The design for the expanded ISRM barrier was based on the maximum CrVI plume concentrations detected, the dissolved oxygen content in the water, and the groundwater flow rate. In 2000, construction began on a 701 m (2,300 ft) long barrier that would stretch the width of the CrVI plume and treat the CrVI for an estimated 15 to 20 years. By 2003, the 66 wells needed to create and operate the barrier were in place, and the barrier had been installed parallel to the riverbank, approximately 152 m (500 ft) from the Columbia River.

To date, characterization data in the majority of wells indicate that ISRM operations are continuing to reduce CrVI; however, the performance of the overall barrier has been mixed. A widespread groundwater plume of nitrate may be aging the barrier faster than expected, reducing its longevity by 7 to 10 years. By 2006, 17 wells were showing some signs of performance deterioration. Specific wells (primarily in the eastern half of the barrier) show CrVI breakthrough, while adjacent wells show no breakthrough. The use of air-rotary drilling to place some of the injection wells is likely to have caused some of these operational difficulties.

In response to these complications, RL is testing two technologies that could potentially repair the wells and bring the barrier up to top performance: (1) a particulate iron injection method (discussed below), and (2) a biostimulation method (previously mentioned). In the meantime, the other 49 wells continue to function to reduce the CrVI and protect the river.

3.5.4 Fortifying the In Situ Redox Manipulation Barrier with Iron

The ISRM barrier depends on the presence of naturally occurring iron in the aquifer to create treatment zones that trap CrVI. When data indicated that CrVI was breaking through the ISRM treatment zones in several locations, scientists proposed that fortifying the barrier with additional iron could offer a sustainable long-term repair.

In 2008, DOE began a test to determine whether injections of tiny iron particles (only 70 nanometers [3 millionths of an inch] in diameter) could fortify the weaker portions of the ISRM barrier. The small size of the particles would allow them to flow into the aquifer, thus treating the water more effectively given the very large surface area of the material (30 m^2/g [150,000 ft^2/lb]). Higher surface area means that more of the iron would be available to react with and remediate the groundwater.

Selecting the right iron particles was critical to the success of the test, so the initial stages of the project focused on identifying potential zero valent iron (ZVI) (i.e., neither positively nor negatively charged) products for injection. This led to the development of laboratory tests to evaluate the geochemical and physical properties of ZVI, and then to the design and execution of an injection test, and finally to post-injection monitoring that would provide performance data.

The search to identify suitable materials yielded an original database of 30 separate ZVI materials. Each of these materials was ranked for injectability, geochemical properties, cost, and availability, which reduced the list to the six materials identified in Table 3-7. Laboratory tests, screening-level geochemical tests, and injection tests identified two candidate compounds, Polymetallix™ [7] and RNIP-M2™[8], and both were tested further for field application. When the RNIP-M2 proved clearly superior in both compounds, its injection characteristics and its ability to sustain the treatment zone, it was chosen as the ZVI for the actual test at the ISRM barrier.

7 Polymetallix is a trademark of Polyflon Company, Norwalk, Connecticut.
8 RNIP-M2 is a registered trademark of Toda Kogyo Corporation, Japan.

Table 3-7. List of Screened ZVI Materials Tested in the Laboratory

Zero Valent Iron Material Name	D50 (μm)	Surface Area (m^2/g)	Percent Iron	Cost/lb	Field Injection
EZVI	1	10	98	$16.00	Y
Polyflon Particles	0.15	37 to 58	greater than 99	$72.00	Y
NanoFe (Lehigh)	0.1	10 to 45	greater than 99	$50.00	Y
Zloy	0.2	15	40	$20.00	Y
H2OMet-XT	~10	--	78	$0.55	N
RNIP-M2	0.07	20.2	65	$32.35	Y

~ = approximately

The field injection test was conducted in August 2008 at the 100-D Area. The first goal was to inject enough ZVI into the more permeable portions of the barrier to ensure that the ZVI could disperse at least 7 m (23 ft) from the injection well. The second goal was to determine whether the selected ZVI could effectively reduce CrVI concentrations in the groundwater.

Over a period of approximately 5 days, 370,970 L (98,000 gal.) of the RNIP-M2 solution was injected into the Ringold Formation aquifer at a rate of 53 L/min (14 gal/min). The ZVI was communicated at least 3 m (9.8 ft) away from the injection well. A borehole was drilled 7 m (23 ft) from the injection well in March 2009 to evaluate the radius of influence. Analysis of aquifer materials showed that approximately 4 wt. percentage nano zero valent iron (nZVI) was present in the targeted permeable layer near the bottom of the aquifer. This verified that the goal of emplacing nZVI at least 7 m (23 ft) into the aquifer was successfully accomplished. Monitoring has shown that the area near the test is strongly reducing, and CrVI has been reduced to the immobile trivalent chromium.

To date, the test has demonstrated that RNIP-M2 could be an effective, easily injected ZVI product to fortify the ISRM barrier. While initial results suggest that such repair is possible, additional monitoring is needed before the long-term effectiveness can be demonstrated.

3.5.5 100-N Area Apatite Barrier Installation

At the 100-N Area, a newly developed method for treating Sr-90 in place is protecting the Columbia River by preventing contamination from reaching the river. Efforts to reduce the amount of Sr-90 entering the Columbia River from closed waste disposal sites at the 100-N Area began in the early 1990s. Ceasing liquid discharges to the ground in 1993 was a major step toward meeting this goal; however, Sr-90 already in the soil beneath the liquid waste disposal sites continued to contaminate groundwater and the Columbia River. Scientists realized from the beginning that pumping and treating contaminated groundwater was unlikely to be a long-term solution. The slow release behavior of Sr-90 present in the soil meant that pumping and treating groundwater would take decades, and groundwater sampling results have proven that theory. Accordingly, the first CERCLA 5-year review reemphasized the need to find other ways to reduce impacts on the Columbia River.

One innovative option was to create a permeable reactive barrier in the groundwater consisting of the mineral apatite. Apatite, a very stable mineral found in teeth and bones, is made up mostly of calcium and phosphate. Scientists proposed injecting those necessary building blocks to form the apatite directly in the groundwater. The apatite could then adsorb the Sr-90 contamination and hold it so it could not migrate

further. Figure 3-16 shows the test site at the 100-N Area where the apatite barrier technology is being developed. If the technology continues to be successful, the test site may soon be expanded into a full-size barrier to protect the Columbia River from Sr-90 contamination.

Figure 3-16. Test Site at 100-N Area where Apatite Barrier Technology is being Developed

After reviewing the available information, the Tri-Parties agreed that using apatite to protect the river was a good long-term strategy. The Tri-Parties also agreed that an extra step should be included to protect the river; phytoremediation using natural occurring plants as a "polishing" step was added to the strategy. The use of plants and phytoremediation as treatment technologies is discussed below. Since that time, the Tri-Parties have worked together to develop a cost-effective plan to use apatite and phytoremediation treatments to reduce the amount of Sr-90 entering the Columbia River.

In July 2005, the plan to inject apatite-forming chemicals into the river shore soils between the closed waste sites and the Columbia River was completed. The plan focused on the soil and groundwater along approximately 91 m (300 ft) of the Columbia River bank where Sr-90 concentrations are highest. The first injections occurred in 2006.

Throughout 2006 and 2007, low-concentration, apatite-forming solutions were injected along the length of the barrier into the soil and groundwater through 10 injection (barrier) wells. The objective of the low-concentration, calcium-citrate-phosphate injections was to stabilize the Sr-90 in the aquifer at the test site. If the technology proved effective, the results could be used to help refine the treatment strategy, which could include high-concentration injections to provide for long-term Sr-90 treatment.

Initially, a tracer injection test and the first apatite injection pilot test were conducted at the upstream end of the test area, during high water conditions in the spring of 2006. A second pilot test was conducted at the downstream end of the test area during low river conditions in September 2006. Analysis of the operational and pilot test monitoring results helped refine the injection techniques, the chemical mix of the injection solution, and the amount of solution injected. Injections into the 10 barrier wells were conducted during two phases: the first phase in February through March 2007, which targeted low river

conditions; and a second phase in June through July 2007, during high river-stage conditions. The results of the low-concentration injections are presented in an interim report (PNNL-17429, *Interim Report: 100-NR-2 Apatite Treatability Test: Low-Concentration Calcium-Citrate-Phosphate Solution Injection for In Situ Strontium-90 Immoblization*).

The results and experience from the low-concentration injections led to the design for a series of higher concentration injections. Six more barrier (injection) wells were installed on the lower end of the existing barrier in the fall of 2007. During the summer of 2008, the 16 barrier wells were injected using adjusted techniques and chemical mixes. The results from these injections are still preliminary, and additional time and monitoring are needed to fully characterize the tests. Apatite is slow to incorporate Sr-90 under field conditions, and it may take up to a year before the results are definitive. In addition, the high strength of the chemical mixture has been slow to decrease in some areas. Some of the monitoring locations have been dry since the low river conditions of late last summer, and a few wells became partially plugged during testing.

Despite these issues, much of the monitoring data is encouraging, showing that apatite is being formed and Sr-90 is being adsorbed as designed. Concentrations of Sr-90, based on gross beta, fell below baseline levels in 19 of the 20 wells (Figure 3-17). Data indicate that Sr-90 in the one remaining well, while still exhibiting levels above baseline minimum values, is on a downward trend. Apatite technology is showing great promise as a remediation option. If the results continue to be positive, a plan to expand the method to a full-scale treatment option will move forward.

3.5.6 100-K Area Calcium Polysulfide Treatability Test

In a continuing search to identify new technologies for remediating CrVI in 100 Area groundwater, an in situ approach that could be a cost-effective supplement to the current pump-and-treat systems was tested in 2005 (DOE/RL-2006-17, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*).

The tested technology involved injecting calcium polysulfide, a strong reducing chemical, into the aquifer. Once in the water, the calcium polysulfide was intended to reduce the mobile CrVI to its less mobile and less toxic trivalent form and create a permeable reactive barrier that will continue to remove CrVI.

The test was performed in the eastern part of the 100-K Area (Figure 3-18) to evaluate the potential practicality and cost of the technology. The test also determined vital hydrologic information for the 100-K Area aquifer, provided experience in designing systems to implement this type of technology, and revealed several lessons learned that will be valuable if this technology is implemented. Given these numerous aspects, the test had the following multiple objectives:

- Verify the ability to achieve in situ CrVI reduction using an active remediation system involving calcium polysulfide and a carbon source, which together reduce the groundwater and aquifer through both inorganic and microbiological processes.
- Determine whether aquifer constituents (e.g., manganese or arsenic) are mobilized because of this reduction, and how other parameters (e.g., nitrate or dissolved oxygen) are affected as a result of the groundwater treatment.
- Obtain operational experience in the treatment of CrVI-contaminated groundwater by the use of calcium polysulfide as the reducing medium.

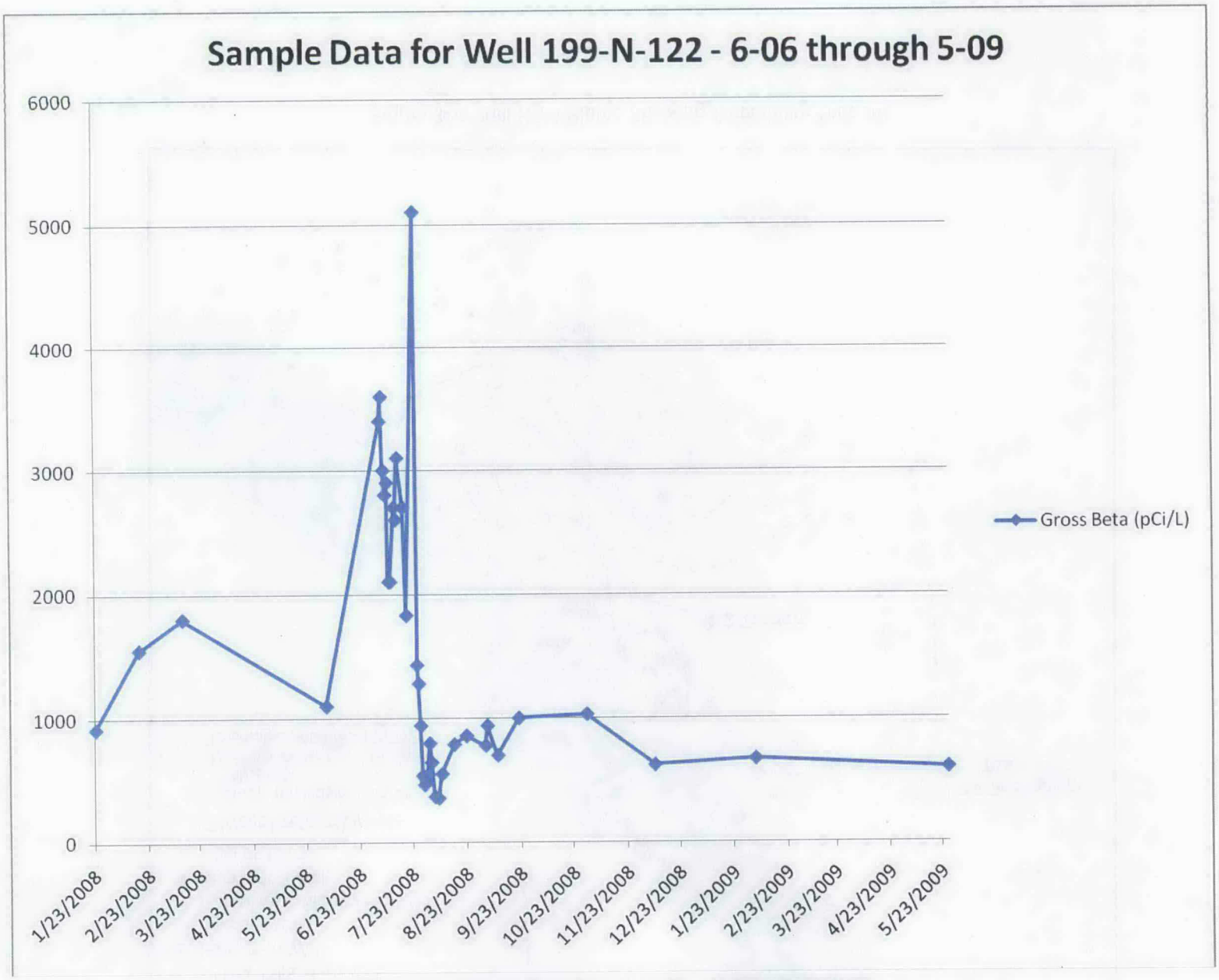


Figure 3-17. Gross Beta Concentrations in Well 199-N-122

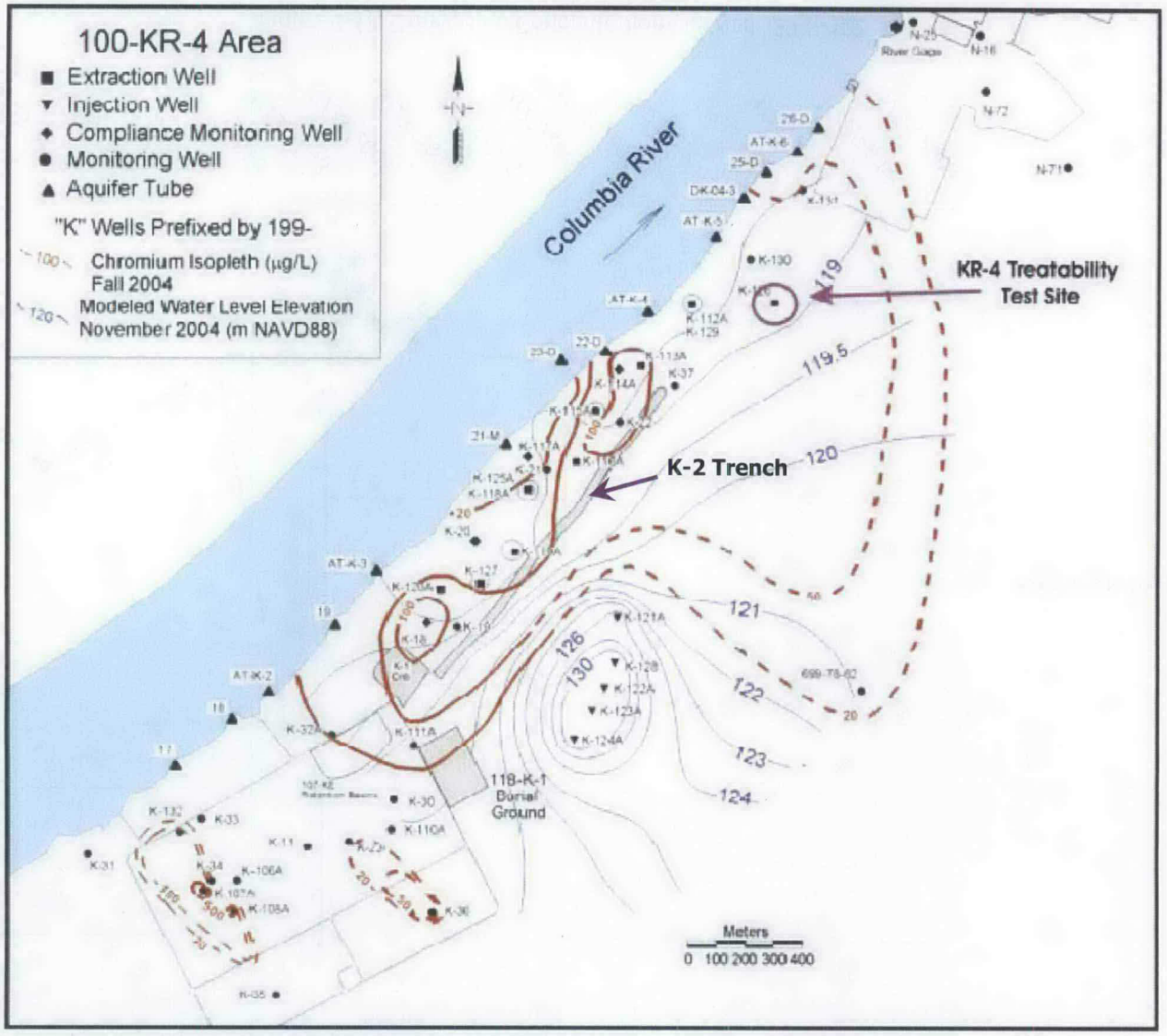


Figure 3-18. 100-KR-4 Plume Showing Treatability Test Site

Five wells were used for the treatability test, which included an extraction well surrounded by four injection wells drilled specifically for this test. During testing, groundwater was withdrawn and mixed with calcium polysulfide in an aboveground tank. This solution reacted for a minimum of 2 hours and then was pumped through the injection wells in approximately equal amounts to permeate the aquifer. This is typically called a "five-spot" configuration, and is ideal for a test of this type because it provides operational field experience and kinetics information in a manageable area and cleans up a section of the aquifer.

The treatability test began on June 28, 2005. Before startup, systems were tested for leaks and proper operation, and a tracer study was initiated. Water was circulated without calcium polysulfide on June 27, 2005 when a lithium bromide tracer was pumped into one of the injection wells. This tracer test (along with slug tests carried out in the extraction and injection wells before and after the treatability test was performed) served to quantify the hydraulic conductivity in the aquifer beneath the treatability test area. The slug tests were rerun after completion of the treatability test to determine if the test had degraded the aquifer.

During the treatability test, 25 samples were collected on a regular basis and analyzed for basic chemical properties (e.g., pH and oxidation-reduction potential) and major and trace element constituents. The amounts of water extracted and injected were recorded, as well as the volume of calcium polysulfide mixed with the water. Over 1,324,894 L (350,000 gal.) were treated during the test, which was completed on August 11, 2005.

All of the performance goals were met by the end of testing. The technology effectively reduced CrVI in the aquifer and created a permeable reactive barrier that continues to treat CrVI under natural groundwater flow conditions. Analysis of groundwater chemistry before, during, and after the test shows that manganese and iron were mobilized under the strongly reducing conditions in the aquifer, and that arsenic was at near-background conditions after test completion. The pre- and post-treatment aquifer tests showed that chemical injection did not degrade the permeability of the aquifer.

This test was considered successful, and the data collected are sufficient to scale-up the treatment technology. Groundwater monitoring in the treatment area shows that, two years after the test, dissolved oxygen is rebounding to near ambient conditions of 7,000 µg/L in the extraction well (199-K-126), but is being maintained at less than half of ambient concentrations in the injection well. Groundwater in a well approximately 200 m (656 ft) downgradient of the test area is also being monitored to evaluate migration of the reduced zone, but this well has yet to show any effects from the treatability test.

3.5.7 100-K Area Phytoremediation Field Demonstration

Through a safe and nonintrusive remedy called phytoremediation, the Coyote willow (which is a common plant that grows along the banks of the Columbia River) could potentially become part of a treatment that stops Sr-90 from entering the water. If early testing confirms that possibility, these natural shrubs (Figure 3-19) could help restore the natural balance of the environment.

Phytoremediation technology employs plants to extract and/or sequester soil contaminants. The Coyote willow is considered the most suitable plant for use along the Columbia River shore. Known for its rapid and robust regrowth abilities, Coyote willow is already used extensively along the Columbia and Yakima Rivers for bank stabilization and revegetation purposes. As part of a chain of remedial technologies aimed at treating Sr-90, phytoremediation using Coyote willow would be a polishing step in multiple processes protecting the river.

Figure 3-19. Coyote Willows Growing in Test Plot at 100-K Area

In the proposed configuration, the treatment system would first incorporate an apatite barrier (previously described). This technology would be designed to extract Sr-90 that is either present near the river now or is expected to move toward the river over the next 300 years. The phytoremediation treatment, designed as an extraction system along the riparian zone of the Columbia River, would be constructed to address Sr-90 in the vadose and saturated zones associated with the Columbia River riparian zone. Once the apatite barrier was fully functional and the Coyote willow had extracted the Sr-90 from the riparian zone, the phytoremediation component could be discontinued.

The key to using phytoremediation as part of the treatment, however, besides the volume of sediment to be treated, is biomass production, which is the focus of the study currently being conducted to determine whether the technology is usable. The study involves two major objectives: (1) determine the most efficient fertilization method for Coyote willow that will generate the greatest biomass possible while also protecting the Columbia River from excess nutrient run-off, and (2) demonstrate the efficacy of using Coyote willow as a phytoremediation tool along the riparian zone associated with the 100-N Area.

The study began in the late spring of 2007, with 50 Coyote willow starts being planted in a fenced area at the 100-K Area. This part of the study targeted plant growth rather than phytoremediation capabilities, so the 100-K site, which is not contaminated with Sr-90, was well suited as a host location. Often flooded by the annual high Columbia River stage well into June, this site is a severe test for the willow shrubs' ability to survive realistic field conditions.

During the first year of the test, there was relatively little growth while the plants became established and developed root systems. In October 2007, the plants were pruned down to the trunk plus primary branches. Forty-nine of the 50 plants survived the winter. In May and June 2008, the site was once again flooded, and serious growth began in July. The second year harvest was completed in October 2008. The average biomass was 369 percent greater than the first year at about 340 kg (750 lb) per acre, which was in line with predictions.

If the Coyote willows continue to perform over the coming year, the next step will be a test at the 100-N Area in actual Sr-90-contaminated soil. Methods for safely planting, tending, and harvesting the willows along the rip-rap that covers the 100-N Area shoreline will need to be developed; however, if the 100-N Area tests prove successful, phytoextraction could be incorporated as part of the treatment protecting the Columbia River from Sr-90 contamination.

In summary, greenhouse, laboratory (growth chamber), and field studies have shown that strontium is a nutritional analog of calcium, a plant macronutrient. As such, the Coyote willows will actively accumulate Sr-90 in their leaves and stems to levels over 70 times that present in the soil pore water surrounding their roots. Given the steadily increasing growth rate of the trees at 100-K following yearly harvests of their above-ground tissue, this type of plant would remove significant amounts of contamination from the riparian area of the 100-N shoreline while not disturbing the natural sediment structure. Laboratory studies have also shown that herbivorous insects such as aphids, or moth larvae, would not be a source of Sr-90 off-site transport from the trees. Further, controlled harvesting schedules, and engineered barriers (fencing and netting), would prevent animal intrusion and plant detritus release (PNNL-18294, *100-N Area Strontium-90 Treatability Demonstration Project: Food Chain Transfer Studies for Phytoremediation Along the 100-N Columbia River Riparian Zone*).

3.6 Assessment of Baseline and Residual Risks in the 100 Area

The following section summarizes the past and ongoing risk assessment activities within the 100 Area. These risk assessments have been conducted in support of remedial decision making, covering specific timeframes, OUs, or geographical areas within the 100 Area. The results from these risk assessments will support the development of remedial alternatives and final action cleanup levels.

3.6.1 Risk Assessments in Support of Interim Action Records of Decision

The cleanup of past-practice waste sites and groundwater at the Hanford Site initially focused on addressing releases to the environment that represent a near-term risk to the public or the environment. This resulted in the cleanup of contaminated waste sites and principal threats to groundwater using interim action RODs. This approach, presented in DOE/RL-91-40, *Hanford Past-Practices Strategy*, uses interim actions to achieve risk reduction sooner rather than later.

3.6.1.1 Qualitative Risk Assessments

QRAs were used to define the basis for remedial actions under interim action RODs. Assessment of human health risks in the QRAs was based on frequent-use and occasional-use scenarios, which reflected current guidance for that time. Onset of human exposure was delayed until 2018, which was used as a target date for completion of remediation in the 100 Area. Frequent and occasional uses were defined using residential and recreational exposure factors obtained from DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*. The contaminants of potential concern (COPCs) were identified from the historical site data and data collected during the LFIs, taking into consideration Hanford Site background concentrations of radionuclides and inorganics in soil, and risk-based screening using residential exposure parameters (DOE/RL-91-45). Human health risks presented in the QRAs were based on the maximum concentrations detected in waste site soils and in groundwater. Human health risks were quantified for a limited set of exposure pathways (soil ingestion, fugitive dust or volatile inhalation, and external exposure). Ecological risks were estimated using a streamlined approach, focusing on a single organism, the Great Basin pocket mouse, using the assumption that the waste site was the home range.

3.6.1.2 Waste Site Cleanup Verification Package

Following completion of remedial actions at a waste site in accordance with the applicable interim action ROD, cleanup verification or confirmatory sampling and laboratory analysis are performed to confirm attainment of RAGs and, therefore, demonstrate that RAOs for interim site closure have been met. A RAG is a specific numeric goal against which cleanup verification data are evaluated to demonstrate attainment of RAOs. The RAGs for the protection of human health were developed using an unrestricted use scenario, which represented a rural residential exposure scenario.

During the remediation process, if waste site sampling shows that the RAOs for direct exposure, groundwater protection, or river protection have not been met throughout the vadose zone, further remedial action is performed, followed by additional verification sampling. If evaluation of the cleanup verification samples shows that the RAOs for a remaining site are met, compliance is documented in the appropriate closeout documentation.

The exposure factors and assumptions defining the rural residential scenario are defined in DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area.* Soil RAGs for protection of groundwater also reflected unrestricted use and were intended to achieve state or federal drinking water standards. In addition, soil RAGs were developed to protect aquatic organisms in the Columbia River. However, soil RAGs were not developed for the protection of terrestrial ecological receptors due to the absence of regulatory guidance at that time.

3.6.2 River Corridor Baseline Risk Assessment

As described in the previous sections, the remedial actions completed to date in the River Corridor were implemented primarily under interim action RODs. There is a requirement under CERCLA to perform a baseline risk assessment to characterize current and potential threats to human health and the environment before final action RODs can be issued. These requirements include the following:

- A baseline risk assessment is required by regulation at 40 CFR 300.430, "Nine Criteria for Evaluation," with the purpose of characterizing current and potential threats to human health and the environment.
- EPA guidance states that interim action can occur without a completed baseline risk assessment and that, in such cases, a complete baseline risk assessment will be needed to support development of a final action ROD (OSWER Directive 9355.0-30, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decision*).

EPA Region 10 guidance acknowledges that a focused risk assessment or QRA can be performed in lieu of a baseline risk assessment to support interim or early actions. A focused risk assessment or QRA should be followed by a complete baseline risk assessment to justify final action decisions. For partially remediated sites, the baseline risk assessment evaluates the site in its present physical condition (EPA 910-R-97-005, *EPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund*).

The RCBRA is being conducted to address the regulatory requirement that a baseline risk assessment be performed and to support final cleanup decisions in the river corridor. The RCBRA has two key elements as shown in Figure 3-20: (1) the source and groundwater component (which addresses potential upland, shoreline, and groundwater risks), and (2) the Columbia River component (which addresses potential risks from Hanford Site releases to the Columbia River). The process of conducting the RCBRA has included input from the Tri-Parties, the Natural Resource Trustee Council, Tribal Nations, and stakeholders.

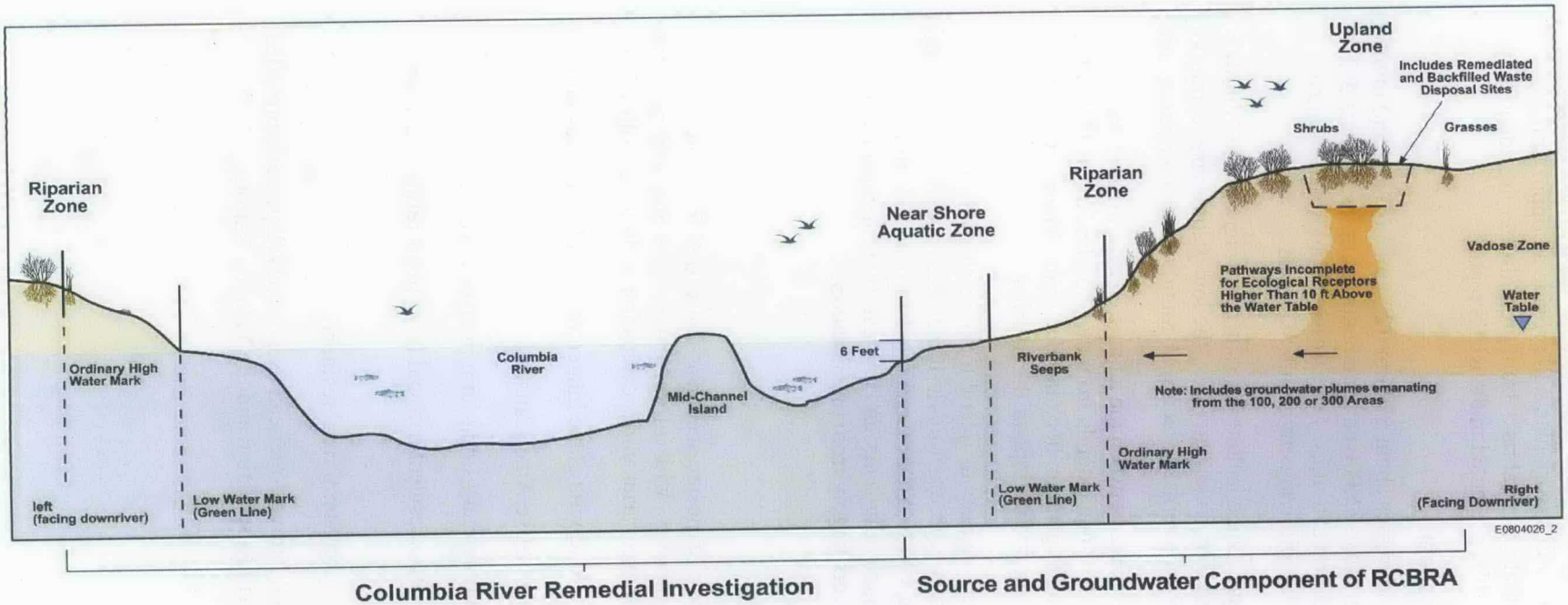


Figure 3-20. River Corridor Baseline Risk Assessment Conceptual Site Model and Study Zones where Animals and People might be Exposed to Contaminants

When complete, the RCBRA will provide a comprehensive analysis of human health and ecological risks in the river corridor. Activities completed pursuant to this work plan will provide an opportunity to refine the conceptual exposure models and verify that potential risks from groundwater are adequately characterized. Results from the risk assessment will be presented in the RI/FS report.

3.6.3 RCBRA Source and Groundwater Component

The RCBRA source and groundwater component addresses about 570 km^2 (220 mi^2) of land and involves analyzing over 440,000 analytical results from more than 35,000 environmental samples. Figures 3-21, 3-22, and 3-23 show several RCBRA sample collection activities. The assessment addresses human health and ecological risks with groundwater and the following environmental zones:

- **Near-shore aquatic zone:** The near-shore aquatic zone includes the surface water of the Columbia River from the area that is permanently inundated by river water (i.e., the low water mark, commonly referred to as the "green line," where the periphyton remain green year-round) up to the riparian zone.
- **Riparian zone:** The riparian zone is a transition area between the aquatic environment in the near-shore zone and the upland zone. The riparian zone extends from the shoreline of the Columbia River to the point on the riverbank where upland vegetation becomes dominant. The riparian zone typically is narrow and varies in width depending on the slope of the riverbank.
- **Upland zone:** The upland zone consists of land that extends inland from the riparian zone and is situated approximately 3 m (10 ft) above the river high water mark. It includes mix waste sites within the 100-B/C, 100-D, 100-F, 100-H, 100-K, and 100-N Areas; the White Bluffs and Hanford townsites; and the 300 Area. The upland zone generally is dry and not readily influenced by river flow. Recharge to groundwater in this zone occurs largely from precipitation.

The environmental zones are shown in Figure 3-24.

3.6.3.1 Human Health Risk Assessment

Human health risks are being assessed for a number of exposure scenarios that varied from low- to high-intensity exposure conditions to provide risk managers with information on how potential risks may vary under a variety of land use conditions. Exposure scenarios under evaluation include the following:

- Future recreational use scenarios (recreational): Avid wild game hunter, avid angler, and casual user.
- Future DOE Tribal use scenario: Non-residential Native American user.
- Future industrial worker scenario (industrial/commercial): Long-term industrial worker.
- Future resident national monument worker scenario (resident national monument/refuge): Seasonal Hanford National Monument worker/resident.
- Future rural residential scenario (rural resident): Long-term rural resident.
- Native American exposure scenarios: Residential Native American users as developed and provided by the Confederated Tribes of the Umatilla Indian Reservation and the Yakama Nation.

Figure 3-21. Soil Sample Collection in the Upland Zone

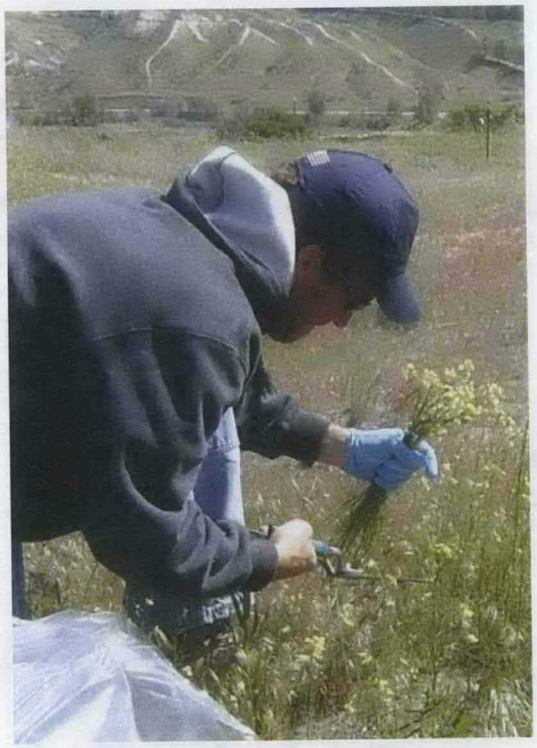


Figure 3-22. Vegetation Sample Collection Targeting Dominant Plant Species

Figure 3-23. Amphibian and Sediment Sample Collection in the Near-Shore Aquatic Zone

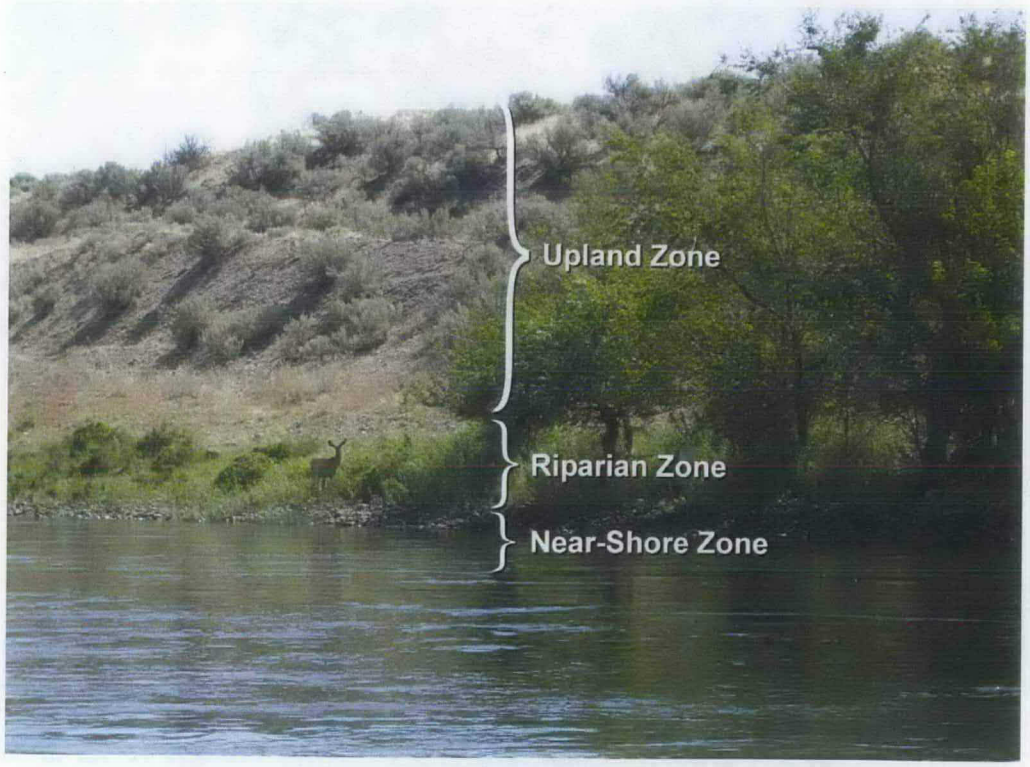


Figure 3-24. Photo Depicting Upland and Shoreline Zones

To support risk management decision making, a range of exposure scenarios is included in the human health risk assessment (HHRA). As previously noted, the interim action RODs prepared for the 100 and 300 Areas relied on qualitative human health and ecological evaluation using only the Great Basin pocket mouse to demonstrate that risks existed and actions were warranted. The RCBRA supports the final action RI/FS and final action RODs by providing the following information:

- The HHRA estimates potential human cancer risks, noncancerous hazards, and dose associated with exposure to residual contamination at 146 remediated 100 Area waste sites under a range of exposure scenarios.
- The HHRA identifies key risk driver chemicals or radionuclides for the various waste sites under a range of human exposure scenarios.
- The HHRA identifies exposure pathways that are key contributors to cumulative risk, hazards, or dose at waste sites for a range of human exposure scenarios.

Risk assessment calculations in the HHRA are being performed independently for the soil source term (includes waste site residual soil and surface soil), the groundwater source term, and fish ingestion. The risk results from exposures to these different media may be summed to estimate the total (additive) risk across each of these media, and can provide some insight into the relative importance of the different sources of risk to a given receptor. It is anticipated that the information to be presented in the HHRA will be sufficient to support risk communication or evaluation of remedial alternatives with regard to all human health scenarios.

3.6.3.2 Ecological Risk Assessment

The primary purpose of the ecological risk assessment portion of the RCBRA is to support remedial action decisions that reduce risks to ecological receptors. Through remedial actions, contamination will be reduced to levels that result in the recovery and maintenance of healthy local populations and communities of biota. The ecological risk assessment evaluates contaminants that may pose current risks to receptors associated with residual contamination from waste sites and from associated contaminated soil and groundwater in the River Corridor. The ecological risk assessment addresses residual contaminant concentrations at remediated waste sites in the upland zones and the transport of contaminants from waste sites to the Columbia River riparian and near-shore zones. In addition, ecological management goals for the River Corridor include considering impacts to state or federally listed threatened or endangered species, protecting rare habitats, and minimizing contaminant loading (or bioaccumulation) into biota.

Near-Shore Zone

Media and biota sample data collected from 50 study areas in the near-shore environment of the River Corridor and 10 reference area locations (throughout the Hanford Site) are being evaluated for Hanford Site contaminants of potential ecological concern. These data represent current conditions in study areas where no remedial actions have been conducted; however, the study areas potentially are affected by contaminated groundwater plumes passing through and/or entering the near-shore zone. These results are used to present a baseline ecological risk assessment of the River Corridor near-shore zone.

The near-shore ecological risk assessment evaluates risks to a comprehensive array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics. The following representative near-shore aquatic receptors are being evaluated in the ecological risk assessment:

- **Lower trophic level:**
  - Plants (algae and vascular plants), aquatic insects, snails, clams, and mussels
- **Middle trophic level:**
  - Herbivores: Mallard duck
  - Omnivores: carp
  - Invertivores: Woodhouse's toad, sculpin, bufflehead duck, and eastern and western kingbirds
- **Upper trophic level:**
  - Carnivores: salmon and mink

There are uncertainties associated with obtaining representative samples of porewater (i.e., a sample that could represent an acute or chronic exposure of concern). Uncertainties were identified with the measurement of exposures for aquatic organisms that inhabit the hyporheic zone. This is relevant because one of the RAOs for groundwater, under the interim action RODs, is protection of aquatic organisms in the Columbia River. The aquatic receptor exposure point is within the river substrate (the salmon redds) at depths of up to 46 cm (18 in), where embryonic salmon and fry could be present during portions of the year. Currently, groundwater sampling from near-river monitoring wells (compliance wells) is being used to evaluate performance of the groundwater remedial system. To account for dilution within the aquifer between the monitoring wells and the exposure point within the river, a two-fold dilution attenuation factor is used in accordance with the interim action RODs (Ecology, et al., 1996).

Flow paths in the groundwater/river zone of interaction vary with daily and seasonal fluctuations in river stage. River water infiltrates the banks during high river stages, moves inland, then downward, and mixes with groundwater discharging through the riverbed. This suggests that the discharge to the river is a mixture of groundwater and river water. Monitoring and modeling studies suggest that dilution of groundwater by river water may range from nearly complete to approximately equal during the daily river stage cycle. Better characterization of dilution is necessary because mixing processes strongly influence the concentrations of contaminants at the location of exposure (i.e., in the riverbed) (PNNL-13674; PNNL-16805, *Investigation of the Hyporheic Zone at the 300 Area, Hanford Site*; PNNL-16894, *Investigation of the Strontium-90 Contaminant Plume Along the Shoreline of the Columbia River at the 100-N Area of the Hanford Site*). Several uncertainties are associated with evaluating compliance with aquatic water quality standards. An additional study will be performed before issuing the final action ROD and will include the following:

- Determine if there is a sampling technique that can accurately represent exposure conditions in the hyporheic zone.
- Determine if near-shore monitoring wells (compliance wells not including aquifer tubes) are adequate for determining protection of aquatic receptors in the absence of sampling within the hyporheic zone.
- Determine if the two-fold dilution attenuation factor is appropriate for the groundwater river interface for purposes of assessing risks from contaminants in groundwater, or developing cleanup levels in groundwater.

Riparian Zone

Media and biota sample data collected from 18 study areas in the riparian environment of the River Corridor and 7 reference area locations (throughout the Hanford Site) were evaluated for Hanford Site contaminants of potential ecological concern. These data represent current conditions in study areas where no remedial actions have been conducted. However, contaminated groundwater plumes passing through and/or entering the riparian environment potentially affect the study areas. These results are used to present a baseline ecological risk assessment of the River Corridor riparian zone.

The riparian ecological risk assessment evaluated risks to a comprehensive array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics. The following are the representative riparian receptors evaluated in the ecological risk assessment:

- **Lower trophic level:**
  - Plants and soil invertebrates
- **Middle trophic level:**
  - Herbivores: pocket mouse and California quail
  - Omnivores: deer mouse and meadowlark
  - Invertivores: grasshopper mouse and eastern and western kingbird
- **Upper trophic level:**
  - Insectivores: bank swallow and myotis bat
  - Invertivores: great blue heron
  - Carnivores: mink

Current information is considered sufficient and no additional work plan activities are proposed.

Upland Zone

Media and biota sample data collected from study areas associated with 20 remediated waste sites in the upland environment of the River Corridor and 10 reference area locations (throughout the Hanford Site) were evaluated for Hanford Site contaminants of potential ecological concern. These data represent residual conditions for a variety of representative waste sites where remedial actions have been completed. These results are used to present an ecological risk assessment of residual conditions on remediated waste sites in the River Corridor upland zone.

The upland ecological risk assessment evaluated risks to a comprehensive array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics. The following are the representative terrestrial upland receptors evaluated in the ecological risk assessment:

- **Lower trophic level:**
  - Plants and soil invertebrates
- **Middle trophic level:**
  - Herbivores: pocket mouse and California quail
  - Omnivores: deer mouse and meadowlark
  - Invertivores: grasshopper mouse and killdeer
- **Upper trophic level:**
  - Omnivores: badger and red-tailed hawk

Two general types of remediated waste sites were evaluated in the upland environment; some sites required significant excavation and soil removal, while other sites (referred to as "native soil sites") generally required less physical disturbance of soil and the associated ecological communities. The absence of RAGs for protection of ecological receptors in DOE/RL-96-17 created the need to conduct the ecological risk assessment to support final action remedy decisions. A primary goal of the ecological risk assessment was to determine if the RAGs developed for protection of human health are adequately protective of terrestrial receptors.

3.6.3.3 Groundwater

The Code of Federal Regulations (40 CFR 300.430(a)(I)(iii)(F) expects to return useable groundwaters to their beneficial uses whenever practicable. Washington State regulations indicate that groundwater should be evaluated for the "highest beneficial use (i.e., drinking water, unless the aquifer is non-potable for reasons other than contamination, such as high natural total dissolved solids or a water yield insufficient for pumping) (WAC 173-340). In addition to evaluating the highest beneficial use, groundwater plume movement must be evaluated to assess whether there will be impacts on surface water. If impacts are occurring or may reasonably be expected to occur in the future, then human exposures to surface water and groundwater must be evaluated.

Groundwater beneath portions of the River Corridor currently is contaminated and is not withdrawn for beneficial uses. Under current site use conditions, no complete human exposure pathways to groundwater are assumed to exist. Furthermore, regardless of land use designations for soils, contaminated groundwater beneath waste sites is not anticipated to become a future source of drinking water until cleanup criteria are met. However, to evaluate highest beneficial use, groundwater in the HHRA was evaluated for domestic use and for use in irrigation (i.e., home garden and livestock).

Human health risks associated with each groundwater OU were calculated for the following exposure scenarios:

- Rural resident
- Resident national monument/refuge worker
- Tribal Nation scenarios based on traditional lifestyles

3.6.4 Remedial Investigation for Hanford Site Releases to the Columbia River

Given that a primary objective of the Hanford Site cleanup mission is protection of the Columbia River, a remedial investigation of Hanford Site releases to the Columbia River is being conducted. In support of the RI, an extensive data compilation effort was performed from 2004 to 2006 to identify and organize results from previous investigations and programs. The results from more than 5,900 surface water samples, 1,400 sediment samples, and 7,000 biota (fish, shellfish, waterfowl) samples were evaluated to identify data gaps to be addressed during the RI. A remedial investigation work plan was issued in 2008 (DOE/RL-2008-11) to establish the approach for characterizing the nature and extent of Hanford Site related contaminants that have come to be located within the Columbia River and assessing the current risk to ecological and human receptors posed by Site related contaminants. The risk assessment activities performed as part of this work plan will become a component of the RCBRA.

The geographical study area includes the 193 km (120-mi) stretch of the Columbia River from above Wanapum Dam to McNary Dam (the first dam below the Hanford Site), and a limited investigation just upstream from Bonneville Dam. The field investigation activities were initiated in October 2008 and include collection of more than 1,200 surface water, porewater, sediment, soil, and fish samples from areas not addressed by previous environmental monitoring to support the investigation and assessment activities. The fish to be collected are resident species commonly consumed by humans: whitefish,

sucker, walleye, carp, bass, and sturgeon. Salmon were not selected because their migratory nature provides little opportunity for exposure to Hanford Site contaminants. Many of the field investigation activities have been completed through August 2009, with selected sample collection activities shown in Figures 3-25 and 3-26. The remaining field investigation activities are anticipated to be completed in early 2010.

Figure 3-25. River Channel Sediment Sample Collection

Figure 3-26. Fish Collection Using an "Electrofishing" Technique

A key element of the field investigation is a task to identify and characterize sediments from the river bottom in areas where contaminated groundwater is upwelling. The Trident Probe technology (Figure 3-27) is being used to support this task and provides the capability of in-situ conductivity and temperature measurements as well as sample collection for porewater and surface water. The work is being conducted adjacent to each of the reactor sites (100-B/C, 100-K, 100-N, 100-D, 100-H, and 100-F), the Hanford townsite, and the 300 Area using a phased design:

- Phase I was a demonstration of the Trident Probe technology in the Columbia River that was successfully completed in September 2008.
- Phase IIa was completed in August 2009 and consisted of conductivity and temperature mapping surveys at approximately 675 locations.
- Phase IIb consists of porewater collection and screening for key Hanford Site indicator contaminants (e.g., Cr+6, Sr-90, uranium) at approximately 240 locations and is anticipated to be complete in December 2010.

Phase III will be conducted in 2010 to characterize porewater, sediments, and surface water for a suite of analyses at locations selected from the Phase II results.

Figure 3-27. Deployment of the Trident Probe

Following completion of the field investigation and receipt of the analytical data, current risk to ecological receptors and humans will be assessed, and a determination will be made regarding the need for additional investigation and data collection. Any human, wildlife, or plant risk uncertainties regarding

Hanford Site contaminant releases to the Columbia River will be addressed through the investigation of Hanford Site releases to the Columbia River. This work will determine what contaminants are present, how concentrated they are, where they are located, and what (if any) undesirable health effects they may have on people, wildlife, and plants that use or live in the river. When completed, results from the remedial investigation of Hanford Site releases to the Columbia River will be used by risk managers to determine whether there is a need to perform remedial action associated with Hanford Site contaminants that have come to be located in the Columbia River.

If Hanford Site contamination that requires remedial action is identified in the river, and it is associated with a current groundwater or soil contamination source, a cleanup decision that offers protection for the river may be included with the final action ROD for one or more of the River Corridor Areas. If Hanford Site contamination that requires remedial action is identified in the river beyond the River Corridor boundary and it is associated with a past release, a separate remedial decision for the river may be developed.

3.6.5 Additional Evaluation and Assessment Activities

A number of uncertainties are associated with the RCBRA. The purpose of this section is to summarize a subset of the uncertainties for which additional activities will be conducted in the RI/FS to support development of final remedial action decisions. If new uncertainties are identified through the RCBRA, they will be addressed as emerging information as described in Section 5.1.

3.6.5.1 Uncertainties Associated with the Human Health Risk Assessment

Early cleanup decisions were intended to be protective of a potential rural residential exposure and DOE will continue to evaluate the potential risks for this type of exposure. The rural residential scenario evaluated in the HHRA is considered more conservative than the scenario used to develop interim action ROD cleanup levels because it uses a set of exposure assumptions based on current guidance and includes additional exposure pathways when compared with the exposure assumptions and exposure pathways used to develop interim RAGs in DOE/RL-96-17. The following activities address uncertainties for the RI/FS associated with evaluating rural residential exposures.

- Define the appropriate exposure pathways and exposure assumptions for assessing risk from a rural residential use.
- Determine the role of the rural residential exposure scenario in remedy evaluation. DOE is committed to establishing final action cleanup levels at least as protective as those levels identified in interim actions. The current HHRA rural residential exposure scenario and other exposure scenarios will be considered during development of cleanup levels for the final action RODs in the 100 Area. Ecology has stated it will evaluate unrestricted land use in accordance with WAC-173-340.
- Perform a systematic comparison of the exposure assumptions and exposure pathways used in the HHRA and DOE/RL-96-17 to determine the significance of differences between the two scenarios.

Uncertainties associated with the groundwater risk assessment in the HHRA are related to the ability of the existing data set to represent current baseline conditions. Analytical data used for the HHRA are obtained from several groundwater-monitoring programs, including the AEA surveillance program, the RCRA compliance program, and the CERCLA program. Sampling and analysis data from these programs comprehensively define the suite of contaminants associated with existing and potential groundwater contamination sources. However, differences in sampling frequencies (monthly, annually, or tri-annually), differences in analytes analyzed at each monitoring well (radiological and chemical), and

differences in method detection limits create uncertainties associated with the spatial, chemical, and temporal representative qualities of the data set used for the risk assessment.

Activities that would help reduce uncertainties, verify conclusions of the HHRA, and ensure that no contaminants were inadvertently overlooked based on use of the existing data set include the following:

- Identify existing and/or install new monitoring wells that are spatially representative of the groundwater. This set of monitoring wells will represent locations where a receptor potentially could contact groundwater.
- Conduct multiple rounds of sampling to obtain temporal representation of the unconfined aquifer from influence of river stage. Additional rounds of sampling at spatially representative monitoring wells will represent current groundwater conditions and capture the influence of river fluctuations on COPC concentrations.
- Analyze all spatially representative monitoring wells for a focused list of groundwater COPCs identified for each round of sampling. Analyzing each of the monitoring wells for COPCs will provide a data set that is representative of potential releases to the groundwater.
- Evaluate sample results from characterization activities to support final remedial action decisions for groundwater.

3.6.5.2 Uncertainties Associated with the Ecological Risk Assessment

The following RCBRA uncertainties associated with the protection of ecological receptors will be addressed through the RI/FS process.

- Are soil samples collected from the top 15.2 cm (6 in) of the waste site perimeter adequately representative of ecological exposure conditions from residual contamination at remediated waste sites?
- Would additional waste site soil samples collected to conduct supplementary bluegrass bioassays help reduce uncertainties associated with soil contaminants?

4 Approach

This chapter presents preliminary information related to RAOs, remediation goals, assessment of ARARs, and remedial actions that will be fully developed in the course of completing the RI/FS process.

4.1 Preliminary Remedial Action Objectives

As stated in 40 CFR 300, RAOs must be developed to address contaminants of concern, media of concern, potential receptors, and exposure pathways. The RAOs are narrative statements that define the extent to which waste sites require cleanup to protect human health and the environment.

The RAOs are based on the results of the HHRAs, ecological risk assessments, and the RI. Several expedited response and interim remedial actions already have been implemented (including characterization), thereby providing considerable information concerning contamination and risk. Interim action RODs, RODs, and action memoranda were issued for the 100 Area that addressed contaminated waste removal or facility demolition actions. Expedited response measures for contaminated groundwater also were implemented as remedial actions under interim action RODs to keep principal threat contaminants from reaching the Columbia River. Action memoranda directed efforts to remove various facilities and structures and to place reactors in ISS before final disposition. Appendix A provides a summary of the implementation of the CERCLA process to date for the 100 Area, including facility demolition and removal.

A preliminary list of RAOs has been prepared for the 100 Area (Table 4-1). Media specific RAOs for groundwater, surface water, soil, and land use were developed and combined into one list. The RAOs were based on existing River Corridor regulatory documents (e.g., interim action RODs) and were expanded to cover gaps when integrating all media and resources for an area. The RAOs are refined through the RI/FS process during the RI, baseline risk assessment (RCBRA), and the detailed analyses of alternatives conducted in the FS. The final RAOs are determined when the remedy is selected in the ROD.

Table 4-1. Preliminary Remedial Action Objectives for the 100 Area Operable Units

RAO No.	Goal
	Groundwater
1	Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing nonradiological contaminant concentrations above federal and state standards.
2	Prevent unacceptable risk to human health from ingestion of and incidental exposure to groundwater containing radiological contaminant concentrations above federal standards.
	Surface Water
3	Prevent unacceptable risk to human health and ecological exposure to surface water containing nonradiological contaminant concentrations above federal and state standards.
4	Prevent unacceptable risk to human health and ecological exposure to surface water containing radiological contaminant concentrations above federal standards.
	Soil
5	Prevent hazardous chemical contaminants from migrating and/or leaching through soil that will result in groundwater concentrations that exceed standards for protection of surface and groundwater.
6	Prevent migration and/or leaching of radioactive contaminants through soil to groundwater in excess of federal standards.

Table 4-1. Preliminary Remedial Action Objectives for the 100 Area Operable Units

RAO No.	Goal
7	Prevent unacceptable risk to human health and ecological receptors from exposure to the upper 4.6 m (15 ft) of soil contaminated with nonradiological constituents at concentrations above the unrestricted land use criteria for human health or soil contaminant levels for ecological receptors.
8	Prevent unacceptable risk to human health and ecological receptors from exposure to upper 4.6 m (15 ft) of soils and to structures and debris contaminated with radiological constituents.
	Prevent exposure to radiological constituents at concentrations at or above a dose rate limit that causes an excess cancer lifetime risk threshold of 10^{-6} to 10^{-4} above background for the rural residential exposure scenario. An annual dose rate limit of 15 mrem/yr above background achieves EPA excess lifetime cancer risk threshold.
	Protect ecological receptors based on a dose rate limit of 0.1 rad/day for terrestrial wildlife populations, which is a to-be-considered criterion.
	Land Use and Resource
9	Prevent adverse impacts to cultural resources, threatened or endangered wildlife, and ecological receptors using the Columbia River and prevent destruction of sensitive wildlife habitat.
10	Where it is not practicable to remediate levels that will allow for unrestricted use, ensure that appropriate institutional controls and monitoring requirements are established and maintained to protect future users of the remediated waste sites.

EPA = U.S. Environmental Protection Agency

4.2 Preliminary Remediation Goals

The PRGs provide target cleanup levels for use in evaluating how RAOs will be achieved, and they provide preliminary risk reduction targets that a remedial alternative must meet to achieve the criteria set forth in 40 CFR 300.430(e)(9)(iii). The PRGs are refined based on technical feasibility, community acceptance, baseline risk assessment, and other risk management considerations. Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-30 states that, "These preliminary goals may be modified based on results of the baseline risk assessment, which clarifies exposure pathways and may identify situations where cumulative risk of multiple contaminants or multiple exposure pathways at the site indicate the need for more or less stringent cleanup levels than those initially developed as preliminary remediation goals. In addition to being modified based on the baseline risk assessment, preliminary remediation goals and the corresponding cleanup levels may be modified based on the given waste management strategy selected at the time of remedy selection that is based on the balancing of the nine criteria used for remedy selection (55 FR 8717-8718, 'National Oil and Hazardous Substances Pollution Contingency Plan')." This refinement process ultimately results in establishment of final action cleanup levels, which are documented in the ROD.

For the 100 Area, PRGs will be developed for the protection of human health, ecological receptors, and groundwater. The PRGs will be based on regulatory requirements for exposure pathways, the baseline risk assessment, and future land use considerations. They are identified for individual hazardous substances identified as contaminants of concern or COPCs. If multiple contaminants are present at a waste site, the suitability of using individual PRGs as final action cleanup values protective of human health and the environment will be evaluated based on site-specific information and the potential for contaminant interaction.

The PRGs also are compared to each other to determine which offers the most restrictive value that is protective of all pathways, if it is greater than background concentrations and the practical quantitation limit. If the lowest of the PRGs is lower than background concentrations or the practical quantitation limit, then background concentrations or the practical quantitation limit (whichever is higher) become the PRG. The purpose of this process is to identify those constituents that may pose an unacceptable risk or exceed cleanup standards established by ARARs. Meeting PRGs and the potential ARARs and, by extension, achieving RAOs, can be accomplished by reducing concentrations (or activities) of contaminants to PRG levels or by eliminating potential exposure pathways/routes.

Final RAGs developed from the PRGs will be specified in a final action ROD that identifies the selected remedial alternative for 100 Area operable unit waste sites. For the purpose of this analysis, DOE, in collaboration with EPA and Ecology, has determined that the following principles will apply.

- Cleanup levels for contaminated soil and groundwater that were established in interim action RODs and action memoranda will continue to guide ongoing cleanup actions.
- Cleanup levels promulgated after the interim action ROD (e.g., WAC 173-340) will be used to evaluate ongoing cleanup actions. The evaluation will be done for informational purposes, and the later cleanup levels are not legally enforceable requirements for the ongoing cleanup actions.

Therefore, although alternative PRGs may be discussed in this analysis, it is for determining whether the existing cleanup requirements will be protective of human health and the environment. Residual risks following completed remediation of the 100 Area operable units must meet the RAOs. Documentation of actual media contaminant concentrations achieving cleanup objectives will be presented in a CVP for waste sites within the 100 Area. These packages will describe the remediation activities completed, identify any significant contamination remaining, summarize the sampling and data analysis approach, and demonstrate attainment of cleanup levels.

At the time of this writing, the PRGs have not been finalized for this final action RI/FS work plan. The RCBRA, which presents the results of the ecological risk assessment and HHRA, currently is undergoing revision. Following regulatory review, development of the PRGs will be completed during the RI/FS to address protection of human health and ecological receptors. The results provided in the RCBRA will be used to help validate cleanup levels for the final action RODs.

The PRGs for protection of ecological receptors, including aquatic receptors, are expected to consider state and federal screening values, and site-specific cleanup levels. Decisions regarding the application for direct contact exposure and derivation of dilution/attenuation factors also must be completed.

As additional information becomes available from site-specific risk information, RI site characterization, and chemical specific ARARs, the PRGs will be developed for each area. Some of the standards, procedures, and methodologies that will be used to develop PRGs for the 100 Area are discussed below.

4.3 Potential Applicable or Relevant and Appropriate Requirements

Laws and regulations pertaining to the response actions are identified through the ARAR identification process. The ARARs identification process is based on CERCLA guidance (EPA/540/G-89/004; EPA/540/G-89/006, *CERCLA Compliance with Other Laws Manual: Interim Final*; EPA/540/G-89/009, *CERCLA Compliance with Other Laws Manual – Part II, Clean Air Act and Other Environmental Statutes and State Requirements*). CERCLA Section 121 requires, in part, that any applicable or relevant and appropriate standard, requirement, criterion, or limitation under any federal environmental law, or any more stringent state requirement pursuant to a state environmental statute, be met (or a waiver

justified) for any hazardous substance, pollutant, or contaminant that will remain on site after completion of remedial action.

When compiling the requirements presented in this section, the ARARs presented in previous decision documents were reviewed, as well as current requirements that may apply to the investigation and remediation of contaminated waste sites within the 100 Area. In many cases, the ARARs form the basis for the PRGs to which contaminants must be remediated to protect human health and the environment. In other cases, the ARARs define or restrict how specific remedial measures can be implemented. The ARARs identified for the 100 Area operable units are preliminary because the results of the RI have not been documented and the FS remedial alternatives have not been not identified or evaluated. The final ARARs for remediation will be established in the ROD.

Under CERCLA, ARARs consist of two sets of requirements: (1) those requirements that are applicable requirements, and (2) those requirements that are relevant and appropriate requirements of promulgated, environmental laws. CERCLA also provides for the identification of to-be-considered, nonpromulgated advisories, criteria, guidance, or proposed standards, which often are identified with ARARs because they are helpful in selecting or implementing remedies that address, for example, federal and state environmental and public health agencies' advisories, guidance, and proposed standards. However, to-be-considereds are not legally enforceable and are not ARARs. Applicable requirements are those substantive standards that specifically address the situation at a CERCLA site. All jurisdictional prerequisites of the requirement must be met for the requirement to be applicable.

Relevant and appropriate requirements are determined by a two-step process. First, to assign relevance, it must be determined whether the requirement addresses problems or situations sufficiently similar to the circumstances of the proposed response action. Second, for appropriateness, the determination must be made as to whether the requirement also would be well suited to the conditions of the site. A requirement that is relevant and appropriate may not meet one or more jurisdictional prerequisites for applicability, but still may make sense at the site, given the circumstances of the site and the release. In evaluating the relevance and appropriateness of a requirement, the following eight comparison factors in 40 CFR 300.400, "Identification of Applicable or Relevant and Appropriate Requirements," are considered:

- The purpose of the requirement and the purpose of the CERCLA action.
- The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site.
- The substances regulated by the requirement and the substances found at the CERCLA site.
- The actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site.
- Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site.
- The type of place regulated and the type of place affected by the release or CERCLA action.
- The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action.
- (viii) Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site.

The ARARs are evaluated to determine if they apply to chemical-, location-, or action-specific circumstances related to CERCLA response actions. These categories are defined as follows:

- Chemical-specific requirements usually are health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of site cleanup levels that are protective of human health and ecological receptors.
- Location-specific requirements are restrictions placed on the concentration of dangerous substances or the conduct of activities solely because they occur in special geographic areas.
- Action-specific requirements usually are technology- or activity-based requirements or limitations triggered by the remedial actions performed at the site.

Only the substantive requirements (e.g., use of control/containment equipment or compliance with numerical standards) associated with ARARs apply to CERCLA onsite activities. According to CERCLA Section 121(e)(1), ARARs associated with administrative requirements, such as permitting, are not applicable to CERCLA onsite activities. In general, the CERCLA permitting exemption will be extended to all remedial activities conducted at the 100 Area operable units.

To-be-considered materials and information are nonpromulgated advisories or guidance issued by federal or state governments that are not legally enforceable but may contain information that would be helpful in implementing selected remedies.

The requirements of DOE orders must be met but are not identified as ARARs. Similarly, requirements pursuant to the Occupational Safety and Health Administration and other federal and state worker safety requirements are not identified as ARARs because they are employee protection laws and not environmental laws. Workers at CERCLA sites must comply with applicable safety requirements both substantively and administratively.

4.3.1 Waivers from Applicable or Relevant and Appropriate Requirements

EPA may waive ARARs and select a remedial action that does not attain the same level of site cleanup as that identified by the ARARs. The *Superfund Amendments and Reauthorization Act of 1986,* Section 121, identifies circumstances in which EPA may waive ARARs for onsite remedial actions. The circumstances that are pertinent to the Hanford Site remedial actions are as follows.

- The remedial action selected is only a part of a total remedial action (e.g., an interim action), and the final action remedy will attain the ARAR upon its completion.
- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.
- Compliance with the ARAR is technically impracticable from an engineering perspective.
- An alternative remedial action will attain an equivalent standard of performance by using another method or approach.
- The ARAR is a state requirement that the state has not applied consistently (or demonstrated the intent to apply consistently) in similar circumstances.

4.3.2 Potential Applicable or Relevant and Appropriate Requirements for the 100 Area Operable Units

DOE is proposing preliminary ARARs in Appendix B of this work plan in accordance with the Hanford Federal Facility Agreement and Consent Order, Section 7.5. Detailed documentation and further evaluation of the potential ARARs will be provided as an appendix to the individual feasibility studies. ARARs will be finalized though issuing of the RODs.

Groundwater, surface water, and soil cleanup regulations and terrestrial ecological evaluation procedures establish media cleanup standards for nonradioactive and radioactive contaminants. Federal and state air emission standards identify air emission limits and control requirements for any remedial actions that produce toxic air emissions. The RCRA land disposal restrictions will be important standards during the management of wastes generated during remedial actions. The RCRA Corrective Action (as implemented through the Tri-Party Agreement [Ecology et al., 1989a]), as well as treatment, storage, and disposal closure performance standards, are used (when applicable) for cleanup criteria and compliance monitoring requirements that apply to solid waste management units (including RCRA treatment, storage, and disposal units that are regulated units) that are located within the 100 Area.

Potential location-specific ARARs that have been identified for the 100 Area include those that protect cultural, historic, and Native American sites and artifacts, and those that protect critical habitats of federal endangered and threatened species that may occur within the 100 Area.

Action-specific ARARs that could be pertinent to the investigation and remediation include state solid and dangerous waste regulations (for management of characterization and remediation wastes and performance standards for waste left in place), and AEA regulations (e.g., performance standards for high-level radioactive waste sites).

Regarding waste management activities performed during remediation, a variety of waste streams may be generated under an equally wide range of potential remedial actions. It is anticipated that most of the remediation waste will be designated as low-level waste. However, quantities of dangerous or mixed waste, hazardous debris, polychlorinated biphenyl (PCB)-contaminated waste, and asbestos and asbestos-containing material also could be generated. The identification, storage, treatment, and disposal of hazardous waste and the hazardous component of mixed waste are governed by RCRA. The State of Washington implements RCRA requirements under WAC 173-303, "Dangerous Waste Regulations," and has been authorized to implement elements of the RCRA program. Substantive requirements of the state's dangerous waste standards for generation and storage would apply to the management of any dangerous or mixed waste generated during this remedial action. Treatment standards for dangerous or mixed waste subject to RCRA land disposal restrictions are specified in WAC 173-303-140, "Land Disposal Restrictions" (which incorporates 40 CFR 268, "Land Disposal Restrictions," by reference), and also would apply. Substantive portions of RCRA corrective action, as implemented by WAC 173-303-64620, will apply to remedial actions at any solid waste management unit or spill site that presents a threat to human health and the environment including surface impoundments, landfills, waste piles, and land treatment units.

The *Toxic Substances Control Act of 1976* (TSCA) and regulations in 40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions," govern the management and disposal of PCB wastes. The TSCA regulations contain specific provisions for PCB waste, including PCB waste that contains a radioactive component. The PCBs also are considered underlying hazardous constituents under RCRA and, thus, could be subject to WAC 173-303 and 40 CFR 268 requirements.

Removal and disposal of asbestos and asbestos-containing material are regulated under the *Clean Air Act of 1990* and amendments and 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," Subpart M, "National Emission Standards for Asbestos." This regulation provides for special precautions to prevent environmental releases or exposure to airborne emissions of asbestos fibers during remedial actions. The regulation found in 40 CFR 61.52, "Emission Standard," identifies packaging requirements. If encountered during the RI/FS, asbestos and asbestos-containing material may be removed, packaged as appropriate, and disposed at the ERDF.

Waste that is designated as low-level waste and that meets ERDF acceptance criteria is assumed to be disposed at the ERDF. The ERDF is engineered to meet appropriate performance standards under 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," and meet minimum technical requirements for landfills under WAC 173-303-665, "Landfills." Waste designated as dangerous or mixed waste would be treated as appropriate to meet land disposal restrictions (and ERDF waste acceptance criteria) and can be disposed at the ERDF. Applicable packaging and pre-transportation requirements for dangerous or mixed waste generated at the 100 Area operable units would be identified and implemented before disposal. Alternative disposal locations also may be considered when the remedial action occurs, if a suitable and cost-effective location is identified. Potential alternative disposal locations would be evaluated for appropriate performance standards to ensure that they are sufficiently protective of human health and the environment.

If encountered, waste designated as PCB remediation waste likely would be disposed at the ERDF, depending on whether it is low-level waste and meets the waste acceptance criteria. The PCB waste that does not meet ERDF waste acceptance criteria would be retained at a PCB storage area meeting the requirements for TSCA storage and would be transported for future treatment and disposal at an appropriate disposal facility. The TSCA anti-dilution provisions are only applicable to CERCLA response actions that occur once a remedial action is initiated; thus, remediation is based on the "as-found" PCB concentration at a CERCLA site.

CERCLA Section 104(d)(4) states that where two of more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment, the facilities can be treated as one for purposes of CERCLA response actions. Consistent with this, the 100 Area operable units and the ERDF would be considered "onsite" for purposes of CERCLA Section 104, and waste may be transferred between the facilities without requiring a permit.

Remedial actions will be performed in compliance with federal and state waste management requirements, such as the identification and designation of waste streams. Before disposal, waste will be managed in a protective manner to prevent releases to the environment.

It is anticipated that selected remedial action alternatives will have the potential to generate airborne emissions of both radioactive and criteria/toxic pollutants and will need to comply with applicable provisions of the federal *Clean Air Act of 1990* and Amendments and RCW 70.94, "Washington Clean Air Act." Under federal implementing regulations, 40 CFR 61, Subpart H, "Department of Energy Facilities," radionuclide airborne emissions from the facility shall be controlled so as not to exceed amounts that would cause an exposure to any member of the public greater than10 mrem/yr effective dose equivalent. The same regulation addresses point sources (i.e., stacks or vents) emitting radioactive airborne emissions, requiring monitoring of such sources with a major potential for radioactive airborne emissions, and requiring periodic confirmatory measurement sufficient to verify low emissions from such sources with a minor potential for emissions. Under portions of the state implementing regulations, the federal regulations are paralleled by adoption, and in addition more specifically address control of

radioactive airborne emissions where economically and technologically feasible (WAC 246-247-040[3] and -040[4], "Radiation Protection – Air Emissions," "General Standards," and associated definitions). To address the substantive aspect of these requirements, best or reasonably achieved control technology will be addressed by ensuring that applicable emission control technologies (i.e., those successfully operated in similar applications) will be used when economically and technologically feasible based on cost/benefit. If it is determined that there are substantive aspects of the requirement for monitoring of fugitive or nonpoint sources emitting radioactive airborne emissions (WAC 246-247-075[8], "Monitoring, Testing and Quality Assurance"), then these will be addressed by sampling the effluent streams and/or ambient air as appropriate using reasonable and effective methods.

4.4 Development of Vadose Zone Soil Target Analyte Lists and Groundwater Contaminants of Potential Concern

A process has been developed to identify vadose zone soil target analytes for addressing uncertainties associated with the nature and extent of contamination in the vadose zone. Similarly, a process has been developed to identify groundwater COPCs for addressing uncertainties associated with the spatial and temporal distribution of groundwater contamination. The processes (Table 4-2) described in the following sections provide the approach that will be used to select vadose zone soil and target analytes and groundwater COPCs area. The outcome of these processes will be documented in the SAPs prepared for each area.

Table 4-2. Vadose Zone Soil Target Analyte and Groundwater COPC Identification Process

Methodology Step	Vadose Zone Soil Target Analyte Identification	Groundwater COPC Identification
1	Prepare Initial Target Analyte List	Prepare Groundwater Data Set
2	Develop Master Target Analyte List	Identify Groundwater COPCs
3	Develop Location-Specific Target Analyte List	Compare Groundwater COPCs to Master Target Analyte List
4	Agency Review of Locations and Location-Specific Target Analyte List	Agency Review of Monitoring Wells and Groundwater COPCs

COPC = contaminant of potential concern

4.4.1 Methodology for Development of the Vadose Zone Soil Target Analyte List

The approach for development of vadose zone soil target analytes is a multi-step process. The first two steps develop a master list of target analytes for each area. The third step is to develop location-specific (e.g., waste site) target analyte lists where additional characterization is proposed. Finally, the analyte list will receive regulatory review. During this step, concerns regarding the selection process may result in the addition of analytes by the Tri-Parties.

4.4.1.1 Step 1 – Prepare Initial Target Analyte List

Characterization data for vadose zone soils are not available for addressing uncertainties associated with the nature and extent of contamination in the vadose zone. Therefore, remediation and characterization information (historical and current) are identified and reviewed to develop an initial list of target analytes to represent potential contamination in the vadose zone. The following types of reference documents and information sources are evaluated:

- Focused FSs, limited field investigation (LFI) reports
- Interim action RODs
- CVPs, remaining sites verification process (RSVPs)
- Technical baseline reports
- Dangerous waste permit applications
- Databases containing analytical data resulting from these activities (i.e., characterization, remediation, waste management information)
- Other pertinent documents

4.4.1.2 Step 2 – Prepare Master Target Analyte List

After the initial target analyte list is compiled, the information will undergo additional review steps to remove analytes using generally accepted exclusion criteria; a comparison of the soil target analyte list to the groundwater COPC list will be conducted, and the appropriate analytical methods and detection limits for the master target analyte list will be identified.

At the conclusion of this step, the master target analyte list is established. The comprehensive master target analyte list includes all the analytes that could potentially be present in the vadose zone and are important for waste site remediation within the area. The following steps are taken to prepare the master target analyte list:

- Apply the following generally accepted exclusion criteria to the initial set of target analytes. Analytes that meet the exclusion criteria will be eliminated as a COPC. Analytes that do not meet the exclusion criteria will be carried to the next step. The exclusion criteria are as follows:
  - Naturally occurring radionuclides associated with background radiation (including potassium-40, radium-226, radium-228, thorium-228, and thorium-232) will be eliminated as COPCs.
  - Radionuclides with a half-life of 3 years (and no significant daughters) will be eliminated as COPCs. Radionuclides with short half-lives can include antimony-125, beryllium-7, cesium-134, curium-242, radium-224, ruthenium-106, and thorium-228.
  - Essential nutrients are those chemicals considered essential for human nutrition. Recommended daily allowances are developed for essential nutrients to estimate safe and adequate daily dietary intakes (NRC, 1989, *Recommended Daily Allowances*). The following metals are considered essential nutrients: calcium, magnesium, potassium, and sodium.
  - Analytes that have no toxicity values (based on the hierarchy of toxicity values recommended by EPA in OSWER Directive 9285.7-53, *Human Health Toxicity Values for Superfund Risk Assessments*).

- Compare the master target analyte list for vadose zone soil with the groundwater COPC list developed for the area. Groundwater COPCs not found on the master target analyte list for soils are added to the list.
- Identify appropriate analytical methods for each analyte on the master target analyte list. Determine if the detection limits for each target analyte can achieve the RAGs for direct exposure, groundwater protection, and Columbia River protection.

4.4.1.3 Step 3 – Develop Location-Specific Target Analyte List

The master target analyte list represents all potential target analytes that could be present in the vadose zone for an area. Location-specific target analytes will be identified from the master list using the following approach:

- Identify the contaminants of concern for the specific waste sites where characterization is proposed from the applicable interim action ROD (which reflects information from LFIs and technical baseline reports). If the characterization location is not at a waste site, evaluate information from waste sites in the vicinity (where available). Include these analytes on the location-specific target analyte list.
- Identify the contaminants of concern for the specific waste site locations from the verification documentation (CVPs or RSVPs). If the characterization location is not at a waste site, evaluate information from waste sites in the vicinity (where available). Include these analytes on the location-specific target analyte list.
- Evaluate local groundwater monitoring well data (wells located within waste site "zones of influence"). Determine if these local wells have been analyzed for groundwater COPCs.
  - If the groundwater COPCs have been analyzed for but not detected, these analytes will not be included on the location-specific target analyte list.
  - If the groundwater COPCs have been analyzed for and have been detected, these analytes will be included on the location-specific target analyte list.
  - If the groundwater COPCs have not been analyzed for, an additional evaluation will be performed to determine if there is a data need. If there is a data need, these COPCs will be included on the waste site-specific target analyte list.

4.4.1.4 Step 4 – Agency Review of Locations and Location-Specific Target Analyte Lists

In the development of the work plan, Ecology raised concerns about the previous steps in the target analyte selection process. This additional step has been created to allow for the adjustment/addition of sample locations and target analytes on a site-specific basis. This adjustment has been agreed upon to ensure that regulator concerns regarding data gaps and uncertainties are addressed. This review is intended to provide an opportunity to address any information requirements not identified in steps 1 through 3. When additional information needs are identified, the agencies will modify the locations for additional characterization or the location-specific target analyte lists to reflect the additions or modifications determined to be needed on an area basis.

4.4.2 Methodology for Identifying Groundwater Contaminants of Potential Concern

The following process will be used to select COPCs for each of the areas. This process will identify groundwater COPCs that will be carried forward and evaluated for nature and extent of characterization and future risk assessment activities. The following paragraphs describe the steps used in the groundwater COPC selection process. A COPC is a constituent identified as a potential threat to human health or the

environment with data of sufficient quality for use in a baseline QRA. The COPC list will receive regulatory review. During this step, concerns regarding the selection process may result in the addition of analytes by the Tri-Parties.

4.4.2.1 Step 1 – Prepare Groundwater Data Set

A groundwater data set will be prepared for each area to identify groundwater COPCs. Analytical data will be obtained from the Hanford Environmental Information System (HEIS) database for all monitoring and compliance wells identified within the area. The analytical data set will represent groundwater samples collected from these wells between 1992 and the present (approximately 18 years). This timeframe was selected because it captures analytical data collected during the LFI, which were used to prepare the QRA for each groundwater operable unit. The analytical data from each area will be processed using the steps described below prior to COPC selection to identify one set of results per sampling location and time of collection.

- Select only unfiltered analytical results as these data represent total concentrations of the analyte. Use of filtered sampling results may underestimate chemical and radiological concentrations in water from an unfiltered tap. Filtered samples are not used for the COPC selection process.
- Eliminate analytical results that are rejected and flagged with an "R" qualifier.
- Identify the method that provides the most reliable results when an analyte is reported by more than one analytical method.
- Resolve parent, field duplicate, and field split samples into one set of results per location and collection time.

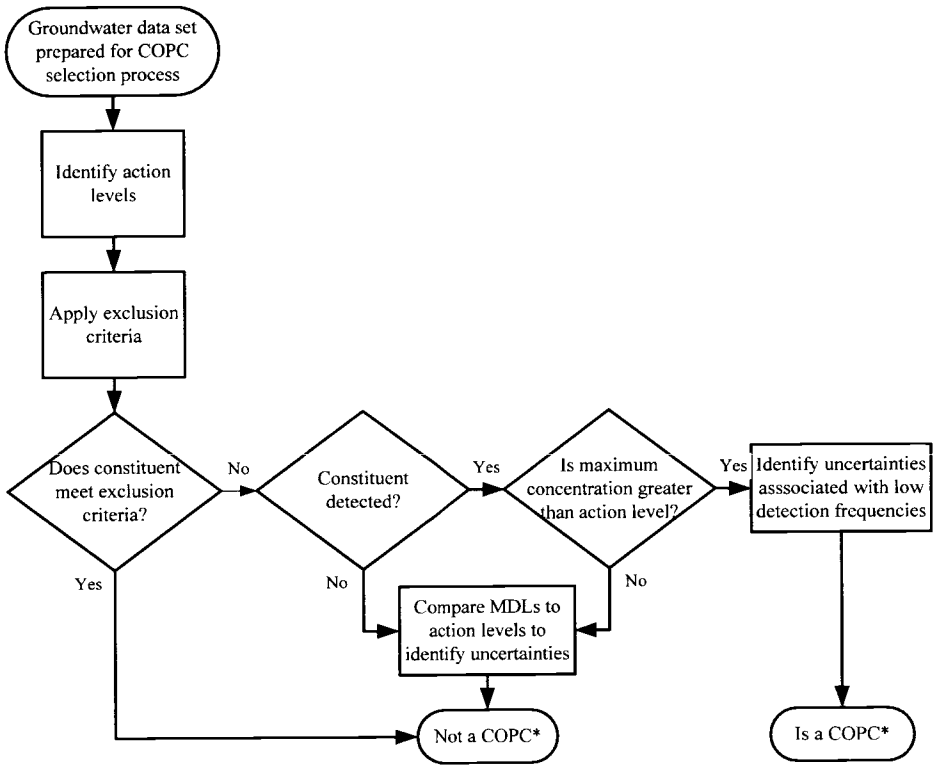
4.4.2.2 Step 2 – Identify Groundwater COPCs

After the groundwater data set has been prepared, the following steps are taken to identify area groundwater COPCs. A flowchart presenting the COPC selection process is shown in Figure 4-1.

Identify Action Levels. Action levels are derived from readily available sources of chemical-specific ARARs or risk-based PRGs using EPA health criteria and default exposure assumptions. The most protective of chemical-specific ARARs for groundwater are identified as the "action level" for each groundwater COPC. A summary of the sources of available chemical-specific ARARs and PRGs is provided below:

- ARAR-based remediation goals: potential chemical-specific ARARs include concentration limits set by the following.
  - Federal environmental regulations such MCLs, secondary MCLs, and non-zero MCL goals established under the *Safe Drinking Water Act of 1974*.
  - Ambient water quality criteria established under the *Clean Water Act of 1977*.
  - Washington State regulations (WAC 173-340-720; WAC 173-340-730 "Surface Water Cleanup Standards"; WAC 246-290-310, "Group A Public Water Supply", "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs), and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington").
- Risk-based PRGs: the risk-based concentration table for residential tap waters is used as the source of PRGs. These values are obtained from "Regional Screening Levels for Chemical Contaminants at Superfund Sites." (EPA, 2009). The PRGs for chemicals with carcinogenic effects correspond to a

10^{-6} incremental risk of an individual developing cancer over a lifetime because of exposure to the potential carcinogen from all significant exposure pathways for a given medium. The PRGs for chemicals with noncancerous effects correspond to a hazard index of 1, which is the level of exposure to a chemical from all significant exposure pathways in a given medium below which it is unlikely for even sensitive populations to experience adverse health effects. The direct contact exposure pathway for groundwater considers exposure from ingestion, inhalation of vapors, and dermal contact.



* Review vadose zone soil target analytes to determine if groundwater COPCs should be added.

Figure 4-1. Contaminant of Potential Concern Selection – A Multi-Step Process

Apply Exclusion Criteria. Analytes that meet the exclusion criteria will be eliminated as a COPC. Analytes that do not meet the exclusion criteria will be carried to the next step. The exclusion criteria are as follows:

- Naturally occurring radionuclides associated with background radiation (including potassium-40, radium-226, radium-228, thorium-228, and thorium-232) will be eliminated as COPCs.
- Radionuclides with a half-life of 3 years (and no significant daughters) will be eliminated as COPCs. Radionuclides with short half-lives can include antimony-125, beryllium-7, cesium-134, curium-242, radium-224, ruthenium-106, and thorium-228.
- Essential nutrients are those chemicals considered essential for human nutrition. Recommended daily allowances are developed for essential nutrients to estimate safe and adequate daily dietary intakes (NRC, 1989). The following metals are considered essential nutrients: calcium, magnesium, potassium, and sodium.

- Water quality parameters that do not have available toxicological information will be eliminated as COPCs. Groundwater samples are frequently analyzed for water quality parameters and used for purposes other than risk assessment.
- Analytes without an action level will be eliminated as a COPC.

The potential impacts to understating overall cumulative effects by eliminating analytes without an action level will be evaluated as an uncertainty. Activities will be conducted to understand potential uncertainties, including determining if the analyte has been associated with a historical operation process release or if a structurally similar analyte can be identified to evaluate its relative toxicity.

Identify Nondetected Analytes. Analytes that are not detected in any of the samples will be eliminated as groundwater COPCs. All constituents that are detected at least once will be carried to the next step. The reporting limits and detection limits for all analytical constituents (whether detected or not) in groundwater will be compared to the action levels. The potential impacts to the risk estimates of eliminating nondetected constituents as COPCs that have detection limits that exceed action levels will be discussed in an uncertainty assessment of this groundwater COPC selection process. Activities that will be conducted to define the uncertainties include: 1) determining if the analyte has been associated with any historical operation processes, with a potential release, or as a potential degradation product and 2) determining if method detection limits can be achieved at concentrations less than or equal to the action level.

Identify Analytes with Maximum Detected Concentrations Less than Action Levels. Maximum concentrations of analytes that are less than their action level are not identified as COPCs. An uncertainty analysis will be conducted for analytes with maximum concentrations slightly less than their action level (i.e., less than 10 times the action level or one order of magnitude). The purpose of this evaluation is to determine if there is the potential for underestimating cumulative effects when concentrations of analytes are near but do not exceed the action level. Additionally, method detection limits for these analytes to determine if they are adequate for confirming their presence or absence at the action level.

Identify Analytes with Maximum Detected Concentrations Greater than Action Levels. Maximum concentrations of analytes detected in groundwater are compared to action levels to identify analytes that are likely to contribute to overall risk. Steps are taken to identify when an analyte is infrequently detected to determine if the results are reproducible or associated with localized contamination. Additionally, method detection limits will be evaluated to determine if they are adequate for determining their presence or absence at the action level. If the results of this comparison show that the presence of an analyte is reproducible, then the analyte is identified as a groundwater COPC.

4.4.2.3 Step 3 – Compare Groundwater COPCs to Master Target Analyte List

This step of the process is used to confirm that the target analytes identified for vadose zone soils are appropriately considered for groundwater. The target analytes identified for vadose zone soil within the area are developed based on the review of available remediation and characterization reference documents. Based on the transport mechanism associated with the target analyte, it is a reasonable assumption that not all target analytes identified for vadose zone soil will be COPCs for groundwater. If a COPC is identified in groundwater that has not been identified on the master target analyte list for soil, it will be added to this list.

4.4.2.4 Step 4 – Agency Review of Monitoring Well Locations and Groundwater COPCs

In the development of the work plan, Ecology raised concerns about the previous steps in the target analyte selection process. This additional step has been created to allow for the adjustment/addition of sample locations and target analytes on a site-specific basis. This adjustment has been agreed upon to ensure that regulator concerns regarding data gaps and uncertainties are addressed. This review is intended to provide an opportunity to address any information requirements not identified in steps 1 through 3. When additional information needs are identified, the agencies will modify the locations for additional characterization or the groundwater COPC list to reflect the additions/modifications determined to be needed on an area basis.

4.5 Preliminary Remedial Actions

A preliminary compilation of potential remedial actions for vadose zone and groundwater are listed in Tables 4-3 and 4-4, respectively. These potential remedial actions will be evaluated further as the RI/FS process proceeds. Supplemental data are needed to determine the vertical and lateral extent of contamination in the soil and the groundwater so a range of remedial alternatives (including ex situ treatment, in situ treatment, or other alternatives) can be evaluated as appropriate.

4.5.1 Vadose Zone

In accordance with applicable CERCLA guidance (EPA/540/G-89/004), a comparative analysis of the alternatives will be conducted. The comparative analysis will facilitate the relative performance of each alternative in terms of the CERCLA evaluation criteria.

4.5.1.1 Alternative 1 – No Action

Evaluation of a no action alternative establishes a baseline for comparison with other remedial alternatives. The no action alternative represents no corrective or remediation activity and unrestricted access. Selecting the no action alternative would require that a waste site or contamination area not pose an unacceptable threat to human health or the environment.

The waste sites addressed in this work plan are expected to require remediation; thus, the no action alternative is not considered viable.

4.5.1.2 Alternative 2 – Institutional Controls

The waste sites addressed in this work plan generally have significant contamination and are not expected to be remediated by institutional controls as a standalone alternative. Institutional controls alone will not protect environmental receptors and have an uncertain capability of protecting long-term human health.

4.5.1.3 Alternative 3 – Containment and Isolation

This alternative implements control of moisture flowing through the contaminated area though an engineered horizontal barrier. Many design options are available that make use of the dry climate and expected limited infiltration quantities of the area. For evaluation of this alternative, the vertical and lateral extent of the contamination is needed to define contaminated volumes and support modeling of protection of groundwater.

Table 4-3. Preliminary Remedial Actions – Vadose Zone

Remedial Technology	Process Option	Descriptions
No action	**No action**	**Source areas and residual contamination in vadose zone are left untreated.**
Access controls; land use restrictions; water- use restrictions		Physical barriers, deed restrictions, emplaced warning indicators, etc.
Excavation	Standard excavation (approx. 6.1 m [20 ft] below ground surface)	Soil in identified source areas is removed using conventional construction equipment.
	Engineered/benched excavation (greater than 6.1 m [20 ft] below ground surface)	Soil in identified source areas is removed using conventional construction equipment with benching below 6.1 m (20 ft).
	Shored excavation (e.g., caisson excavation greater than 6.1 m [20 ft] below ground surface)	Soil in identified source areas is removed to deeper depths (18.3 to 24.4 m [60 to 80 ft]) using shoring.
Physical/chemical treatment	Chemical infiltration	Liquid with chemical reductant (calcium polysulfide) is applied to ground surface at an application rate substantially below what would create saturation, to treat contamination within vadose zone before reaching groundwater.
	Deep soil mixing	Large mixing augers (1.5 to 3 m [5 to 10 ft] diameter) or horizontally rotating heads are used to blend and homogenize chemical reductants with soil.
	Jet grouting with reactive materials	High-pressure injection of reactive slurry into soil is used to hydraulically mix the in situ material with the slurry.
	Foam injection	Injection of a foam-generating chemical reductant (calcium polysulfide)-surfactant solution into vadose zone.
	In situ gaseous reduction with chemical substrate	A gaseous mixture of chemical reductants (hydrogen sulfide) is injected into and drawn through the vadose zone to reduce and immobilize contamination.
	Water flushing	Clean/treated water (applied to the ground surface or in infiltration trenches) is used to flush contamination out of the vadose zone to the water table, where it would be captured and treated.
Chemical/biological treatment	Combined chemical/biological infiltration	Liquid with chemical reductant (calcium polysulfide) and biological carbon source is applied in combination to ground surface at an application rate substantially below what would create saturation, to treat contamination within vadose zone before reaching groundwater.

Table 4-3. Preliminary Remedial Actions – Vadose Zone

Remedial Technology	Process Option	Descriptions
Biological treatment	Biological infiltration	Liquid with biological carbon source is applied to ground surface at an application rate substantially below what would create saturation, to treat contamination within vadose zone before reaching groundwater.
	In situ gaseous reduction with biological substrate	A gaseous mixture of electron donor gases (propane, butane, ethene, and/or methane) is injected into and drawn through the vadose zone to biologically reduce and immobilize contamination.
Containment and isolation	Surface barrier	An impermeable cover (asphalt) is placed over ground surface to prevent surface water infiltration through the vadose zone and limit contamination leaching to groundwater.
	Vegetative cap (evapotranspiration cap)	A native grass cover is placed over ground surface to increase evapotranspiration rates, decrease the amount of surface water infiltration through the vadose zone, and limit contamination leaching to groundwater.

Table 4-4. Preliminary Remedial Actions – Groundwater

Remedial Technology	Process Option	Descriptions
No action	No action (monitored natural attenuation)	Relies on natural attenuation processes to remediate site.
Access controls; land-use restrictions; water- use restrictions		Physical barriers, deed restrictions, emplaced warning indicators, etc.
Extraction	Expand extraction systems	Install additional extraction wells to existing extraction network to control plume migration and remove dissolved contamination mass.
	Current extraction system	Continued operation of existing groundwater extraction wells.
Chemical treatment	Ion exchange	Ions from the aqueous phase are removed by exchange with innocuous ions on the exchange medium.
	Ferrous reduction	Dissolved contaminants are transformed into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. Usually uses pH adjustment, addition of a chemical precipitant, and flocculation.
Biological treatment	Wetlands	Groundwater is discharged to a constructed wetland where contamination sorbs to soil, is biologically reduced, or is taken up by plants and algae.
	Sub-grade bioreactors	Groundwater is amended with electron donor (optional) and injected upgradient of the extraction wells into a shallow infiltration trench backfilled with organic media (wood chips or mulch). Contamination is biologically reduced as it percolates through the trench and before infiltrating back to groundwater where additional treatment will occur.
	Ex situ bioreactors	Groundwater is amended with electron donor (carbon source) and passes through a matrix (fixed bed, fluidized bed, or membranes) with microbial films, where contamination is biologically reduced. Effluent is oxygenated, filtered, and amended before recharge back into the ground.
	Phytoremediation	Use of plants and their associated rhizospheric microorganisms to remove, degrade, or contain chemical contaminants in groundwater.
Physical treatment	Reverse osmosis	Water pressure is used to force water molecules through a very fine membrane, leaving the contaminants behind. Purified water is collected from the clean or "permeate" side of the membrane, and water containing the concentrated contaminants is disposed.
Onsite discharge	Groundwater injection	Treated groundwater is injected into onsite wells.

Table 4-4. Preliminary Remedial Actions – Groundwater

Remedial Technology	Process Option	Descriptions
	Injection of water at the river (mounding)	Treated groundwater or surface water is injected into injection wells, horizontal wells, or infiltration trenches along river.
	Reinfiltration with chemical amendments	Groundwater is amended with chemical reductant (calcium polysulfide) and then applied to ground surface at an application rate substantially below what would create saturation.
	Reinfiltration with biological amendments	Groundwater is amended with biological carbon source and then applied to ground surface at an application rate substantially below what would create saturation, to treat contamination within vadose zone and underlying groundwater.
Chemical treatment	In situ chemical treatment	Subsurface delivery and recirculation of chemical reductants within plume to stimulate reduction of contamination.
	ISRM maintenance/amendment	Inject additional sodium dithionite or non-zero valent iron to in-fill treatment zone gaps in the existing ISRM.
	Reactive chemical barrier	Subsurface delivery and recirculation of chemical reductants along cross-gradient rows transecting plume. Contamination is passively removed as groundwater moves through the treatment zone barriers.
Biological treatment	Reactive biological barrier	Subsurface delivery and recirculation of electron donors along cross-gradient rows transecting plume. Contamination is passively removed as groundwater moves through the treatment zone barriers.
	In situ biological treatment	Subsurface delivery and recirculation of electron donors within plume to stimulate anaerobic biodegradation of contamination.
Chemical/biological treatment	In situ treatment using combined bio and chemical substrate	Subsurface delivery and recirculation of both chemical reductants and electron donors within plume to stimulate chemical and anaerobic biological reduction of contamination.
Physical treatment	Water flushing	Clean/treated water (applied to the ground surface or in infiltration trenches) to flush out contamination in vadose zone and groundwater hot spots to expedite remediation of plumes.
Containment	Containing wall (e.g., slurry wall)	Slurry wall barriers consist of a vertical trench excavated perpendicular to the groundwater flow direction, filled with bentonite slurry to support the trench, and subsequently backfilled with a mixture of low-permeability material.
	Hydraulic containment	Install extraction wells along downgradient edge of plumes to control migration of contamination into the river.

NOTE: The information in this table is partially taken from EPA/540/G-89/004

ISRM = in situ redox manipulation

4.5.1.4 Alternative 4 – Source Removal, Treatment, and Disposal

Under this alternative, soil with contaminant concentrations above the future remediation goals would be removed, treated as appropriate, and disposed at the ERDF or other approved disposal facilities. This alternative would prevent contamination from reaching groundwater in the future.

For evaluation of this alternative, the vertical and lateral extents are needed to define contaminated volumes and support modeling of protection of groundwater. As a removal action progresses, an observational approach would be used to further define the extent of contamination. As previously unidentified contamination sources are located, a "plug-in" approach could be invoked to apply this alternative. The removed contamination would be treated for disposal in an onsite or offsite facility.

4.5.1.5 Alternative 5 – In Situ Treatment

In situ soil treatment involves injecting chemical or biological agents to react with the contaminant. This alternative would render the contaminant nonhazardous or immobilize it to prevent its movement to a receptor. This alternative would deliver the reactant to the entire contamination plume though physical mixing of the soil or infiltration techniques.

For in situ treatment applications, physical and chemical heterogeneity of the aquifer materials in the 100 Area must be considered in the design of the treatment system. The same data are required as with the ex situ and barrier alternatives.

4.5.2 Groundwater

In accordance with applicable CERCLA guidance (EPA/540/G-89/004), a comparative analysis of the alternatives will be conducted. The comparative analysis will facilitate the relative performance of each alternative in terms of the CERCLA evaluation criteria.

4.5.2.1 Alternative 1 – No Action

Evaluation of a no action alternative establishes a baseline for comparison with other remedial alternatives. The no action alternative represents no corrective or remediation activity and unrestricted access. Selecting the no action alternative would require that the area of contaminated groundwater not pose unacceptable threat to human health or the environment.

4.5.2.2 Alternative 2 – Institutional Controls

The areas of contaminated groundwater addressed in this work plan generally have significant contamination and are not expected to be remediated by institutional controls as a standalone alternative. Institutional controls alone will not protect environmental receptors and have an uncertain capability of protecting long-term human health.

4.5.2.3 Alternative 3 – Containment and Isolation

Physical barriers to contain the groundwater are likely not viable. Permeable reactive barriers to treat contaminants as they pass through the barrier or to capture contaminants in a stabilized form continue to be tested in the 100 Area. An ISRM barrier has been installed in the 100-D Area to reduce CrVI to trivalent chromium as the groundwater flows through the barrier. In the 100-N Area, injections of apatite are underway to form a barrier to Sr-90 movement. The strontium is integrated into the apatite crystal structure and immobilized as it undergoes radioactive decay. One concern expressed with these types of barriers is that the groundwater must flow to the barriers for treatment and, with low groundwater flow rates, many years are required to treat the entire contaminated volume.

Hydraulic barriers may be created by injecting clean water or by removing water to alter the local groundwater flow. Such barriers may be applicable for protecting localized or sensitive receptors from contamination.

To evaluate these alternatives, data are needed to understand the groundwater flow patterns and the aquifer permeability for introducing the chemical or other materials to form the barrier.

4.5.2.4 Alternative 4 – In Situ Treatment

In situ groundwater treatment involves injecting chemical or biological agents to react with the contaminant. This alternative would render the contaminant nonhazardous or immobilize it to prevent its movement to a receptor. The actions in this alternative are similar to creating a permeable reactive barrier, but this alternative would deliver the reactant to the entire contamination plume instead of allowing the normal groundwater flow to carry the contaminant to the reactant. The treatment agents could be introduced through injection wells or by infiltration through the unsaturated soil to the groundwater.

For in situ treatment applications, physical and chemical heterogeneity of the aquifer materials in the 100 Area must be considered in the design of the treatment system. The same data are required as needed for the ex situ and barrier alternatives.

4.5.2.5 Alternative 5 – Ex Situ Groundwater Treatment

With this alternative, contaminated groundwater is extracted, treated to remove contaminants, and reinjected into the aquifer. Several processes have been identified and demonstrated to remove the contamination, and the most commonly used are ion exchange, chemical or biological reaction to precipitate the contaminant for removal, chemical or biological treatment to convert the contaminant to a nonhazardous form, and electrochemical treatment.

For evaluation of this alternative, the vertical and lateral extent of contamination must be determined. The identification of other chemical species in the groundwater is necessary in order to select the appropriate chemical or biological process and to identify any potential adverse reactions. The treatment to remove the contaminant also may convert a nonhazardous component to a hazardous component. Groundwater flows must be understood so the network of extraction and reinjection wells can be properly designed.

4.5.3 Combined Alternatives

For the 100 Area, the best alternatives likely will involve a combination of in situ, ex situ, and source removal actions. Various actions may be applied in different areal locations of a plume, such as the source area versus the distal portions of the plume, and in the vadose zone versus the saturated zone.

When considering design of any remedial system for the 100 Area, the following should be considered:

- Target contaminants for remediation
- Chemistry of the groundwater
- Geochemistry and mineralogy of the aquifer materials
- Geochemical interactions of the added chemicals or biological agents, water, and aquifer materials, including any potential byproducts
- Impact on adjacent remedial systems

- Physical heterogeneity of the aquifer
- Hydrogeological conditions
- Risk to receptors

The preferred approach involves analysis of all evaluation criteria for each of the alternatives under consideration.

4.6 NEPA Values

Under DOE Order 451.1B, *National Environmental Policy Act Compliance Program*, Section 5.a.(13), DOE will "...incorporate NEPA values, such as analysis of cumulative, offsite, ecological, and socioeconomic impacts, to the extent practicable, in DOE documents prepared under the Comprehensive Environmental Response, Compensation, and Liability Act." These NEPA values include, but are not limited to, cumulative, ecological, cultural, historical, and socioeconomic impacts, and irreversible and irretrievable commitments of resources.

For the 100 Area operable units, the NEPA value analyses will be documented in conjunction with the CERCLA criteria in (a) each FS specific to an area and (b) in the resulting CERCLA ROD. The aforementioned NEPA values will be based on consideration of detailed information presented in the 100 Area CERCLA Evaluation Criteria, specific site characteristics, contaminants of potential concern, and the evaluation of the remedial action alternatives. A "sliding scale" of analysis of the NEPA values for the 100 Area (using DOE's "Green Book" [DOE, 2004, "Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements"]) will be applied, in conjunction with consideration of the CERCLA applicable or relevant and appropriate requirements (to be detailed in 100 Area feasibility studies). The principal impacts and resource areas of concern associated with the NEPA values are expected to include (but not be limited to) solid and liquid radioactive and hazardous waste management, air emissions, potential adverse effects to historical and cultural resources, ecological resources, socioeconomics (including environmental justice concerns), and transportation. The following is a general discussion of NEPA values anticipated to be addressed for the 100 Area, with the analysis to be provided in each FS.

In general, when soils at a site are found to be contaminated with hazardous substances in concentrations presenting a material threat to human health and the environment, it would be expected that the threat would be mitigated by meeting the applicable ARAR standards as well as following current DOE policy and guidance. The net anticipated effect could be a positive contribution to cumulative environmental effects at the Hanford Site through removal, treatment, and disposal of such hazardous substances and contaminants of concern into a facility that has been designed and legally authorized to safely contain such contaminants. DOE expects that the primary facility to receive contaminated soils will be the Hanford ERDF.[9]

Any airborne releases of radiological contaminants that could occur during these removal actions would be controlled in accordance with DOE radiation control and DOH air pollution control standards to minimize emissions of air pollutants at the Hanford Site, and protect all communities residing outside the Site boundaries. As part of the development of the CERCLA remedial investigation and feasibility study,

[9] Note that NEPA values in the planning for the ERDF operation were explained in detail in the original ERDF NEPA Roadmap, DOE/RL-94-41, *NEPA Roadmap for ERDF Regulatory Package,* for the ERDF Remedial Investigation/Feasibility Study (RI/FS, DOE/RL-93-99, *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility*) as described in the most recent ERDF ROD Amendment (May 2007).

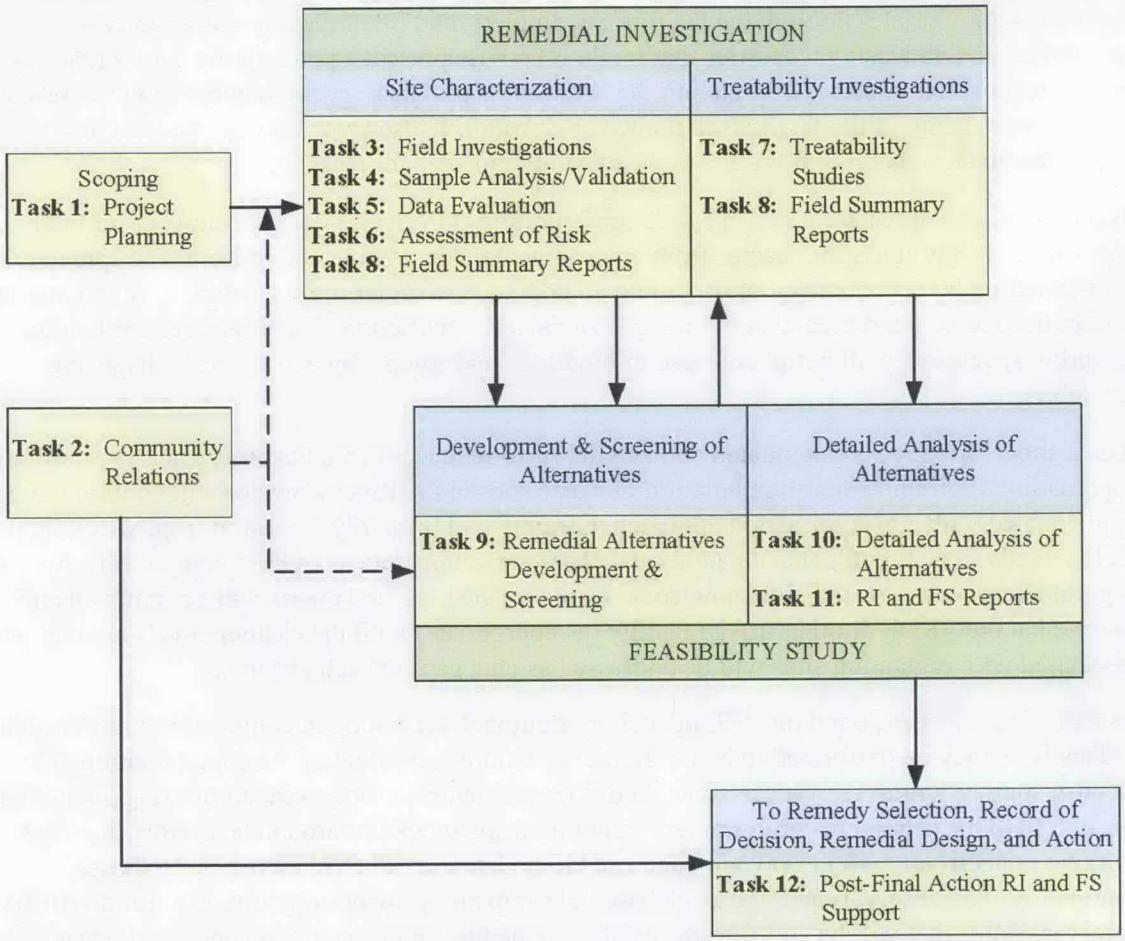
investigations and site-specific surveys are performed to assess the presence of historical, cultural, and ecological resources on the sites planned for remediation. Impacts on ecological resources near the removal actions would be mitigated in accordance with DOE/RL-96-32, *Hanford Site Biological Resources Management Plan* and DOE/RL-96-88, *Hanford Site Biological Resources Mitigation Strategy* and with the applicable standards of all relevant biological species protection regulations. Although these sites previously have been disturbed, only isolated cultural resource artifacts would be potentially encountered during project activities. Impacts to other cultural values including the viewshed from nearby traditional cultural properties could be minimized through implementation of DOE/RL-98-10, DOE/RL-2005-27, *Revised Mitigation Action Plan for Environmental Restoration Disposal Facility*, and consultation with area Tribal Nations throughout the design and project implementation. This could help ensure appropriate mitigation to avoid or minimize any adverse effects to natural and cultural resources and address any other relevant concerns.

Per Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, DOE seeks to ensure that no group of people bears a disproportionate share of negative environmental consequences resulting from proposed federal actions. Because access to the Hanford Site is restricted to the public, the majority of potential environmental impacts from the proposed action would be associated with onsite activities and would not affect populations residing offsite; thus, the potential for environmental justice concerns is small.

In addition, DOE is including the combined effects anticipated from ongoing CERCLA/Tri-Party Agreement (Ecology et al., 1989a) response actions as part of the cumulative impact analysis in the forthcoming draft Tank Closure and Waste Management EIS. Cumulative groundwater impacts from the proposed actions evaluated in the EIS as well as from other ongoing Hanford Site activities, including Tri-Party Agreement (Ecology et al., 1989a) cleanup actions, are included in this site-wide cumulative impact analysis. The cumulative impact analysis will present the public with an additional, separate opportunity for comment as part of the Tank Closure and Waste Management EIS NEPA process, and will be used to inform the public concerning the effects of ongoing cleanup actions on the Hanford Site in combination with other planned site activities.

5 Remedial Investigation/Feasibility Study Tasks

This chapter describes the tasks and processes that will be used during the final RI/FS. These descriptions incorporate RI site characterization tasks, data evaluation methods, analysis of remedial alternatives and reporting, and the preliminary determination of tasks to be conducted after site characterization. Figure 5-1 illustrates the relationships among these CERCLA RI/FS tasks. As part of the RI process, continued implementation of interim cleanup actions during the RI/FS process has been ongoing at the Hanford Site for the past 15 years.



CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
RI/FS = remedial investigation/feasibility study

Figure 5-1. CERCLA Remedial Investigation/Feasibility Study Process

An integrated cleanup program has been implemented in the River Corridor with a primary objective of protecting the Columbia River. Elements of the integrated cleanup program include D4 of contaminated and excess facilities, placing shutdown reactors in ISS, removing of contaminated soil and debris from waste sites, and cleaning up or immobilizing of contaminants in groundwater. Implementation of these cleanup actions in the River Corridor has reduced risk and produced large quantities of information and data that are valuable to guide development of the RI/FS work plan. Continued implementation of these cleanup actions throughout the RI/FS process will produce additional information to address many of the

current data gaps and provide opportunities for refinement of site knowledge. These activities continue to be efficient and cost-effective approaches for addressing the additional information needed to complete the RI/FS process.

Elements of the integrated cleanup program that will continue to be implemented through the RI/FS process and their associated relevance toward the objective of protecting the Columbia River are summarized below.

- Facilities – Eliminate potential for future environmental releases and provide access to underlying soil. Contaminated and excess facilities will be removed and disposed at the ERDF or other offsite facility (as appropriate) through the D4 process. Implementation of these actions removes contamination and waste inventories that might otherwise present a potential for future releases to the environment if left in place. Completing the D4 process provides access to underlying waste sites that are present in many of the facilities in the River Corridor. It also provides opportunities for discovery of new waste sites that will be added to the existing remedies for cleanup.

- Reactors – Contain reactor cores in a safe configuration (ISS) while decay occurs before final disposition. ISS protects the reactor from environmental degradation and prevents the spread of contamination by "cocooning," or providing an upgraded, weather resistant shell to isolate the reactor core until final action remedial activities are conducted. This action also minimizes the facility footprint by removing all peripheral reactor buildings and equipment and properly disposing the debris.

- Waste sites – Remove contaminated soil and debris to reduce potential exposure and prevent future degradation of groundwater. Remediation of waste sites in the River Corridor will continue to be implemented with a bias for action approach. Cleanup will primarily consist of implementation of the RTD remedy, which will generate additional characterization data to address many of the current data gaps and help refine overall site knowledge. Contaminated soil and debris will be removed and disposed at the ERDF or other offsite facility (as appropriate) until the cleanup levels are met. Risk associated with remaining sites will be addressed as data gaps in each addenda.

  As part of the remedy, borehole drilling and/or additional test pitting in conjunction with sampling and analysis may be performed to better define the nature and extent of the contamination and identify sources within the vadose zone. Activities are guided during excavation using data obtained through field measurements or in process sampling using quick turnaround laboratory analyses working concurrently with excavation and used to update the site characteristics databases continually. The observational-approach based cleanup also provides opportunities for discovery of new waste sites that will be added to the existing remedies for cleanup. Sequencing of waste site cleanup is based on the Tri-Party Agreement (Ecology et al., 1989a) milestone framework. Within this framework, knowledge of operational process (e.g., sodium dichromate use) and past releases may be used to target and prioritize specific waste sites or areas with contaminants that presently exist in or potentially impact groundwater.

  Effective implementation of waste site cleanup prevents further degradation of groundwater, thereby increasing the likelihood for success of cleanup actions (e.g., pump-and-treat) directed specifically at contaminated groundwater.

- Groundwater – Restore groundwater to its beneficial use (40 CFR 300.430(a)(I)(iii)(F)/highest beneficial use (WAC 173-340-730(1)(a))) to protect human health, the environment, and the Columbia River. Groundwater remedial actions are expected to restore groundwater to drinking water standards, or the most stringent ARAR. In those cases where groundwater discharges are impacting

the Columbia River "surface water," ensure that the water quality criteria for aquatic life are achieved. The cleanup levels will be established in the final ROD. It is intended that these objectives be achieved, unless technically impractical, within a reasonable time. The primary cleanup approach is to pump-and-treat contaminated groundwater. This is supplemented with other technologies (e.g., chemical treatment) to remediate specific contaminants or to address select areas of high concentration within contaminant plumes.

Community involvement during the RI activities will be consistent with Ecology et al., 2002, *Hanford Site Tri-Party Agreement Public Involvement Community Relations Plan.*

5.1 Task 1 – Project Planning

Project planning includes the previously approved interim action RI/FS work plans for the individual OUs (summarized in Appendix A), the systematic planning workshops (including the CSM plates) for each area, uncertainty team meetings, development of the CSM, and development of data needs and SAPs for each plan.

Existing LFI work plans describe the approach and rationale for initial characterization activities. The approach and rationale to support the final action RODs are supplemental to previously approved interim action RI/FS work plans and incorporate the additional data needs to support the final action decisions for the 100 Area. Project planning is complete when the work plan is approved. The FSs generated in support of remediation process optimization are a significant element of the ongoing remediation activities and will be incorporated into the 100 Area FSs, which lead to a final action ROD. Appendix C provides a list of proposed Tri-Party Agreement (Ecology et al., 1989a) milestones associated with the final action ROD activities for the 100 Area operable units.

5.1.1 Remedial Investigation/Feasibility Study Change Control

Extensive fieldwork is planned for each area. Normal reporting processes will continue to provide progress reporting and preliminary findings during and after the implementation of the RI/FS work plan. Emerging information during investigations can be classified into the following three categories, each requiring a different response.

- The first category of new information is not relevant to the RI/FS report. Information that might be classified as not relevant might include new information on the details associated with historical operation and general weather conditions.
- The second category of new information is relevant to the RI/FS report, but generally within expected ranges or bounds for the type of data. This information will be considered in the development of the RI report, but would not likely lead to changes in the RI/FS work plan.
- The third category is information or results from field activities that might call the CSM into question (e.g., waste sites extending and/or below the ordinary high-water mark, waterfront structures, and pipelines extending into the Columbia River). Unexpected results of sample analysis or field observations could fit into this category. This category could lead to changes in the RI/FS work plan activities.

Significant changes to the work plan, including changes in the schedule by two months or more to complete sampling and analysis for an area or decreasing the number of sampling locations or contaminants of concern, would occur formally and with regulatory approval. At a minimum, the

disposition of emerging information will be reported at regular 100 Area Tri-Party Agreement (Ecology et al., 1989a) project manager meetings.

Minor changes, including changes in sample locations by a few meters (e.g., less than 3 m [10 ft]) because of physical obstructions, changes in location to better meet the DQO/SAP, or additions of sample depth(s), can be made and documented in the field log in accordance with Section 12.4 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b).

More significant changes in sample locations that do not affect the DQO/SAP will require notification and approval of the waste site remediation task lead as detailed in the SAP. Changes to sample locations that could result in impacts to meeting the DQO/SAP will require RL and regulatory approval. Significant differences in geophysical or hydrological conditions encountered require regulatory notification. If such differences are determined to result in an impact to meeting the objectives of the DQO/SAP, RL and regulatory approval is then required.

Revisions to the SAP will be evaluated and processed in accordance with Section 9.3 of the Tri-Party Agreement Action Plan (Ecology et al., 1989b).

5.2 Task 2 – Community Relations

The Community Relations Plan (Ecology et al., 2002) outlines stakeholder and public involvement processes and opportunities. Public involvement during the RI activities will be consistent with the Community Relations Plan. The project will use existing tribal, stakeholder, and public forums to ensure input to the work plan. The Hanford Site is located on lands ceded by Tribal Nations according to the following treaties.

- Confederated Tribes of the Umatilla Indian Reservation through the *Treaty with the Walla Walla, Cayuse, and Umatilla, 1855*
- Yakama through the *Treaty with the Yakima, 1855*
- Nez Perce through the *Treaty with the Nez Perce Indians, 1855*

Although not a signatory to a treaty, the Wanapum territory traditionally included the Hanford Site.

Involvement efforts fall into three categories: tribal, stakeholder, and public. All interactions with the HAB and public are done through and coordinated with the RL public involvement manager.

5.2.1 Tribal Nations Involvement

All interactions with Tribal Nations are done through the RL tribal liaison. RL has biweekly conference calls with the tribes to brief them on upcoming issues of interest. As Tribal Nations are not stakeholders, their involvement is on a government-to-government basis. Where possible, briefings to Tribal Nations will be done through existing forums. RL will work with Tribal Nations to ensure ongoing communication and involvement in the River Corridor decision-making process.

Relationship with the Tribal Nations is based on treaties, statutes, executive orders, and DOE policy statements. The treaties secured to the Tribal Nations certain rights and privileges to continue traditional activities outside the reservations, and established a trust relationship between the federal government and the Tribal Nations. To meet this responsibility, and to facilitate consultations, Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*, states that each federal agency "shall have an accountable process to ensure meaningful and timely input by tribal officials in the development

of regulatory policies that have tribal implications." More specifically, under DOE O 144.1, *Department of Energy American Indian Tribal Government Interactions and Policy*, Attachment 2, *Memorandum for Heads of Department Elements*, DOE "will implement a proactive outreach effort of notice and consultation regarding current and proposed actions affecting tribes... This effort will include timely notice to all potentially impacted Indian nations in the early planning stages of the decision-making process..." Further, under this order, "consultation will include the prompt exchange of information regarding identification, evaluation, and protection of cultural resources. To the extent allowed by law, consultation will defer to tribal policies on confidentiality and management of cultural resources."

5.2.2 Stakeholder Involvement

The Community Relations Plan identifies processes governing public information and involvement processes. Stakeholders are individuals who see themselves affected by and/or have an interest in Hanford Site issues. They commit time and energy to participate in decisions. Hanford Site stakeholders include local governments, local and regional businesses; Hanford Site workforce; local, regional, and national environmental interest groups; and local and regional public health organizations. Another group of stakeholders with whom the Tri-Parties work is the Hanford National Resources Trustees and the State of Oregon. The HAB is a *Federal Advisory Committee Act 1972* Board consisting of 31 individuals representing a balanced mix of the diverse interests affected by Hanford Site cleanup issues. The HAB advises the Tri-Parties on cleanup issues. The body of HAB advice was reviewed for this work plan to ensure responsiveness to HAB values, principles, and issues. The HAB's River and Plateau Committee addresses River Corridor and Central Plateau issues. The cleanup program will work with DOE to identify opportunities to inform and involve this committee on significant work plan issues and progress. The River and Plateau Committee meets approximately 10 times per year. Based on the timing of the development of significant work plan components (e.g., the CSM and data needs), periodic updates will be provided to the River and Plateau Committee.

The River and Plateau Committee provides an ongoing opportunity for informal stakeholder feedback on work plan components and evolving project activities. The committee discusses issues and decides whether an issue should be brought to the HAB.

5.2.3 Public Involvement

In addition, public involvement is governed by Tri-Party Agreement (Ecology et al., 1989a) activities. The public consists of those individuals who are aware of but may choose not to be involved in decisions. At this time, public meetings or comment periods are not conducted on the initial draft work plan. As subsequent addenda to the work plan are developed, consultation with the Tri-Parties, River and Plateau, and Public Involvement and Communication Committees would determine the need for public involvement.

5.3 Task 3 – Field Investigations

Field investigations will be conducted in the 100 Area to supplement information received from the LFIs and in response to results from ongoing remedial actions under interim action RODs (e.g., CERCLA 5-year reviews). The field investigation and data collection activities will address additional data needs developed through the systematic planning process (Section 1.5) and refined using EPA's DQO process documented in the addenda. The specific data needs for each area are defined in each addendum.

The scope of the field investigation will be described in a SAP. The primary objective of the SAP is to provide sampling strategies to obtain the supplemental data required to satisfy specific data needs

identified during the systematic planning workshops. An RI –area specific SAP will be prepared for each 100 Area and will be included in the respective addendum.

It is anticipated that the RI field investigations will use similar approaches to those in the LFIs and remedial actions under interim action RODs for characterizing site conditions; delineating waste disposal; defining the nature and extent of contamination; and characterizing human health, ecological, and environmental impacts. Future field investigation approaches will include the following:

- Field screening (e.g., radionuclides and volatile organic compounds)
- Soil gas surveys
- Wipe sampling
- Boreholes and test pits
- Surface and subsurface soil sampling
- Surface and borehole geophysics
- Sludge sampling
- Sediment sampling
- Groundwater sampling
- Porewater sampling
- Aquifer testing
- River gauging
- Ecological surveys and sampling

Selection of sites or locations where additional vadose zone soil characterization is planned as part of the RI/FS field investigation is based on the consideration of the following criteria:

- Existing plans/commitments for remedial action per interim action per interim action RODs
- Historical demolition activities and associated end-state
- Proximity to high concentration groundwater plumes
- Volume and concentration of liquid disposal activities
- Historical impacts to groundwater quality
- Extent of excavation relative to the bottom of the engineered structure(s)
- Contaminants sampled to support site reclassification relative to contaminants identified in historical investigations (e.g., decontamination and repair, LFIs)
- Concentration of residual soil contamination relative to screening levels for groundwater protection
- Concentration of residual soil contamination relative to WAC 173-340 2007 values
- Characterization information beneath extent of excavation
- Evidence of deep soil contamination
- Contaminant mobility properties in soil (i.e. distribution coefficient)
- Potential data needs identified in the systematic planning workshops
- Anticipated applicability of RI/FS characterization results to other sites

Consideration and relative weighting of the criteria at specific sites or locations may vary based on process history and present conditions at the site or locations being evaluated. Selection of sites or locations where additional vadose zone soil characterization is planned as part of the RI/FS field investigation will be based on discussion with and concurrence by the Tri-Parties and is presented in the

addenda. The Tri-Party Agreement (Ecology et al., 1989a) allows for the initiation of site survey and screening activities before submittal of the RI/FS work plan. These nonintrusive activities include the following:

- Surveillance for location of sites
- Surface radiation surveys
- Surface geophysical surveys
- Air sampling
- Soil gas surveys
- Biotic surveillance

These surveys allow for a quicker start of characterization activities upon approval of the RI/FS work plan, and results may be factored into the work plan as appropriate. To further expedite the process, near surface vadose zone sampling may commence two weeks after receipt of lead regulatory agency comments on the initial draft of the RI/FS work plan, if the comments regarding vadose zone sampling have been resolved.

5.3.1 Supplemental Investigations

The following supplemental activities have been identified to prove input to the CERCLA cleanup process. These five items below support information needs for the entire River Corridor and will be addressed separately from other field investigation activities described in the specific SAPs. As specific schedules and details associated with these activities are developed, communication and input from the regulators will be obtained:

- Evaluating and developing approaches to obtain data that will demonstrate compliance with ambient water quality standards in the river for final ROD decisions. In April 2008, a technical review panel was convened to evaluate groundwater interactions with the Columbia River (SGW-39305). The panel suggested that the current mixing/dilution conceptual model should be re-evaluated. In addition, data may be needed to show representativeness of contaminant concentrations for compliance. Therefore, evaluation will include determination of whether 1:1 dilution assumption for groundwater entering the river is valid, and may include evaluation of whether data from aquifer tube samples are representative. Data collected as part of the remedial investigation for Hanford Site releases to the Columbia River may be useful in this evaluation.

- Collecting data and developing River Corridor background values for antimony, boron, molybdenum, and selenium. Site-specific background values for these constituents may be needed to determine final soil RAG values where calculated risk-based concentrations and/or ecological protection concentrations are less than background. Interim remedial actions have used Washington State background values for antimony and selenium; interim soil RAGs for boron and molybdenum are above expected site-specific background values.

- Re-evaluate soil cleanup level for CrVI to support the final ROD. The lowest soil RAG for CrVI under the interim RODs is 2.0 mg/kg. However, the calculated WAC-173-340-747(3)(a) (2007) soil RAG value may be below the current limits of analytical quantitation in environmental samples, depending on the soil-partitioning value and groundwater-to-river dilution attenuation factor used, and final soil cleanup values may default to the limits of quantitation. Because there is uncertainty in analytical detection and quantitation of CrVI near the limits of detection, it may be necessary to consider the realistic capabilities of analytical performance in determination of a final soil cleanup value.

- Determining a site-specific soil-partitioning value for antimony. This value is necessary for calculation of WAC-173-340-747(3)(a) (2007) soil RAG values for antimony. Antimony is not a significant contaminant in the River Corridor, and determination will include review of scientific literature, which suggests antimony soil-partitioning values in the range of 1.4 to 45 ml/g.

- Re-evaluate soil cleanup levels for arsenic to support the final ROD. The soil RAG for arsenic under the interim RODs is 20 mg/kg, based upon Tri-Party Agreement (Ecology et al., 1989a) to use the WAC 173-340-740(2) (1996) Method A value (DOE/RL-96-17, Rev. 5). The WAC 173-340-740(2) (2007) Method A value is also 20 mg/kg. The WAC 173-340-740(3) (2007) Method B and WAC 173-340-747(3)(a) (2007) soil values for arsenic are below the Hanford Site arsenic background of 6.5 mg/kg. Selection of a final soil cleanup level for arsenic in the River Corridor will be accomplished through development of final RODs.

5.4 Task 4 – Sample Analysis/Validation

Each work plan addendum will identify areaspecific target analytes, analytical methods, and quantification levels for analysis of media samples collected. The data obtained will be reviewed, verified, and validated. Data verification will be performed to ensure and document that the reported results reflect those activities that were actually performed.

The data verification checks include review for completeness, use of the correct analytical methods/procedures, review for transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and the correct application of conversion factors. Laboratory personnel may perform data verification.

Data validation will be performed to ensure that the data quality goals established during the RI/FS planning phase have been achieved. Validation activities will be based on EPA functional guidelines (EPA, 1988a. *Laboratory Data Validation: Functional Guidelines for Evaluating Inorganics Analysis;* EPA, 1988b, *Laboratory Data Validation: Functional Guidelines for Evaluating Organics Analysis*). Data validation may be performed by the analytical laboratory, the Sample and Data Management organization, and/or by a party independent of both the data collector and the data user.

5.5 Task 5 – Data Evaluation

Following verification and validation, data will be evaluated to assess whether the original questions were answered (e.g., project DQOs). The data quality assessment process compares completed field sampling activities to those proposed in corresponding sampling documents, and provides an evaluation of the resulting data. The data quality assessment process (EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners*) is discussed in further detail in each SAP.

The RI data will be managed through a data management system to provide accurate, appropriate, consistent, traceable, and defensible data to all users throughout the project. The data management process will provide project teams with electronic data access to control revisions and additions to the data set. The types of data expected to be managed during the RI include the following:

- Analytical laboratory data
- Physical data
- Borehole logs
- Well construction reports
- Geographical information systems data

- Modeling data inputs and outputs
- Drawings
- Historical narrative/reports
- Process engineering data
- Environmental surveillance data
- Geophysical or geochemical data

In order to meet modeling input and output data needs, DOE will conduct a verification and validation of residual radioactivity for chemicals. Further details of the data management process are provided in each SAP.

5.6 Task 6 – Assessment of Risk

Section 3.6 discusses the process and activities for evaluating baseline and residual risks for the 100 Area. The sample collection tasks under the RI/FS do not include additional risk assessment. RI/FS information and data will be compared to the assumptions and conclusions of the RCBRA (and other pertinent assessments) to determine if there is any impact on risk conclusions that would affect final action decision making. Methods that can be used for comparison are discussed below. Results of this evaluation will be in the RI/FS report.

The data generated from the sampling plan will be combined with existing data in the HEIS database for use in evaluating the nature and extent of area contamination. This section briefly summarizes methods that may be employed to compare the RI data with RCBRA data. Results from this comparison will be used by the Tri Parties to determine if RI data might affect the risk analyses in the RCBRA.

5.6.1 Graphical Data Displays

As part of data interpretation, graphical representation of analytical results will be generated for use in evaluation of contaminant trends. Exploratory data analysis plots allow for visual inspection and summary of the data. Each plot described below provides a different visual presentation of the distributions of contaminants.

The choice of plotting procedures depends on the hypothesis being tested and may include and/or depend on the following:

- The type of difference that is to be displayed, such as an overall shift in concentration.
- When the centers are nearly equal, a difference between the upper tails of the two distributions (elevated concentrations in a small fraction of one distribution).

A number of established methods for graphically displaying data that could be used for the RI/FS:

- **Histograms.** Histograms split the full range of results into equal-width data classes (intervals).
- **Estimated (Probability) Density Functions.** In density functions, the horizontal axis indicates the analyte results in the appropriate units. The curve, or density estimate, is a smoothed histogram.
- **Box Plots**. Box plots summarize information about the shape and spread of the distribution of data. Box plots consist of a box, a (median) line across the box, whiskers (lines extended beyond the box and terminated with a perpendicular line segment), and points outside the whiskers.

- **Bivariate Plots.** Scatter plots are an example of a bivariate display used to look for a mutual relationship or correlation between two variables of interest in the same sample. Data relating to one variable (y-axis) are plotted against data from a second variable (x-axis).
- **Spatial Plots.** Spatial plots present data across a given area using a variety of techniques. One simple plot used to provide information on spatial trends for two-dimensional data is a circle plot. Circle plots provide simple graphical representations of the magnitude of results at each sample location.

In addition to test results described in this section, the data will be plotted spatially and evaluated relative to the conceptual site model. Spatial plots of the data are used to verify or better define the site conceptual model.

5.6.2 Statistical Methods

To determine whether the RI data set may affect the risk analysis in the RCBRA, the data sets will be compared, and uncertainties for chemical, spatial, and temporal similarities or differences will be evaluated. Results of these data collection efforts will be statistically evaluated by one or more of the following statistical methods. Resulting data gaps from these data collection efforts will be filled appropriately.

- **Student's t-test.** This is a parametric, two-sample test that determines whether the mean concentration of site data is statistically greater than the mean concentration of background or reference site data.
- **Welch's t-test.** Welch's t-test is an adaption of the Student's t-test, described above, for use in circumstances where the variances of the site and background data are unequal.
- **Wilcoxon rank sum test (or Mann-Whitney U-test.** This test is the nonparametric equivalent to the t-test. The Wilcoxon test pools site and background or reference site data into one aggregate set and determines whether the average rank of the site data is greater than that of the background data.
- **Bartlett's test.** This test is used to determine the homogeneity of variance between samples from two populations.
- **Gehen test.** When, as is frequently the case for environmental data, some of the data area "censored" or reported as below a detection limit, and especially when not all the detection limits are identical, the Gehan modification to the Wilcoxon test is useful. The Gehan test uses a modified ranking of sample results to accommodate nondetected values together with detected values, and then applies the Wilcoxon rank sum test.
- **Quantile test.** The quantile test determines whether more of the observations in the top 20 percent (chosen percentile) of the combined data set come from the site data set than would be expected by chance, given the relative sizes of the site and background data sets.
- **Statistical Quantities.** Percentiles or quantiles are measures of relative standing that are useful for summarizing data. A percentile is the data value that is greater than or equal to a given percentage of the data values. Stated in mathematical terms, the pth percentiles is data value that is greater than or equal to p% of the data values and is less than or equal to (1-p%) of the data values.
- **Slippage test.** This test is based on the maximum observed concentration in the background or reference site data set and the number of potentially affected site concentrations that exceed the maximum concentration in the background or reference data set.

5.6.3 Assessment of Risk for Arsenic and Lead

Soils in the large parts of Washington State contain levels of arsenic and lead caused by past releases from metal smelters and historical application of agricultural pesticides. This low to moderate-level soil contamination, dispersed over large geographic areas, is referred to as area-wide soil contamination. Some areas of the Hanford Site (including the 100-D and 100-H Areas) are affected by application of lead-arsenate pesticides prior to 1943. The residual contamination at the Hanford Site created a problem for the Tri-Parties during implementation of interim remedial actions: residual arsenic made it difficult to close out interim clean up of sites contaminated by the Hanford Site production processes. The Tri-Parties dealt with this problem by establishing an interim remedial action goal of 10 mg/kg arsenic. DOE in coordination with EPA and Ecology will conduct the necessary work to determine a final cleanup level of residual arsenic. This may include site-specific terrestrial ecological evaluations consistent with the elements of WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures." During its state fiscal year (SFY) 2009-2010, Ecology Environmental Assessment Program and Toxics Cleanup Program has initiated work on site-specific cleanup levels for smelter-and orchard-affected lands elsewhere in the state. Ecology's Nuclear Waste Program participated in scoping those SFY 2009-2010 studies.

5.7 Task 7 – Treatability Studies

Treatability studies may be conducted to provide additional area-specific data to reduce cost and performance uncertainties, to allow a treatment alternative to be fully developed and evaluated during the RI/FS detailed analysis, and to support the remedial design of a selected alternative. The process for incorporating the treatability study into the RI/FS process includes the following steps:

1. Determine data needs.
2. Review the existing site data and available information on technologies to determine if existing data are sufficient to evaluate alternatives.
3. Perform treatability studies, as appropriate, to determine performance, operating parameters, and relative costs of potential remedial technologies.
4. Evaluate the data to ensure that DQOs are met.

The *Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide* (DOE, 2008) also has been used at the Hanford Site to assess whether the maturity of critical technology elements is sufficient for incorporation into final designs. The technology readiness assessment process consists of the following three parts:

1. Identify the critical technology elements.
2. Assess the technology readiness level of each critical technology element using the technical readiness scale used by the U.S. Department of Defense and the National Aeronautics and Space Administration, and adapted by the assessment team for use by DOE.
3. Evaluate technology testing or engineering work necessary to bring immature technologies to appropriate maturity levels.

Treatability studies and remedial actions under interim action RODs conducted to date in the 100 Area include groundwater pumping with treatment by ion exchange ISRM using a reactive treatment zone injected with sodium dithionite, biostimulation, electrocoagulation, calcium polysulfide, and apatite barrier.

Several projects are currently underway, or were previously completed, as technology demonstrations to evaluate other innovative in situ treatment technologies, including in situ bioremediation and calcium polysulfide injection, and an ex situ pilot test of electrocoagulation for CrVI removal. Possible future treatability studies to help bring these technologies to full-scale implementation include studies of ion exchange regeneration, in situ carbon polysulfide treatment, and bioreduction approaches. More detail on treatability studies for each 100 Area is discussed in their respective addendum.

5.8 Task 8 – Field Summary Reports

As the field investigations and treatability studies are completed, field summary reports are prepared to document the data collection and to provide updates to the CSM. The field summary reports, which are used during preparation of the RI/FS reports, discuss the investigative approach used, the results, and conclusions.

5.9 Task 9 – Remedial Alternatives Development and Screening

The development and screening of remedial alternatives begins once sufficient data are available. This task may occur concurrently with the preparation of field summary reports. The primary objective of this task is to develop an appropriate range of remedial options that will be analyzed more fully in Task 10. Appropriate remedial options may include the complete elimination of hazardous substances, the reduction of concentrations of hazardous substances to acceptable health based levels, and the prevention of exposure to hazardous substances via engineering or institutional controls.

Remedial alternatives are developed by assembling combinations of technologies for affected media into alternatives that address the contamination for each area. This process consists of the following six general steps (EPA/540/G-89/004):

1. Develop RAOs specifying the contaminants and media of interest, exposure pathways, and PRGs that permit a range of treatment and containment alternatives to be developed. The PRGs are developed based on chemical specific ARARs (when available), other available information (e.g., reference doses), and areaspecific risk related factors.

2. Develop general response actions for each medium of interest defining containment, treatment, excavation, pumping, or other actions, singly or in combination, which may be taken to satisfy the RAOs for the area.

3. Identify volumes or areas of media to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the RAOs and the chemical and physical characterization of the area.

4. Identify and screen the technologies applicable to each general response action to eliminate those technologies that cannot be technically implemented at the area. The general response actions are further defined to specify remedial technology types (e.g., the general response action of treatment can be further defined to include chemical or biological technology types).

5. Identify and evaluate technology process options to select a representative process for each technology type retained for consideration. Although specific processes are selected for alternative development and evaluation, these processes are intended to represent the broader range of process options within a general technology type.

6. Assemble the selected representative technologies into alternatives representing a range of treatment and containment combinations, as appropriate.

The screening should be used to identify and distinguish any differences among the various alternatives and to evaluate each alternative for effectiveness, implementability, and cost. The result of this task is a refined list of remedial alternatives for a specific area that is judged as the best or most promising based on these evaluation factors and should be retained for more detailed analysis.

The remedial action alternatives developed through this process are screened and FS-level designs and costs are developed for the preferred alternative.

5.10 Task 10 – Detailed Analysis of Alternatives

During the detailed analysis, the alternatives that passed screening are further refined and analyzed. A number of alternatives should be developed that provide a range of options and sufficient information to compare alternatives against one another. For source control options, the following type of alternatives should be developed to the extent practicable (EPA/540/G-89/004).

- A number of treatment alternatives, ranging from an alternative that would eliminate or minimize to the extent feasible the need for long-term management (including monitoring) at a site, to an alternative that would use treatment as a primary component of an alternative to address the principal threats at the site. Alternatives within this range typically will differ in the type and extent of treatment used and the management requirements of treatment residuals or untreated wastes.

- One or more alternatives that involve containment of waste, with little or no treatment, but protect human health and the environment by preventing potential exposure and/or reducing the mobility of contaminants.

- A no action alternative.

For groundwater response actions, the range of alternatives may use different technologies to achieve cleanup levels within varying timeframes.

The selection of the preferred alternative is determined through the application of nine evaluation criteria identified in the detailed analysis of alternatives. These criteria are grouped by their importance. Each alternative must meet the following threshold criteria:

- Overall protection of human health and the environment
- Compliance with ARARs

The analysis of alternatives is based on the following primary balancing criteria:

- Long-term effectiveness and permanence
- Reductions in toxicity, mobility, and volume through treatment

- Short-term effectiveness
- Implementability
- Cost

Modifying criteria evaluated following comment on the proposed plan and addressed in the ROD are as follows:

- State acceptance
- Community acceptance

5.11 Task 11 –Remedial Investigation/Feasibility Study Report(s)

The previous tasks lead to preparation of the RI/FS reports. As an outcome of the systematic planning process, the results of the source and groundwater investigations and the RCBRA will be presented together in the RI/FS reports.

The RI report presents the collection of data and evaluations to characterize site conditions, determine the nature and extent of contamination, and assess risk to human health and the environment. The field summary reports prepared under Task 8 address these RI elements for individual field investigation activities and are discussed overall within the RI report. The FS report presents the RAOs; development, screening, and detailed evaluation of remedial alternatives; and selection of the preferred remedy. The results of treatability studies also are presented, if available.

5.12 Task 12 – Post-Remedial Investigation/Feasibility Study Support

Upon agency acceptance of the 100 Area RI/FS reports, a proposed plan and ROD will be prepared that address all media for each area. These documents will incorporate all existing completed remedial actions under interim action RODs, validate their completion, and identify any remaining actions to support completion, including presumptive remedies, plug-in approaches, and contingent remedies, as appropriate. No further action will be required for sites that already have been through the CVP process.

5.12.1 Proposed Plan

The proposed plan is the mechanism by which the lead agency presents the preferred alternative to the public. The plan should briefly describe the remedial alternatives analyzed, propose a preferred alternative, and summarize the information used to select the preferred alternative. The purpose of the proposed plan is to summarize the RI/FS information and provide the public with a reasonable opportunity to comment on the preferred alternative (as well as alternative plans under consideration) and to participate in the selection of remedial alternatives for the OUs. Following public review and comment on the proposed plan, a responsiveness summary will be prepared that summarizes significant comments, criticisms, and new relevant information received during the comment process. The responsiveness summary will be incorporated into the final action ROD.

5.12.2 Record of Decision

Following receipt of public comments and any final comments from supporting agencies, a remedy is selected and documented in a final ROD. The ROD documents the remedial action plan for a site or OU and serves four basic functions (EPA/540/R-98/031, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents*). The ROD serves as:

- A legal document in that it certifies that the remedy selection process was carried out in accordance with CERCLA and, to the extent practicable, in accordance with the NCP.
- A substantive summary of the technical rationale and background information contained in the Administrative Record file (e.g., RI/FS including the baseline risk assessment).
- A technical document that provides information necessary for determining the conceptual engineering components, and that outlines the remedial action objectives and cleanup levels for the selected remedy.
- A key communication tool for the public that explains the contamination problems the remedy seeks to address and the rationale for its selection.

5.12.3 Post-Record of Decision Activities

The selected remedial alternative is implemented when the final action ROD is approved. This stage may involve remedial design and design verification studies, construction, remediation process optimization, and operation and maintenance of the implemented processes. Performance is evaluated during 5-year reviews. Actions identified in the first two 5-year reviews associated with the groundwater interim action RODs have been completed or are in progress. The next 5-year review will occur in 2011.

If new information is generated that could affect the implementation of the selected remedy, the information can be addressed through one of the following means:

- A memorandum to the post-ROD file for an insignificant or minor change.
- An ESD for a significant change.
- A ROD amendment for a fundamental change.

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6 Project Management Considerations

This chapter discusses project organization, project coordination, change control, and the dispute resolution processes. Change control processes increase in definition as needed, to document and achieve approval for changes that arise during the RI/FS. Problems are resolved at the lowest possible level, with higher levels of project oversight engaged to resolve the issues.

6.1 Project Organization

RL is responsible for the Hanford Site cleanup of the River Corridor. The RL contractors implement cleanup for RL and are responsible for planning, coordinating, and executing the RI/FS activities. The lead regulatory agency authorizes the work scope in accordance with the Tri-Party Agreement (Ecology et al., 1989a) and oversees the work for regulatory compliance. Figure 6-1 illustrates the project organization structure for cleanup of the 100 Area.

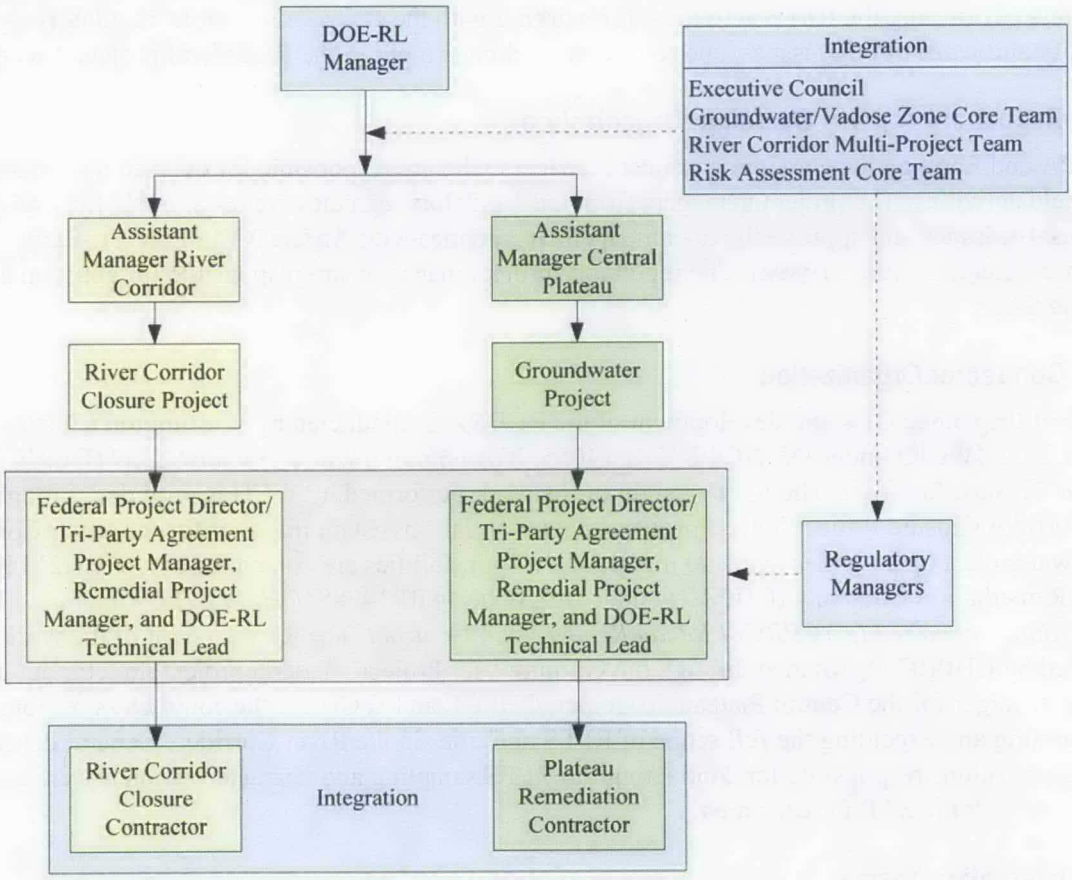

Figure 6-1. Project Organization

6.1.1 U.S. Department of Energy, Richland Operations Office Project Organization

Cleanup actions for source and groundwater OUs in the River Corridor are programmatically separated between RL projects and associated Hanford Site contractors. RL has established an interface control agreement (08-AMRC-0116, "Contract No. DE-AC06-05RL14655 – Interface Agreement for Coordinating Groundwater and Vadose Zone Cleanup Programs") between programs to ensure

integration and coordination between source and groundwater actions and to identify responsibilities for its associated contractors. As cleanup progresses and the Tri-Parties work toward establishing final action RODs for the River Corridor, effective integration between RL programs and responsible contractors will continue to be a focus and an expectation of the Tri-Parties and Hanford Site stakeholders.

The RL River Corridor Closure Project is responsible for cleanup of source OUs in the River Corridor. The federal project director for the River Corridor Closure Project reports to the assistant manager for River Corridor. RL's responsibility for groundwater cleanup lies with the Groundwater Project. The Groundwater Project federal project director reports to the assistant manager for the Central Plateau. The assistant manager for the River Corridor and the assistant manager for the Central Plateau report to the RL office manager.

The RL federal project directors are responsible for authorizing the respective contractors to perform the RI/FS activities for the 100 Area. The federal project director also is responsible for obtaining lead regulator approval of the work plan and SAP, which authorize the RI/FS activities under the Tri-Party Agreement (Ecology et al., 1989a). The RL technical leads are responsible for day-to-day oversight of contractors performing the RI/FS activities, for working with the contractors and the regulatory agencies to identify and work through issues, and to provide technical input to the RL federal project directors.

6.1.2 Regulatory Agency Oversight Organization

Both EPA and Ecology have assigned project managers who are responsible for overseeing various RI/FS field activities. The project managers from the regulatory agencies are responsible for working with RL to resolve issues and approve the documents in accordance with Article XVI of the Tri-Party Agreement (Ecology et al., 1989a). The regulatory project managers are responsible for approving work plans and SAPs.

6.1.3 Contractor Organization

Cleanup of the source OUs and development of the RCBRA is conducted by Washington Closure Hanford, LLC (WCH) under DE-AC06-05RL14655, *Washington Closure Hanford, LLC (WCH), River Corridor Closure Contract*. The RL oversight of the work performed by WCH is provided through the River Corridor Closure Project federal project director and the assistant manager for the River Corridor. Groundwater cleanup activities and lead integration responsibilities are conducted by the CH2M HILL Plateau Remediation Company (CHPRC) under DE-AC06-08RL14788, *CH2M HILL Plateau Remediation Company LLC(CPRC) Plateau Remediation Contract*. The RL oversight of the work performed by CHPRC is provided through the Groundwater Project's federal project director and the assistant manager for the Central Plateau. Together, CHPRC and WCH are the contractors responsible for integrating and executing the full scope of RI/FS activities in the River Corridor. General descriptions of the key positions responsible for conducting the RI/FS sampling and characterization activities are provided in each the SAP for each area.

6.1.4 Integration Teams

RL has established multiple teams to facilitate integration of work between RL programs, contractors, and the regulatory agencies. The teams report to the Groundwater/Vadose Zone Executive Council, which oversees the integration of groundwater and vadose zone work scope and provides policy direction. The Executive Council prepares, updates, and assesses the progress of priorities to guide integration activities. The Executive Council is chaired by the Assistant Manager for Central Plateau and members include the Assistant Manager for the River Corridor, and the Assistant Manager for Tank Farms. The RL Groundwater Remediation Project Federal Project Director is an ex-officio member of the Council.

Federal Project Directors for affected projects participate in meetings as needed to support specific agenda topics. The teams that are relevant to the scope of RI/FS activities in the River Corridor are as follows:

- **Groundwater/Vadose Zone Multi-Project Team:** The purpose of the Groundwater/ Vadose Zone Multi-Project Team is to ensure successful implementation of the "Interface Agreement for Coordination of Groundwater and Vadose Zone Cleanup Programs," (08-AMRC-0116). This Multi-Project Team oversees all aspects of groundwater and vadose zone work at the Hanford Site, including integration of fieldwork, decision processes, treatability testing, and remedy implementation. This includes Central Plateau and River Corridor work scope, as well as vadose zone investigations.
- **River Corridor Multi-Project Team:** The River Corridor Multi-Project Team develops and maintains an integrated approach to assessment and decision making for River Corridor Project remediation decisions. The River Corridor Multi-Project Team ensures that all River Corridor source, vadose zone, and groundwater OU cleanup decisions are coordinated between the River Corridor Project and the other Hanford Site CERCLA projects.
- **Risk Integration Core Team:** The Risk Integration Core Team provides a forum for coordinating Hanford Site risk assessments to ensure their applicability to remediation, corrective action, closure, and disposal decisions. This team identifies risk assessment activities that are underway and planned for Hanford Site projects and determines whether those activities require DOE management decisions to improve their coordination, consistency, and effectiveness. The team identifies issues affecting multiple projects that may require resolution by the Groundwater/Vadose Zone Executive Council.

Each of these teams meets on a regular basis to discuss integration items, opportunities, and emerging issues. Team representatives are made up of RL and contractor representatives. In addition, individuals representing the regulatory agencies typically are invited to participate in the team meetings.

6.2 Project Coordination, Decision Making, and Documentation

Coordination among EPA or Ecology, the lead agency (DOE), and the contractors performing the work is essential for successful execution of the RI/FS. The RI/FS work plan will be developed using the systematic planning process (completed for each area, with the approval of each addendum to this work plan). Coordination with other agencies, the Tribal Nations, and local public and private organizations will be handled as described in the Community Relations Plan.

Documented consensus from the regulatory agency project managers is important for dynamic field activities. Before mobilization, the lines of communication and authority will be clearly outlined and the project managers and field team lead will determine how often or when to make and document decisions. These periodic decisions help avoid the need for remobilization after work has been completed at a particular location.

Field decisions will be documented stating consensus decisions. A decision log will be kept to track each decision, and the decision log will refer to attachments as applicable. Larger scale changes may require formal decision memorandums. In either case, the project manager for the Groundwater Project and the regulatory agency project managers will be involved in the decision and documentation.

6.3 Change Control and Dispute Resolution

The SAPs represent the Tri-Parties' assessment of the data needs at the end of the systematic planning process. As new information becomes available, changes to work scope may be required. These changes will be made to the sampling plans for the specific areas and may not require a corresponding change to the work plan.

Changes that affect the Tri-Party Agreement (Ecology et al., 1989a) are documented using change control forms. The class or level of the change (i.e., signatory, executive management, or project management) is noted and the description/justification and impact of the change is documented.

Dispute resolution is handled in accordance with the Tri-Party Agreement (Ecology et al., 1989a), Article XVI. The Tri-Parties are to make reasonable attempts to resolve all disputes informally at the project manager level. Disputes that cannot be resolved informally are submitted in writing to, and resolved by, the Interagency Management Integration Team at the executive manager level. If resolution is not achieved at this level, the dispute is forwarded to higher levels of management. As a last resort, the formal dispute resolution processes outlined in the Tri-Party Agreement (Ecology et al., 1989a), Article VIII or XXVI, is used.

To promote dispute avoidance, potential problems will be identified during field preparation planning, and associated contingency/variance plans will be developed.

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Appendix A

Summary of Existing CERCLA Documentation

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A1 Introduction

The tables in this appendix, grouped by area, provide information on an operable unit (OU)-by-OU basis for the investigative phase, including work plan development and remedial investigation/feasibility study process, the decision process including records of decision and action memoranda, and the post-record of decision requirements (e.g., remedial design/remedial action documentation). Tables A-1 through A-7 also provide references for 100 Area common investigations and reports that address conditions across multiple OUs. Table A-6 contains four isolated unit OUs that require no further action, and Table A-7 contains 100 Area common investigations and annual remedy performance reviews relevant to some areas.

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Table A-1. Summary of Existing CERCLA Primary Documents and Decisions for the 100-D/H Area

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-DR-1 Source OU High-priority/primary liquid site Contains soil, buildings, and burial grounds Lead agency: Ecology	DOE/RL-89-09, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-DR-1 Operable Unit, Hanford Site, Richland, Washington.* WHC-SD-EN-TI-181, *100-D Area Technical Baseline Report.*	DOE/RL-92-11, *100 Area Feasibility Study, Phases 1 and 2.* DOE/RL-93-29, *Limited Field Investigation Report for the 100-DR-1 Operable Unit.*DOE/RL-94-64, *100-DR-1 Operable Unit Focused Feasibility Study Report.*DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-95/126, *Declaration of the Record of Decision, 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.* *EPA, Ecology, and DOE, 1997, Amendment to the Record of Decision for the USDOE Hanford 100-BC-1, 100-DR-1, and 100-HR-1 Operable Unit Interim Remedial Actions.* DOE/RL-98-37, *Removal Action Report for the 105-DR and 105-F Building Interim Safe Storage Projects and Ancillary Buildings.* EPA, Ecology, and DOE, 1998, "Action Memorandum 105-F and 105-DR Reactor Buildings and Ancillary Facilities, Hanford Site, Benton County, Washington. EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA, Ecology, and DOE, 2000, "Action Memorandum 105-D and 105-H Reactor Facilities and Ancillary Facilities, Hanford Site, Benton County, Washington." EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area,* Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan,* Rev. 4, September 2004.
100-DR-2 Source OU Contains soil, buildings, and burial grounds Lead agency: Ecology In April 1994, 100-DR-3 was consolidated into the 100-DR-2 OU	WHC-SD-EN-TI-181, *100-D Area Technical Baseline Report.* DOE/RL-93-46, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-DR-2 Operable Unit, Hanford Site, Richland, Washington.*	DOE/RL-92-11, *100 Area Feasibility Study, Phases 1 and 2.* .DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.* DOE/RL-93-99, *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility.*	DOE/RL-98-37, *Removal Action Report for the 105-DR and 105-F Building Interim Safe Storage Projects and Ancillary Buildings.* EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.

Table A-1. Summary of Existing CERCLA Primary Documents and Decisions for the 100-D/H Area

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-HR-1 Source OU High-priority/primary liquid site Contains soil, buildings, and burial grounds Lead agency: Ecology	DOE/RL-88-35, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-1 Operable Unit Hanford Site, Richland, Washington.* DOE/RL-88-36, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-3 Operable Unit, Hanford Site, Richland, Washington.* BHI-00127, *100-H Area Technical Baseline Report.* DOE/RL-94-101, *Proposed Plan for Interim Remedial Measures at the 100-HR-1 Operable Unit.*	DOE/RL-92-11, *100 Area Feasibility Study, Phases 1 and 2.* DOE/RL-93-51, *Limited Field Investigation Report for the 100-HR-1 Operable Unit.* DOE/RL-94-63, *100-HR-1 Operable Unit Focused Feasibility Study Report.* DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-95/126, *Declaration of the Record of Decision, 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.* EPA, Ecology, and DOE, 1995, "Action Memorandum.183-H Solar Evaporation Basin Waste Expedited Response Action Cleanup Plan, 1996, U.S. Department of Energy, Hanford Site, Richland, Washington." EPA, Ecology, and DOE,1997, *Amendment to the Record of Decision for the USDOE Hanford 100-BC-1, 100-DR-1, and 100-HR-1 Operable Unit Interim Remedial Actions.* EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA, Ecology, and DOE, 2000, "Facilities and Ancillary Facilities, Hanford Site, Benton County, Washington." EPA, Ecology, and DOE, 2003, "Action Memorandum, 200 West Area, Central Waste Complex, 183-H Solar Evaporation Basin Waste, Hanford Site, Benton County, Washington, 2003." EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-HR-2 Source OU Contains soil, buildings, and burial grounds Lead agency: Ecology	BHI-00127, *100-H Area Technical Baseline Report.*	DOE/RL-92-11, *100 Area Feasibility Study, Phases 1 and 2.* DOE/RL-94-65, *100-HR-2 Operable Unit Focused Feasibility Study.* DOE/RL-94-53, *Limited Field Investigation Report for the 100-HR-2 Operable Unit.*DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area,* Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan,* Rev. 4, September 2004.
100-HR-3 Groundwater OU Contains groundwater under and between the 100-DR and 100-H Reactor areas Lead agency: Ecology	DOE/RL-88-35, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-3 Operable Unit, Hanford Site, Richland, Washington.* DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action.*	DOE/RL-92-11, *100 Area Feasibility Study, Phases 1 and 2.* DOE/RL-93-43, *Limited Field Investigation Report for the 100-HR-3 Operable Unit.* DOE/RL-94-67, *100-HR-3 Operable Unit Focused Feasibility Study.* DOE/RL-95-83, *The Pilot-Scale Treatability Test Summary for the 100-HR-3 Operable Unit.*	EPA/ROD/R10-96/134, *Declaration of the Record of Decision, 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington.* EPA/AMD/R10-00/122, *Interim Remedial Action Record of Decision Amendment, 100-HR-3 Operable Unit, Hanford Site, Benton County, Washington.* EPA, Ecology, and DOE, 2003, *Explanation of Significant Difference for the HR-3-Operable Unit Record of Decision.*	DOE/RL-96-90, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*, Rev. 0, April 1997, (updated by DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action,* Rev. 0-A, April 2003). DOE/RL-99-51, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 Groundwater Operable Unit In Situ Redox Manipulation,* Rev. 1, June 2000. DOE/RL-2006-75, *Supplement to 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump-and-Treat System,* Rev. 1, September 2008.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Ecology = Washington State Department of Ecology
OU = operable unit
ROD = record of decision

Table A-2. Summary of Existing CERCLA Primary Documents and Decisions for the 100-K Area

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-KR-1 Source OU Contains soil sites contaminated by liquid discharges Lead agency: EPA	DOE/RL-90-20, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-1 Operable Unit Hanford Site, Richland, Washington.*	DOE/RL-93-78, *Limited Field Investigation Report for 100-KR-1 Operable Unit*, Rev. 0. DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.* EPA and DOE, 2005, "Action Memorandum for the Non-Time-Critical Removal Action for the 100-K Ancillary Facilities.	DOE/RL-98-71, *Proposed Plan for the K Basins Interim Remedial Action*, Rev. 0, April 1999. DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area,* Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004. DOE/RL-2005-26, *Removal Action Work Plan for 105-KE/105-KW Reactor Facilities and Ancillary Facilities,* Rev. 1, February 2007; includes 27 ancillary facilities.
100-KR-2 Source OU Contains soil, buildings, and burial grounds Lead agency: EPA In October 1994, 100-KR-3 was consolidated into the 100-KR-2 OU		DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.* DOE/RL-98-66, *Focused Feasibility Study for the K Basins Interim Remedial Action.* DOE/RL-99-89, *Remedial Design Report and Remedial Action Work Plan for the K Basins Interim Remedial Action.*	EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-99/059, *Declaration of the Record of Decision, 100-KR-2 Operable Unit, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.* DOE/RL-2004-48, *Proposed Plan for an Amendment to the K Basins Interim Remedial Action Record of Decision, Hanford Site, Richland, Washington*, Rev. 1. EPA, 2005, *Interim Remedial Action Record of Decision Amendment 100 K Area K Basins, Hanford Site – 100 Area, Benton County, Washington,* June. EPA and DOE, 2005, "Action Memorandum for the Non-Time-Critical Removal Action for the 100-K Ancillary Facilities."	DOE/RL-98-71, *Proposed Plan for the K Basins Interim Remedial Action*, Rev. 0, April 1999. DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area,* Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004. DOE/RL-2005-26, *Removal Action Work Plan for 105-KE/105-KW Reactor Facilities and Ancillary Facilities,* Rev. 1, February 2007; includes 27 ancillary facilities.

Table A-1. Summary of Existing CERCLA Primary Documents and Decisions for the 100-D/H Area

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-KR-4 Groundwater OU Contains groundwater under the 100-K Area Lead agency: EPA	DOE/RL-90-21, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit Hanford Site, Richland, Washington.*	DOE/RL-93-79, *Limited Field Investigation Report for the 100-KR-4 Operable Unit.* DOE/RL-94-48, *100-KR-4 Operable Unit Focused Feasibility Study.* DOE/RL-98-66, *Focused Feasibility Study for the K Basins Interim Remedial Action.* DOE/RL-2005-05, *Treatability Test Plan for Fixation of Chromium in the Groundwater at 100-K.*	EPA/ROD/R10-96/134, *Declaration of the Record of Decision 100-HR-3 and 100-KR-4 Operable Units, Hanford Site, Benton County, Washington.*	DOE/RL-94-113, *Proposed Plan for Interim Remedial Measure at the 100-KR-4 Operable Unit*, Rev. 1, September 1995. DOE/RL-96-84, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action*, Rev. 0-A, April 2003. DOE/RL-96-90, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*, Rev. 0, April 1997 (updated as DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*, Rev. 0-A, April 2003). DOE/RL-2006-52, *The KW Pump and Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action*, Rev. 1, December 2006. DOE/RL-2006-75, *Supplement to 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump-and-Treat System*, Rev. 0, December 2007.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Ecology = Washington State Department of Ecology
OU = operable unit
ROD = record of decision

Table A-3. Summary of Existing CERCLA Primary Documents and Decisions for the 100-B/C Area

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-BC-1 Source OU High-priority/primary liquid site Contains soil, building structures and burial grounds Lead agency: EPA	DOE/RL-90-07, *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-1 Operable Unit Hanford Site, Richland, Washington.*	DOE/RL-92-11, *100 Area Feasibility Study Phases 1 and 2.* DOE/RL-93-06, *Limited Field Investigation Report for the 100-BC-1 Operable Unit.* DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA, 1995, "Action Memorandum: Expedited Response Action Proposal; 100-BC-1 Demonstration Project; U.S. Department of Energy Hanford Site; Richland, Washington." EPA/ROD/R10-95/126, *Declaration of the Record of Decision, 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.* EPA, 1997, "Approved Action Memorandum for the 100-B/C Area Ancillary Facilities and the 108-F Building Removal Action, U.S. Department of Energy Hanford Site, Richland, WA." EPA/AMD/R10-97/044, *Amendment to the Record of Decision, 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA and DOE, 2001, "Action Memorandum 105-B Reactor Facility, Hanford Site, Benton County, Washington. EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-BC-2 Source OU Contains soil, building structures, and burial grounds Lead agency: EPA In February 1994, 100-BC-3 and 100-BC-4 were consolidated into 100-BC-2	DOE/RL-91-07, *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-2 Operable Unit Hanford Site, Richland, Washington.*	DOE/RL-92-11, *100 Area Feasibility Study Phases 1 and 2.* DOE/RL-94-42, *Limited Field Investigation Report for the 100-BC-2 Operable Unit.* DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA, Ecology, and DOE, 2001, "Action Memorandum for 105-D and 105-H Reactor Buildings and Ancillary Facilities, Hanford Site, Benton County, Washington." EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision,* February.	DOE/RL-97-37, *Sampling and Analysis Plan for Release of the 105-C Below-Grade Structures and Underlying Soils*, Rev. 0, February 1998. DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-BC-5 Groundwater OU Contains groundwater under the 100-B/C Area Lead agency: EPA There is no cleanup ROD or action remedy for the 100-BC-5 OU, only the monitoring of existing conditions	DOE/RL-90-08, *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-5 Operable Unit Hanford Site, Richland, Washington.*	DOE/RL-92-11, *100 Area Feasibility Study Phases 1 and 2.* DOE/RL-93-37, *Limited Field Investigation Report for the 100-BC-5 Operable Unit.* DOE/RL-94-112, *Proposed Plan for Interim Decision at the 100-BC-5 Operable Unit, Hanford Site, Richland, Washington.*		PNNL-13326, *Groundwater Sampling and Analysis Plan for the 100-BC-5 Operable Unit*, September 2000.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Ecology = Washington State Department of Ecology
OU = operable unit
ROD = record of decision

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Table A-4. Summary of Existing CERCLA Primary Documents and Decisions for 100-F and Isolated Units 100-IU-2 and 100-IU-6

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-FR-1 Source OU High-priority/primary liquid site Lead agency: EPA	DOE/RL-90-33, *Remedial Investigation/Feasibility Study Work Plan for the 100-FR-1 Operable Unit Hanford Site, Richland, Washington.*	DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.* DOE/RL-93-82, *Limited Field Investigation Report for the 100-FR-1 Operable Unit.*	DOE/RL-98-37, *Removal Action Report for the 105-DR and 105-F Building Interim Safe Storage Projects and Ancillary Buildings.* EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, *Declaration of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-FR-2 Source OU Contains soil, buildings, and burial grounds Lead agency: EPA		DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	DOE/RL-98-37, *Removal Action Report for the 105-DR and 105-F Building Interim Safe Storage Projects and Ancillary Buildings.* EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ROD/R10-00/121, Declaration *of the Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 5, September 2004. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-FR-3 Groundwater OU Lead agency: EPA		DOE/RL-93-83, *Limited Field Investigation Report for the 100-FR-3 Operable Unit.*		PNNL-13327, *Groundwater Sampling and Analysis Plan for the 100-FR-3 Operable Unit*, September 2000.
100-IU-2 Source OU White Bluffs Townsite area Lead agency: EPA		DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-IU-6 Source OU Hanford Townsite area Lead agency: EPA		DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-99/039, *Interim Action Record of Decision, 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 10-KR-1, 100-KR-2, I00-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington.* EPA/ESD/R10-00/045, *Explanation of Significant Difference for the 100 Area Remaining Sites ROD, USDOE Hanford 100 Area, 100-IU-6 Operable Area.* EPA, Ecology, and DOE, 2004, *Explanation of Significant Differences for the 100 Area Remaining Sites Interim Remedial Action Record of Decision.*	DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.

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Ecology = Washington State Department of Ecology
OU = operable unit
ROD = record of decision

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Table A-5. Summary of Existing CERCLA Primary Documents and Decisions for the 100-N Area

Operable Unit	Work Plan	Remedial Investigation/ Feasibility Study	Decisions	Post-ROD
100-NR-1 Source Operable Unit Contains soil, buildings, and burial grounds (includes consolidated 100-NR-3 sites) Lead agency: Ecology	DOE/RL-90-23, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-3 Operable Unit, Hanford Site, Richland, Washington.* DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington.*	DOE/RL-92-11, *100 Area Feasibility Study Phases 1 and 2.* DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.* DOE/RL-93-80, *Limited Field Investigation for 100-NR-1 Abatement Assessment.*	EPA, Ecology, and DOE, 1996b, "Action Memorandum N Area Waste Expedited Response Action Cleanup Plan, U.S. Department of Energy, Hanford Site, Richland, WA." EPA, Ecology, and DOE, 1999, "Action Memorandum 100-N Area Ancillary Facilities, Hanford Site, Benton County, Washington." EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision, U.S. Department of Energy / Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units.* EPA/ROD/R10-00/120, *Interim Remedial Action Record of Decision, U.S. Department of Energy 100 Area, 100-NR-1 Operable Unit.* EPA, Ecology, and DOE, 2003,, *Explanation of Significant Difference for the 100-NR-1 Operable Unit Treatment, Storage, and Disposal Interim Action Record of Decision and 100-NR-1/100-NR-2 Operable Unit Interim Action Record of Decision.* Ecology, 2005, "Action Memorandum 105-N Reactor Facility and 100-N Heat Exchanger Building, Hanford Site, Benton County, Washington.	DOE, "Notice of Change to the Waste Volume Estimates in the N Area Waste Expedited Response Action Memorandum," March 1997. DOE, "Inclusion of 105-N Roof Waste in the Future Action Memorandum for the 100-N Area Ancillary Facilities," September 1998. DOE, "Final Waste Volumes for N Area Project and Clarification to the N Area Waste Expedited Response Action Memorandum," December 1998. Ecology, "Replacement Page 30 of Table 3 of Interim Remedial Action Record of Decision for 100-NR-1 and 100-NR-2 OU of Hanford 100-N Area," October 1999. Ecology, "Replacement of Appendix B in Interim Remedial Action Record of Decision for 100-NR-1 and 100-NR-2 OU," November 1999. DOE/RL-2000-16, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-1 Treatment, Storage, and Disposal Units*, Rev. 2, March 2001. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-NR-2 Groundwater Operable Unit Groundwater under the 100-N and Shoreline site N Springs Lead agency: Ecology	DOE/RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington.* DOE/RL-91-46, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-2 Operable Unit, Hanford Site, Richland, Washington.*	DOE/RL-92-11, *100 Area Feasibility Study Phases 1 and 2.* DOE/RL-93-81, *Limited Field Investigation Report for the 100-NR-2 Operable Unit, Hanford Site Richland, Washington.*	DOE/RL-93-231994, *N Springs Expedited Response Action Proposal*, Rev. 0. Ecology, 1997a,"Action Memorandum: N Springs Expedited Response Action Cleanup Plan." DOE,1995, "Request to Change N Springs Action Memorandum." DOE, 1997, "Clarification to Language in Action Memorandum: N Springs Expedited Response Action Cleanup Plan and Modification of Performance Monitoring for N Springs Pump and Treat." EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision, U.S. Department of Energy / Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units.* Ecology, 1999b, "Replacement Page 30 of Table 3 of Interim Remedial Action Record of Decision for 100-NR-1 and 100-NR-2 OU of Hanford 100-N Area1999." EPA/ROD/R10-00/120, *Interim Remedial Action Record of Decision, U.S. Department of Energy 100 Area, 100-NR-1 Operable Unit.* EPA, Ecology, and DOE, 2003, *Explanation of Significant Difference for the 100-NR-1 Operable Unit Treatment, Storage, and Disposal Interim Action Record of Decision and 100-NR-1/100-NR-2 Operable Unit Interim Action Record of Decision.*	DOE/RL-2001-27, *Remedial Design Report/Remedial Action Work Plan for the 100-NR-2 Operable Unit*, Draft A, November 2001.

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Ecology = Washington State Department of Ecology
OU = operable unit
ROD = record of decision

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Table A-6. Summary of Existing CERCLA Primary Documents and Decisions for Remaining 100-IU Areas

Operable Unit	Work Plan	Remedial Investigation/Feasibility Study	Decisions	Post-ROD
100-IU-1 Source OU Riverland railroad wash station Lead agency: EPA	DOE/RL-95-60, *Proposed Plan for the 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units.*	DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA, 1993, "Action Memorandum: Expedited Response Action Proposal; Riverland Site, U.S. Department of Energy Hanford Site, Richland, Washington." PA/ROD/R10-96/151, *Declaration of the Record of Decision, USDOE Hanford 100 Area, 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units.*	DOE/RL-94-30, *Riverland Expedited Response Action Assessment*, Rev. 0, June 1995. EPA, "Notice of partial deletion of the Hanford 100-Area (USDOE) Superfund site from the National Priorities List," July 1998. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-IU-3 OU North slope or Wahluke Slope" Lead agency: Ecology	DOE/RL-93-47, *North Slope (Wahluke Slope) Expedited Response Action Cleanup Plan.* DOE/RL-95-60, *Proposed Plan for the 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units.*	DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	Ecology and DOE, 1997, "Action Memorandum 100-IU-3 Operable Unit (Wahluke Slope), Hanford Site, Adams, Grant, and Franklin Counties, Washington." EPA/ROD/R10-96/151, *Declaration of the Record of Decision, 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units, Hanford Site, Benton County, Washington.*	EPA, "Notice of partial deletion of the Hanford 100-Area (USDOE) Superfund site from the National Priorities List," July 1998. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-IU-4 OU Buried sodium dichromate drums Lead agency: Ecology	DOE/RL-95-60, *Proposed Plan for the 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units.*	DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	Ecology, 1993, "Action Memorandum Approval: Sodium Dichromate Barrel Landfill, U.S. Department of Energy Hanford Site, Richland, WA." EPA/ROD/R10-96/151, *Declaration of the Record of Decision, 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units, Hanford Site, Benton County, Washington.*	DOE/RL-93-25, *Sodium Dichromate Barrel Landfill Expedited Response Action Proposal*, September 1993. DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.
100-IU-5 OU Pickling acid cribs Lead agency: EPA	DOE/RL-95-60, *Proposed Plan for the 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units.*	DOE/RL-94-61, *100 Area Source Operable Unit Focused Feasibility Study.*	EPA/ROD/R10-96/151, *Declaration of the Record of Decision, 100-IU-1, 100-IU-3, 100-IU-4, and 100-IU-5 Operable Units, Hanford Site, Benton County, Washington.*	DOE/RL-96-22, *100 Area Remedial Action Sampling and Analysis Plan*, Rev. 4, September 2004.

Note: These operable units have undergone final CERCLA actions.

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

Ecology = Washington State Department of Ecology

EPA = U.S. Environmental Protection Agency

OU = operable unit

ROD = record of decision

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Table A-7. Summary of 100-Area Common Investigations and Reports Mandated by CERCLA

100 Area Risk Assessment Documentation	100 Area Groundwater Reports	100 Area Annual CERCLA Remedy Performance
These documents describe the plan, scope, and results of risk assessment activities to support cleanup decision making for the 100 Area.	These reports provide details of the nature and extent of groundwater contamination for all groundwater operable units in the 100 Area.	These reports provide a summary of the performance of the interim actions selected for the 100 Area. They discuss not just monitoring, but also the characteristics of the plume, analyze requirements of the remedial design/remedial action work plan, remedy performance information. Only for locations with decisions on chromium cleanup groundwater remedies for sites 100-HR-3, 100-KR-4, and 100-NR-2.
DOE/RL-2004-37, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment (RCBRA)*, Rev. 2, May 2005. DOE/RL-2005-42, *100 Area and 300 Area Component of RCBRA Sampling and Analysis Plan*, Rev. 1, November 2006. DOE/RL-2007-21, *Risk Assessment Report for the100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment*, Draft A, June 2007.	Groundwater monitoring plans for each area (already listed in Table 2-2 through Table 2-7). PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*, March 2007. DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*, Rev. 0, March 2008.	DOE/RL-2006-08, *Calendar Year 2005 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations*, Rev. 0, May. *DOE/RL-2006-76*, Calendar Year 2006 Annual Summary Report for 100-HR-3, 100-KR-4 and 100-NR-2 Operable Units Pump-and-Treat Operations, Decisional Draft, May 2007.

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

OU = operable unit

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Appendix B

Identification of Potential Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

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B1 Introduction

This appendix also provides U.S. Environmental Protection Agency (EPA) Region 6 screening levels. EPA Region 10 risk evaluation unit calls for the use of these Region 6 screening levels because they are updated regularly.

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36 CFR 800, "Protection of Historic Properties," *Code of Federal Regulations*. Available at: http://frwebgate6.access.gpo.gov/cgi-bin/PDFgate.cgi?WAISdocID=096828340001+2+2+0&WAISaction=retrieve.

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173-303-070, "Designation of Dangerous Waste."
173-303-073, "Conditional Exclusion of Special Wastes."
173-303-077, "Requirements for Universal Waste."
173-303-120, "Recycled, Reclaimed, and Recovered Wastes."
173-303-140, "Land Disposal Restrictions."
173-303-170, "Requirements for Generators of Dangerous Waste."
173-303-200, "Accumulating Dangerous Waste On-Site."
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Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
CHEMICAL-SPECIFIC ARARs				
***Safe Drinking Water Act of 1974*; 40 CFR 141, "National Primary Drinking Water Regulations"**				
40 CFR 141.61, "Maximum contaminant levels for organic contaminants" 40 CFR 141.50, "Maximum contaminant level goals for organic contaminants"	Establishes MCLs and MCL goals as criteria for groundwater and surface water that are or may be used for drinking water. The standards/goals are designed to protect human health from adverse effects of organic contaminants in the drinking water.	Groundwater in the 100 Area contains contaminants that require remediation; it is not currently used for drinking water but is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
40 CFR 141.62, "Maximum contaminant levels for inorganic contaminants" 40 CFR 141.51, "Maximum contaminant level goals for inorganic contaminants"	Establishes MCLs and MCL goals as criteria for groundwater and surface water that are or may be used for drinking water. The standards/goals are designed to protect human health from adverse effects of inorganic contaminants in the drinking water.	Groundwater in the 100 Area contains contaminants that require remediation; it is not currently used for drinking water but is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
40 CFR 141.66, "Maximum contaminant levels for radionuclides" 40 CFR 141.55, "Maximum contaminant level goals for radionuclides"	Establishes MCLs and MCL goals as criteria for groundwater and surface water that are or may be used for drinking water. The standards/goals are designed to protect human health from adverse effects of inorganic contaminants in the drinking water.	Groundwater in the 100 Area contains contaminants that require remediation; it is not currently used for drinking water but is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
***Clean Water Act of 1977;* 40 CFR 131, "Water Quality Standards"**				
40 CFR 131.10, "Designation of uses"	Establishes numeric water quality criteria for the protection of human health and aquatic organisms. Toxic criteria for the protection of aquatic life is provided in the water quality criteria regulations 40 CFR 131.36(b)(1), "EPA's Section 304(a), Criteria for Priority Toxic Pollutants," which supersede criteria adopted by the state, except where the state criteria are more stringent than the federal criteria.	Groundwater in the 100 Area contains contaminants that require remediation; groundwater also discharges into the Columbia River.	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
***Toxic Substances Control Act (TSCA);* 40 CFR 761, "Polychlorinated Biphenyls Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions"**				
40 CFR 761.50(b)1, 2, 3, 4 and 7, "Applicability," "PCB Waste" 40 CFR 761.50(c), "Applicability," "Storage for Disposal"	Establishes general PCB disposal requirements for the storage and disposal of PCB wastes including liquid PCB wastes, PCB items, PCB remediation waste, PCB bulk product wastes, and PCB/radioactive wastes at concentrations greater than 50 ppm.	PCB wastes may be encountered and or generated during the RI and subsequent remediation of the 100 Area.	ARAR	Soil excavation and remediation, equipment and debris handling and disposal, and IDW management and disposal.
40 CFR 761.60(a), "Disposal Requirements" "PCB liquids" 40 CFR 761.60(b), "Disposal Requirements" "PCB Articles" 40 CFR 761.60(c), "Disposal Requirements" "PCB Containers"	Establishes requirements applicable to the handling and disposal of PCB liquids, PCB articles, and PCB containers.	PCB liquids, articles, and/or containers may be encountered and or generated during the RI and subsequent remediation of the 100 Area.	ARAR	Equipment and debris handling, storage, and disposal; IDW management and disposal.

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
40 CFR 761.61, "PCB remediation waste"	Provides cleanup and disposal options for PCB remediation waste based on the concentration at which the PCBs are found.	PCB remediation wastes may be encountered and or generated during the RI and subsequent remediation of the 100 Area.	ARAR	Soil remediation, RTD, and IDW management and disposal.
***Clean Air Act of 1977;* 40 CFR 60, "Standards of Performance for New Stationary Sources"**				
40 CFR 60, "Standards of Performance for New Stationary Sources"	Applies to specific stationary sources that emit toxic air pollutants where construction or modification of the facility commences after the effective date of any standard promulgated in this regulation.	Target analytes detected in soil and groundwater within the 100 Area include constituents that would constitute hazardous air pollutants if released to the air.	ARAR	Soil and groundwater remediation activities such as treatment systems that have the potential to emit regulated hazardous air pollutants and are considered a new source.
***Clean Air Act of 1977;* 40 CFR 61, "National Emission Standard for Hazardous Air Pollutants"**				
40 CFR 61.01, "Lists of pollutants and applicability of part 61" 40 CFR 61.05, "Prohibited activities" 40 CFR 61.12, "Compliance with standards and maintenance requirements" 40 CFR 61.14, "Monitoring requirements"	Provides general requirements for facility operations that emit regulated hazardous air pollutants. The regulation applies to any stationary source for which a standard has been prescribed.	Target analytes detected in soil and groundwater within the 100 Area include constituents that would constitute hazardous air pollutants if released to the air.	ARAR	Soil and groundwater remediation activities such as treatment systems that have the potential to emit regulated hazardous air pollutants subject to this part.

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
40 CFR 61.92, "Standard" (National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities)	Requires that emissions of radionuclides to the ambient air from DOE facilities shall not exceed amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr.	Target analytes detected in soil and groundwater in the 100 Area include constituents that would constitute radionuclides regulated as hazardous air pollutants.	ARAR	Soil and groundwater remedial activities (e.g., RTD, soil vapor extraction, decontamination, and demolition) implemented during the RI/FS t.hat have the potential to emit hazardous radionuclides.
***Clean Air Act of 1977;* 40 CFR 61 Subpart M, "National Emission Standard for Asbestos"**				
40 CFR 61.140, "Applicability" 40 CFR 61.145, "Standard for demolition and renovation"	Defines regulated ACM and regulated removal and handling requirements. Specifies sampling, inspection, handling, and disposal requirements for regulated sources having the potential to emit asbestos. Specifically, no visible emissions are allowed during handling, packaging, and transport of ACM.	Encountering ACM on pipelines or buried asbestos within the 100 Area is possible during the RI and/or during remediation activities.	ARAR	Site investigation and remediation activities that include demolition and/or renovation and associated handling, packaging and transportation of ACM, including IDW management and disposal.
40 CFR 61.150, "Standard for waste disposal for manufacturing, fabricating, demolition, renovation, and spraying operations"	Identifies requirements for the removal and disposal of asbestos from demolition and renovation activities.	Encountering ACM on pipelines or buried asbestos within the 100 Area is possible during the RI and/or during remediation activities.	ARAR	Site investigation and remediation activities that include demolition and/or renovation and associated handling, packaging and transportation of ACM including IDW management and disposal.
***Clean Air Act of 1977;* 40 CFR 50, "National Primary and Secondary Ambient Air Quality Standards"**				
40 CFR 50.7, "National primary and secondary ambient air quality standards for ambient air quality standards for $PM_{2.5}$"	Establishes primary and secondary air quality standards for particulate matter, which are 15 $\mu g/m^3$ annually or 65 $\mu g/m^3$ per 24-hour average concentration. This requirement is applicable to airborne releases of radionuclides and criteria pollutants.	Soil and groundwater target analytes detected in the 100 Area include radionuclides that may be generated during characterization or remedial actions. Although national primary and secondary ambient air quality standards for particulate matter is not an ARAR, it should be considered if RIs or treatment operations	TBC	Soil and groundwater remediation (e.g., RTD).

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
		raise emissions above the standard.		
		Radionuclide ARAR Dose Compliance Concentrations for Superfund		
OSWER Directive 9200.4-18, *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination* OSWER Directive 9200.4-31P, *Distribution of OSWER Radiation Risk Assessment Q&A's Final Guidance*	This memorandum presents clarification for establishing protective cleanup levels in media for radioactive contamination at CERCLA sites. The EPA has determined that the dose limits established by the NRC in 62 FR 39058, "Radiological Criteria for License Termination Final Rule" (25 mrem/yr which is equivalent to 5×10^{-4} increase lifetime risk) will not provide a protective basis for establishing PRGs under CERCLA. A dose of 15 mrem/yr effective dose (approximately equivalent to 3×10^{-4} increase in lifetime risk) is preferred as the maximum dose limit for humans. In the final guidance, EPA further clarifies that 15 mrem/yr is not a presumptive cleanup level under CERCLA. Rather, site decision makers should continue to use the CERCLA risk range when ARARs are not used to set cleanup levels. This is for several reasons, as using dose based guidance would result in unnecessary inconsistency regarding how radiological and nonradiological (chemical) contaminants are addressed at CERCLA sites.	Target analytes detected in soil and groundwater in the 100 Area include constituents that would constitute radionuclides regulated as NESHAPs.	TBC	Development of media cleanup levels.

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
LOCATION-SPECIFIC ARARs				
Archaeological and Historic Preservation Act of 1974				
40 CFR 6.301(c), "Applicant Requirements"	Requires that remedial actions do not cause the loss of any archaeological or historic data. This act mandates preservation of the data; it does not require protection of the actual waste site or facility.	Archaeological and historic sites have been identified within the 100 Area.	ARAR	Investigation and remediation activities that occur in areas near archeological or historic sites.
National Historic Preservation Act of 1966				
36 CFR 800, "Protection of Historic Properties" 40 CFR 6.301(b), "Applicant Requirements" Executive Order 11593, *Protection and Enhancement of the Cultural Environment* 36 CFR 65, "National Historic Landmarks Program" 36 CFR 60, "National Register of Historic Places"	Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation, mitigation processes, and consultation with interested parties.	Cultural and historic sites have been identified within the 100 Area.	ARAR	Investigation and remediation activities that occur in areas near cultural or historic sites.

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
***Native American Graves Protection and Repatriation Act of 1990;* 43 CFR 10, "Native American Graves Protection and Repatriation Regulations"**				
43 CFR 10, "Native American Graves Protection and Repatriation Regulations"	Establishes federal agency responsibility for discovery of human remains, associated and unassociated funerary objects, sacred objects, and items of cultural patrimony. Requires Native American consultation in the event of discovery.	Native American archaeological, cultural, and historic sites have been identified within the 100 Area; Native American remains and associated objects may be present.	ARAR	Investigation and remediation activities that occur in areas near Native American archaeological, cultural, and historic sites that contain associated remains and objects.
Endangered Species Act of 1973				
50 CFR 402, "Interagency Cooperation—Endangered Species Act of 1971, as amended" 40 CFR 6.302(c), "Responsible Official Requirements"	Prohibits actions by federal agencies that are likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of habitat critical to them. Mitigation measures must be applied to actions that occur within critical habitats or surrounding buffer zones of listed species, in order to protect the resource.	Federal endangered and/or threatened species including fish, plants, and animals are found within the 100 Area.	ARAR	Remediation actions and investigation activities that occur within critical habitats or designated buffer zones of federal listed species.
Floodplain Management, Executive Order 11988				
Executive Order 11988, *Floodplain Management* 10 CFR 1022, "Compliance with Floodplain and Wetland Environmental Review Requirements"	Take action to avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values of the floodplain.	Some of the waste sites within the 100 Area subject to remediation are located within the Columbia River floodplain.	ARAR	Remedial actions will occur in the floodplain.

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
ACTION-SPECIFIC ARARs				
***Safe Drinking Water Act of 1974;* 40 CFR 144, "Underground Injection Control Program"; and 40 CFR 146, "Underground Injection Control Program Criteria and Standards"**				
40 CFR 144, "Underground Injection Control Program" 40 CFR 146, "Underground Injection Control Program: Criteria and Standards"	Establishes criteria and standards for an underground injection control program.	Groundwater in the 100 Area contains contaminants that require remediation; treated groundwater may be discharged through underground injection wells.	ARAR	Groundwater remedial activities may involve underground injection.
***Clean Air Act of 1977;* 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants"**				
40 CFR 61.05, "Prohibited Activities"	Identifies prohibited activities from stationary sources of air pollutants including operating a stationary source that is in violation of any national emission standard unless specifically exempted; or operating any existing source that is subject to national emission standards, in violation of the standards.	Target analytes detected in soil and groundwater in the 100 Area include constituents that would be subject to NESHAPs requirements.	ARAR	Investigative and remedial actions from stationary sources that have the potential to emit regulated hazardous air pollutants (e.g., vapor extraction systems, decontamination stations, and waste storage structures).
40 CFR 61.12, "Compliance with Standards and Maintenance Requirements"	Requires the owner and operator of each stationary source to maintain and operate the source and associated air pollution control equipment in a manner that minimizes emissions.	Target analytes detected in soil and groundwater in the 100 Area include constituents that would be subject to NESHAPs requirements.	ARAR	Investigative and remedial actions from stationary sources that have the potential to emit regulated air pollutants (e.g., vapor extraction systems, waste decontamination stations, waste storage structures).

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application
40 CFR 61.14, "Monitoring Requirements"	Requires the owner and operator to maintain and operate each monitoring system in a manner consistent with air pollution control practices for minimizing emissions.	Soil, air, and groundwater in the 100 Area contain target analytes that include NESHAPs regulated hazardous air pollutants that will need to be monitored.	ARAR	Investigative and remedial soil, air, groundwater monitoring systems and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that may produce airborne emissions of radioactive particulates to unrestricted areas.
40 CFR 61.92, "Standard" (National Emission Standards for Hazardous Air Pollutants)	Limits exposure of radioactive contamination release to an equivalent of 10 mrem/yr for an offsite receptor.	Soil, air, and groundwater in the 100 Area contain target analytes (radionuclides) that if released into the air, would be subject to radionuclide emission requirements.	ARAR	Remediation activities including decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, each of which may provide airborne emissions of radioactive particulates to unrestricted areas.
40 CFR 61.93, "Emission monitoring and test procedures"	Specifies that radionuclide emission measurements shall be made at all release points that have the potential to discharge radionuclides to the air in quantities that cause an effective dose equivalent in excess of 1percent of the standard. The regulation also requires that all radionuclides which could contribute greater than 10 percent of the potential dose equivalent for a release point be measured.	Soil, air, and groundwater in the 100 Area contain target analytes (radionuclides) that if released into the air, would be subject to NESHAPs radionuclide emission requirements.	ARAR	Remediation activities including decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, each of which may provide airborne emissions of radioactive particulates to unrestricted areas.

Table B-1. Identification of Potential Federal Applicable or Relevant and Appropriate Requirements and to be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Potential Relevancy	Possible Application

NOTE: The references cited in this table are included in the references section of this appendix.

ACM	=	asbestos containing material.	NESHAP	=	National Emissions Standards for Hazardous Air Pollutant.
ARAR	=	applicable or relevant and appropriate requirement.	NRC	=	U.S. Nuclear Regulatory Commission.
CERCLA	=	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980.*	PCB	=	polychlorinated biphenyl.
CFR	=	*Code of Federal Regulations.*	PRG	=	preliminary remediation goal.
DOE	=	U.S. Department of Energy.	RI	=	remedial investigation.
EPA	=	U.S. Environmental Protection Agency.	RI/FS	=	remedial investigation/feasibility study.
IDW	=	investigation derived waste.	RTD	=	removal, treatment, and disposal.
MCL	=	maximum contaminant level.	TBC	=	to be considered.
MNA	=	monitored natural attenuation.			

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
CHEMICAL-SPECIFIC ARARs				
***Model Toxics Control Act;* WAC 173-340, "Model Toxics Control Act – Cleanup"**				
WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards"	Establishes soil cleanup levels where residential land use represents the reasonable maximum exposure under both current and future site use conditions. Cleanup standards require specification of the following: hazardous substance concentrations that protect human health and the environment (clean up levels), the location of the site where clean up levels must be attained ("points of compliance"), and other regulatory requirements that apply to the clean up action because of the type of action or location of the site. These requirements are specified in the applicable state and federal laws and are generally established in conjunction with the selection of a specific cleanup action.	Soil in the 100 Area contains contaminants that require remediation. The human health conceptual exposure model for the 100 Area is considered rural residential land use. This land use assumes the reasonable maximum exposure to soil will be unrestricted by future users and therefore corresponds to Method B soil cleanup levels.	ARAR	Soil cleanup actions where concentration of hazardous substances in the soil exceed Method B cleanup levels at the point of compliance.
WAC 173-340-747, "Deriving Soil Concentrations for Ground Water Protection"	Establishes soil cleanup levels where residential land use represents the reasonable maximum exposure under both current and future site use conditions. Cleanup standards require specification of the following: hazardous substance concentrations that protect human health and the environment (cleanup levels), the location of the site where cleanup levels must be attained ("points of compliance"), and other regulatory requirements that apply to the cleanup action because of the type of action or location of the site. These requirements are specified in the applicable state and federal laws and are generally established in conjuncture with the selection of a specific cleanup action.	Soil in the 100 Area contains contaminants that require remediation. The human health conceptual exposure model for the 100 Area is considered rural residential land use. This land use assumes the reasonable maximum exposure to soil will be unrestricted by future users.	ARAR	Soil cleanup actions where concentration of hazardous substances in the soil exceeds soil concentration for protection of groundwater at the point of compliance.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-340-720, "Ground Water Cleanup Standards" WAC 173-340-720(4), "Method B Cleanup Levels for Potable Ground Water" WAC 173-340-720(7), "Adjustments to Cleanup Levels"	Groundwater cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions. Groundwater cleanup levels are established at concentrations that do not directly or indirectly cause violations of surface water, sediments, soil, or air cleanup standards.	Groundwater in the 100 Area contains contaminants that require remediation; it is not currently used for drinking water but is a potential drinking water source and it discharges into the Columbia River (which is used for drinking water).	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
WAC 173-340-730, "Surface Water Cleanup Standards"	Surface water cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions.	Groundwater in the 100 Area contains contaminants that require remediation and discharges into the Columbia River. The Columbia River is a current and future source of drinking water.	ARAR	Soil, groundwater, and surface water remediation activities that impact surface water.
WAC 173-340-7490, "Terrestrial Ecological Evaluation Procedures" WAC 173-340-7493, "Site-Specific Terrestrial Ecological Evaluation Procedures" WAC 173-340-7494, "Priority Contaminants of Ecological Concern"	Defines goals and procedures for determining whether a release of hazardous substances to soil may pose a threat to the terrestrial environment. Characterizes existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil; and establishes site-specific cleanup standards for the protection of terrestrial plants and animals.	Soil in the 100 Area contains contaminants that require evaluation to determine if ecological exposures have the potential to cause significant adverse effects.	ARAR	Soil remediation activities including containment, RTD, and MNA.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
***Hazardous Waste Management Act of 1976;* WAC 173-303, "Dangerous Waste Regulations"**				
WAC 173-303-645 (3), "Releases from Regulated Units"	Provides standards for groundwater protection including background, MCLs, and ACLs. The MCLs are established at the same levels as SDWA MCLs, and where SDWA MCLs do not exist, health based ACLs may be established that are protective of human health and environment.	Some 100 Area are regulated under state dangerous waste regulations and require groundwater remediation.	ARAR	Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA).
***Water Pollution Control Act;* WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"**				
WAC 173-201A-240(3), "Toxic Substances"	Establishes water quality standards for surface waters of the State of Washington consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife.	Groundwater in the 100 Area contains contaminants that require remediation and discharges into the Columbia River. The use designations for the Columbia River include aquatic life use (spawning and rearing), primary contact recreation, water supply (drinking, irrigation, and agriculture), and miscellaneous uses (wildlife habitat, harvesting, commerce, boating, and aesthetics).	ARAR	Soil, groundwater, and surface water remediation activities that impact surface water.
LOCATION-SPECIFIC ARARs				
***Habitat Buffer Zone for Bald Eagle Rules;* WAC 232-12-292, "Bald Eagle Protection Rules"**				
WAC 232-12-292, "Bald Eagle Protection Rules"	Protects eagle habitat to maintain eagle populations so the species is not classified as threatened, endangered, or sensitive in Washington State.	Bald eagles nest, feed, and overwinter along the shores of the Columbia River.	ARAR	Investigative and remediation activities that impact bald eagle habitat.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
ACTION-SPECIFIC ARARs				
***Hazardous Waste Management Act of 1976;* WAC 173-303, "Dangerous Waste Regulations"**				
WAC 173-303-016, "Identifying Solid Waste" WAC 173-303-017, "Recycling Processes Involving Solid Waste"	Establishes criteria for solid and recycled solid wastes.	Solid wastes and/or recycled solid wastes may be generated during the 100-Area RI/FSs.	ARAR	Investigative and remediation activities.
WAC 173-303-070, "Designation of Dangerous Waste"	Establishes the method for determining if a solid waste is a dangerous waste (or an extremely hazardous waste).	Dangerous/hazardous waste may be generated during the 100 Area RI/FSs.	ARAR	Investigative and remediation (including waste treatment) activities that generate wastes (e.g., drums, barrels, tanks, containers, bulk wastes, debris, and contaminated soil).
WAC 173-303-073, "Conditional Exclusion of Special Wastes"	Establishes the conditional exclusion and the management requirements of special wastes, as defined in WAC 173-303-040.	Special wastes may be generated during the 100 Area RI/FSs.	ARAR	FS remediation activities (disposal, storage, recycling, and onsite treatment) that manage special wastes consistent with the requirements of the Washington Administrative Code.
WAC 173-303-077, "Requirements for Universal Waste"	Identifies those wastes exempted from regulation under WAC 173-303-140 and WAC 173-303-170 through 173-303-9907 (excluding WAC 173-303-960). These wastes are subject to regulation under WAC 173-303-573.	Universal wastes may be generated during the 100 Area RI/FSs.	ARAR	FS remediation activities (disposal, storage, recycling, and onsite treatment) that manage universal wastes consistent with the requirements of the Washington Administrative Code.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-303-120, "Recycled, Reclaimed, and Recovered Wastes" WAC 173-303-120(3), "Recycled, Reclaimed, and Recovered Wastes" WAC 173-303-120(5), "Recycling of Used Oil"	These regulations define the requirements for the recycling of materials that are solid and dangerous waste. Specifically, WAC 173-303-120(3) provides for the management of certain recyclable materials, including spent refrigerants, antifreeze, and lead acid batteries. WAC 173-303-120(5) provides for the recycling of used oil.	Recycled, reclaimed, and recovered wastes may be generated during the 100 Area RI/FSs.	ARAR	FS remediation recycling activities consistent with the requirements of the *Washington Administrative Code* and are not otherwise subject to CERCLA as hazardous substances.
WAC 173-303-140, "Land Disposal Restrictions"	This regulation establishes treatment requirements and disposal prohibitions for land disposal of dangerous waste and incorporates by reference (WAC 173-303-140[2)][a], "Land Disposal Restrictions") the federal land disposal restrictions of 40 CFR 268, "Land Disposal Restrictions," that are applicable to solid waste that is designated as dangerous or mixed waste in accordance with WAC 173-303-070(3), "Designation Procedures."	Onsite land disposal may be a selected remedy for 100 Area dangerous waste and debris.	ARAR	Investigative and remediation wastes destined for onsite land disposal.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-303-170, "Requirements for Generators of Dangerous Waste"	Establishes the requirements for dangerous waste generators. WAC 173-303-170(3) includes the substantive provisions of WAC 173-303-200, "Accumulating Dangerous Waste On-Site," by reference. WAC 173-303-200, "Accumulating Dangerous Waste On-Site," further includes certain substantive standards from WAC 173-303-630 and -640 by reference. Specifically, the substantive standards for management of dangerous/mixed waste are relevant and appropriate to the management of dangerous waste that will be generated during the remedial action.	Dangerous wastes may be generated from the RI/FS of the 100 Area.	ARAR	IDW and remediation wastes (contaminated soil and groundwater, personnel protective gear, treatment chemicals, etc.).
WAC 173-303-200, "Accumulating Dangerous Waste On-Site"	Establishes the requirements for accumulating wastes onsite. WAC 173-303-200 further includes certain substantive standards from WAC 173-303-630, "Container Management," and -640 by reference.	Dangerous waste may be generated from the RI/FS of the 100 Area.	ARAR	Management of dangerous waste during remedial and investigative actions.
WAC 173-303-64610, "Purpose and Applicability" WAC 173-303-64620, "Requirements"	Establishes requirements for corrective action for releases of dangerous wastes and dangerous constituents including releases from solid waste management units.	Releases of dangerous wastes and dangerous constituents have occurred within the 100 Area that may present a threat to human health and the environment.	ARAR	Investigative and remediation of dangerous wastes and dangerous constituents from solid waste management units and spill sites. Corrective action can also be applied at TSD units whenever a release occurs.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-303-610(2), "Closure and Post-Closure"	Establishes closure requirements applicable to all dangerous waste facilities and post-closure care requirements applicable to all regulated units (as defined in WAC 173-303-040, "Definitions") at which dangerous wastes will remain after closure (including tank systems, landfills, surface impoundments, waste piles, and miscellaneous units).	Dangerous wastes may remain in the 100 Area after closure.	ARAR	Remedial design and operation of regulated units that contain dangerous wastes and that will remain in the 100 Areas after closure
WAC 173-303-665(6), "Dangerous Waste Regulations," "Landfills," "Closure and postclosure"	Specifies closure and post-closure requirements for landfills.	The FS may propose containment as a preferred remedy.	ARAR	Design and operation of an engineered landfill cover.
***Water Well Construction Act of 1971;* WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells"**				
WAC 173-160-161, "How Shall Each Water Well Be Planned and Constructed?"	Identifies well planning and construction requirements.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
WAC 173-160-171, "What Are the Requirements for the Location of the Well Site and Access to the Well?"	Identifies the requirements for locating a well.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
WAC 173-160-181, "What Are the Requirements for Preserving the Natural Barriers to Ground Water Movement Between Aquifers?"	Identifies the requirements for preserving natural barriers to groundwater movement between aquifers.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-160-400, "What Are the Minimum Standards for Resource Protection Wells and Geotechnical Soil Borings?"	Identifies the minimum standards for resource protection wells and geotechnical soil borings.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
WAC 173-160-420, "What Are the General Construction Requirements for Resource Protection Wells?"	Identifies the general construction requirements for resource protection wells.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
WAC 173-160-430, "What Are the Minimum Casing Standards?"	Identifies the minimum casing standards.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
WAC 173-160-440, "What Are the Equipment Cleaning Standards?"	Identifies the equipment cleaning standards.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
WAC 173-160-450, "What are the Well Sealing Requirements?"	Identifies the well sealing requirements.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-160-460, "What is the Decommissioning Process for Resource Protection Wells?"	Identifies the decommissioning process for resource protection wells.	Groundwater monitoring and treatment wells and borings occur in the 100 Area.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
***Clean Air Act;* WAC 173-400, "General Regulations for Air Pollution Sources"**				
WAC 173-400, "General Regulations for Air Pollution Sources"	Defines methods of control to be employed to minimize the release of air contaminants associated with fugitive emissions resulting from materials handling, construction, demolition, or other operations. Emissions are to be minimized through application of best available control technology.	Soil and groundwater remedial actions implemented in the 100 Area have the potential to emit emission subject to these standards because soil and groundwater target analytes detected in the 100 Area include covered hazardous air pollutants.	ARAR	Actions performed at the 100 Area that could result in the emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during the RI/FS that have the potential to emit visible, particulate, fugitive, and hazardous air emissions and odors.
WAC 173-400-040, "General Standards for Maximum Emissions"	All sources and emissions units are required to meet the general emission standards unless a specific source standard is available. General standards apply to visible emissions, particulate fallout, fugitive emissions, odors, emission detrimental to health and property, sulfur dioxide, and fugitive dust.	Soil and groundwater remedial actions implemented in the 100 Area have the potential to emit emission subject to these standards because target analytes detected in the 100 Area include covered regulated hazardous air pollutants.	ARAR	Remedial actions that have the potential to release hazardous air emissions.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-400-075, "Emission Standards for Sources Emitting Hazardous Air Pollutants"	Establishes national emission standards for hazardous air pollutants. Adopts, by reference, 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," and appendices.	Soil and groundwater target analytes detected in the 100 Area include covered regulated hazardous air pollutants.	ARAR	Actions performed at the 100 Area that could result in the emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during the RI/FS that have the potential to emit visible, particulate, fugitive, and hazardous air emissions and odors.
***Water Pollution Control Act;* WAC 173-218, "Underground Injection Control Program"**				
WAC 173-218, "Underground Injection Control Program"	Protects ground water quality by regulating the discharge of fluids into underground injection control wells.	Groundwater in the 100 Area contains contaminants that require remediation. Treated groundwater may be discharged through underground injection wells.	ARAR	Groundwater remedial activities may involve underground injection.
Solid Waste Management – Reduction and Recycling; WAC 173-350, "Solid Waste Handling Standards"				
WAC 173-350-025, "Owner Responsibilities for Solid Waste" WAC 173-350-040, "Performance Standards" WAC 173-350-300, "On Site Storage, Collection and Transportation Standards" WAC 173-350-900, "Remedial Action"	Establishes minimum functional performance standards for the proper handling and disposal of solid waste. Requirements for the proper handling of solid waste materials originating from residences, commercial, agricultural and industrial operations and other sources and identifies those functions necessary to ensure effective solid waste handling programs at both the state and local level.	Solid, nondangerous waste will be generated during the implementation of the 100 Area RI/FSs.	ARAR	Investigative and remedial actions that generate solid, nondangerous waste.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
***Clean Air Act;* WAC 173-460, "Controls for New Sources of Toxic Air Pollutants"**				
WAC 173-460-010, "Purpose" WAC 173-460-030, "Applicability" WAC 173-460-060, "Control technology requirements" WAC 173-460-070, "Ambient impact requirement." WAC 173-460-080, "First tier review" WAC 173-460-150, "Table of ASIL, SQER and de minimis emission values"	Establishes control of new sources emitting toxic air pollutants to prevent air pollution, reduce emissions to the extent reasonably possible, and maintain such levels of air quality as will protect human health and safety. Toxic air pollutants include carcinogens and noncarcinogens listed in WAC 173-460-150. Three major requirements of this regulation include (1) implementation of best available control technology for toxics, (2) quantification of toxic air pollutant emissions, and (3) health and safety protection demonstration.	Target analytes detected in soil and groundwater in the 100 Area include constituents that would constitute toxic air pollutants if released to the air.	ARAR	Groundwater and soil remediation activities such as treatment systems that have the potential to emit hazardous air emissions and would be considered a new source.
***Clean Air Act ;* WAC 173-470, "Ambient Air Quality Standards for Particulate Matter"**				
WAC 173-470-100, "Ambient Air Quality Standards"	Sets maximum acceptable levels for particulate matter in the ambient air at 150 $\mu g/m^3$ over a 24-hour period, or 60 $\mu g/m^3$ annual geometric mean. It also sets the 24-hour ambient air concentration standards for particles less than 10 µm in diameter (PM_{10}) at 105 $\mu g/m^3$ and 50 $\mu g/m^3$ geometric mean.	Although ambient air quality standards for particulate matter are not ARARs, they should be considered if RIs or treatment operations raise emissions above the standard.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, containment) that have the potential to emit particulate matter above maximum acceptable levels.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-470-110, "Particle Fallout Standards"	Establishes the standard for particle fallout not to exceed 10 g/m^2 per month in an industrial area or 5 g/m^2 per month in residential or commercial areas. Alternative levels for areas where natural dust levels exceed 3.5 g/m^2 per month are set at 6.5g/m^2 per month, plus background levels for industrial areas and 1.5 g/m^2 per month, plus background in residential and commercial areas.	Particulates and dust can be generated during RI/FS actions.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, containment) that have the potential to emit particulate matter above maximum acceptable levels.
***Clean Air Act;* WAC 173-480; "Ambient Air Quality Standards and Emission Limits for Radionuclides"**				
WAC 173-480-040, "Ambient Standard"	Defines the maximum allowable level for radionuclides in the ambient air, which shall not cause a maximum accumulated dose equivalent of 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. However, ambient air standard under 40 CFR, Subparts H and I are not to exceed amounts that result in an effective dose equivalent of 10 mrem/yr to any member of the public.	Target analytes detected in soil and groundwater in the 100 Area include radionuclides that could be emitted to ambient air during RI/FS actions.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, vacuuming/exhaust) that have the potential to emit radionuclides above maximum acceptable levels.
WAC 173-480-050, "General standards for maximum permissible emissions"	At a minimum, all emission units shall make every reasonable effort to maintain radioactive materials in effluents to unrestricted areas, ALARA. Control equipment of sites operating under ALARA shall be defined as reasonably available control technology and as low as reasonably achievable control technology.	The potential for fugitive and diffuse emissions due to demolition and excavation and related activities will require efforts to minimize those emissions. This requirement is action-specific.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, vacuuming/exhaust) that have the potential to emit radionuclides above maximum acceptable levels.

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 173-480-070, "Emission Monitoring and Compliance Procedures"	Requires that radionuclide emissions shall be determined by calculating the dose to members of the public using Department of Health approved sampling procedures at the point of maximum annual air concentration in an unrestricted area where any member of the public may be.	Target analytes detected in soil and groundwater in the 100 Area include radionuclides that could be emitted to unrestricted areas during RI/FS actions.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that have the potential to emit radionuclides to unrestricted areas above maximum acceptable levels.
WAC 173-480-060, "Emission Standards for New and Modified Emission Units"	Requires that construction, installation, or establishment of a new air emission control units utilize BARCT.	Target analytes detected in soil and groundwater in the 100 Area include radionuclides that could be emitted from air emission control units during RI/FS actions.	ARAR	Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that require air pollution control equipment and have the potential to emit radionuclides.
***Nuclear Energy and Radiation;* WAC 246-247, "Department of Health," "Radiation Protection -- Air Emissions"**				
WAC 246-247-035 (1)(a)(ii), "National Standards. Adopted by Reference for Sources of Radionuclide Emissions"	Established requirements equivalent to 40 CFR 61, Subpart H, by reference. Radionuclide airborne emissions from the waste site shall be controlled so as not to exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem/yr effective dose equivalent.	Substantive requirements of this standard are applicable because the remedial action may include activities such as excavation, decontamination, and stabilization of contaminated areas that many provide airborne emissions of radioactive particles.	ARAR	Investigative and remedial activities.
WAC 246-247-040(3), "General Standards" WAC 246-247-040(4), "General Standards"	Requires that emissions be controlled to ensure emission standards are not exceeded.	Target analytes detected in soil and groundwater in the 100 Area reactor sites include radionuclides that could be emitted during RI/FS actions.	ARAR	Investigative and remediation activities (e.g., RTD, excavation, demolition, ventilation).

Table B-2. Identification of Potential State of Washington Applicable and Relevant or Appropriate Requirements and to Be Considered for the Remedial Action Sites

Citation	Description of Requirement	Rationale for Use	Relevancy	Possible Action(s)
WAC 246-247-075, "Monitoring, Testing and Quality Assurance"	Establishes the monitoring, testing, and quality assurance requirements for radioactive air emissions. Emissions from non-point and fugitive sources of airborne radioactive material shall be measured. Measurement techniques may include, but are not limited to sampling, calculation, smears, or other reasonable method for identifying emissions as determined by the lead agency.	Target analytes in the 100 Area reactor sites include radionuclides that could be emitted as airborne radioactive material during RI/FS actions.	ARAR	Investigative and remediation activities (e.g., RTD, excavation, demolition, ventilation) that could be emitted from fugitive sources.

NOTE: The references cited in this table are included in the references section of this appendix.

ACL	=	alternative concentration limit	IDW	=	investigation derived waste
ALARA	=	as low as reasonably achievable	MCL	=	maximum contaminant level
ARAR	=	applicable or relevant and appropriate requirement	MNA	=	monitored natural attenuation
BARCT	=	best available radionuclide control technology	RI	=	remedial investigation.
CERCLA	=	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*	RI/FS	=	remedial investigation/feasibility study
			RTD	=	removal, treatment, and disposal
CFR	=	*Code of Federal Regulations*	SDWA	=	*Safe Drinking Water Act of 1974*
FS	=	feasibility study	TSD	=	treatment, storage, and/or disposal (unit)

Appendix C

Proposed Tri-Party Agreement Milestones Associated with the Final Action Record of Decision Activities for the 100 Area Operable Units

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C1 Introduction

Table C-1 provides proposed *Hanford Federal Facility Agreement and Consent Order* (Ecology et al, 1989) milestones associated with the final action ROD activities for the 100 Area operable units.

C2 References

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List," *Code of Federal Regulations*. Available at: http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr300_08.html

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC 9601, et seq. Available at: http://uscode.house.gov/download/pls/42C103.txt.

DOE/RL-2006-70, 2007, *Treatability Test Plan for Removal of Chromium from Groundwater at 100-D Area Using Electrocoagulation*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=91&parent=0

PNNL-16424, 2007, *Treatability Test Plan for an In Situ Biostimulation Reducing Barrier*, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16424.pdf

Table C-1. Proposed Tri-Party Agreement Milestones Associated with the Final Action Record of Decision Activities for the 100 Area Operable Units

Tri-Party Agreement Milestone No.	Milestone	Due Date
M-015-00D	DOE shall complete the RI/FS process through the submittal of a proposed plan for all 100 Area and 300 Area OUs.	12/31/2012
M-016-110-T01	DOE shall take actions necessary to contain or remediate CrVI groundwater plumes in each of the 100 Area NPL OUs such that ambient water quality standards for CrVI are achieved in the hyporheic zone and river water column.	12/31/2012
M-016-110-T02	DOE shall take actions necessary to remediate CrVI groundwater plumes such that CrVI will meet drinking water standards in each of the 100 Area NPL OUs.	12/31/2020
M-016-110-T03	DOE shall take actions necessary to contain the strontium-90 groundwater plume at the 100-NR-2 OU such that the default ambient water quality standard (8 pCi/L) for strontium-90 is achieved in the hyporheic zone and river water column.	12/31/2016

Table C-1. Proposed Tri-Party Agreement Milestones Associated with the Final Action Record of Decision Activities for the 100 Area Operable Units

Tri-Party Agreement Milestone No.	Milestone	Due Date
M-016-110-T04	DOE shall implement remedial actions selected in all 100 Area RODs for groundwater OUs so that no contamination above drinking water standards or ambient water quality standards enters the Columbia River unless otherwise specified in a CERCLA decision.	12/31/2016
M-016-110-T05	DOE will have in place an operational and functional remedial system designed to meet federal drinking water standards for uranium throughout the groundwater plume in the 300-FF-5 OU unless otherwise specified in a CERCLA decision document.	12/31/2018
M-016-111A	Expand current pump-and-treat system at the 100-KR-4 OU to be operational and functional at a total 900-gpm capacity.	05/31/2009
M-016-111B	Expand current pump-and-treat system at the 100-HR-3 OU using ex situ treatment, in situ treatment, or a combination of both, to be operational and functional at a total 500-gpm capacity, or as specified in the work plan.	12/31/2010
M-016-111C	Expand current pump-and-treat system at the 100-HR-3 OU using ex situ treatment, in situ treatment, or a combination of both, to be operational and functional at a total 800-gpm capacity, or as specified in the work plan.	12/31/2011
M-016-112A	DOE shall complete demonstrations for biostimulation and electrocoagulation according to previously approved test plans (DOE/RL-2006-70, *Treatability Test Plan for Removing Chromium from Groundwater at 100-D Area Using Electrocoagulation*; PNNL-16424, *Treatability Test Plan for an In Situ Biostimulation Reducing Barrier*).	12/31/2009
M-015-60	If an amendment to the 100-NR-1/100-NR-2 ROD for interim action is issued, DOE shall submit a remedial design/remedial action work plan.	6 months after the ROD amendment
M-015-61	Submit RI/FS work plan for the 100-NR-1 and 100-NR-2 OUs.	12/31/2009
M-015-62-T01	Submit an FS report and proposed plan for the 100-NR-1 and 100-NR-2 OUs, including groundwater and soil. The FS report and proposed plan will evaluate the permeable reactive barrier technology and other alternatives and will identify a preferred alternative in accordance with CERCLA requirements.	12/31/2011
M-015-63	Submit CERCLA RI/FS work plan for the 100-FR-1/100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 OUs for groundwater and soil.	09/30/2009
M-015-64-T01	Submit CERCLA RI/FS report and proposed plan for the 100-FR-1/100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 OUs for groundwater and soil.	11/30/2011

Table C-1. Proposed Tri-Party Agreement Milestones Associated with the Final Action Record of Decision Activities for the 100 Area Operable Units

Tri-Party Agreement Milestone No.	Milestone	Due Date
M-015-65	Submit CERCLA RI/FS work plan for the 100-KR-1, 100-KR-2, and 100-KR-4 OUs for groundwater and soil.	05/31/2009
M-015-66-T01	Submit CERCLA RI/FS report and proposed plan for the 100-KR-1, 100-KR-2, and 100-KR-4 OUs for groundwater and soil.	07/31/2011
M-015-67	Submit CERCLA RI/FS work plan for the 100-BC-1, 100-BC-2, and 100-BC-5 OUs for groundwater and soil.	09/30/2009
M-015-68-T01	Submit CERCLA RI/FS report and proposed plan for the 100-BC-1, 100-BC-2, and 100-BC-5 OUs for groundwater and soil.	11/30/2011
M-015-69	Submit RI/FS work plan for the 100-HR-1, 100-HR-2, 100-HR-3, 100-DR-1, and 100-DR-2 OUs for groundwater and soil.	05/31/2009
M-015-70-T01	Submit FS report and proposed plan for the 100-HR-1, 100-HR-2, 100-HR-3, 100-DR-1, and 100-DR-2 OUs for groundwater and soil.	07/30/2011

Notes:

DOE = U.S. Department of Energy

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

FS = feasibility study

CrVI = hexavalent chromium

NPL = National Priorities List (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List")

OU = operable unit

Tri-Party Agreement = Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*

RI/FS = remedial investigation/feasibility study

ROD = record of decision

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Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units

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

U.S. DEPARTMENT OF ENERGY

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Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan Addendum 2: 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units

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Executive Summary

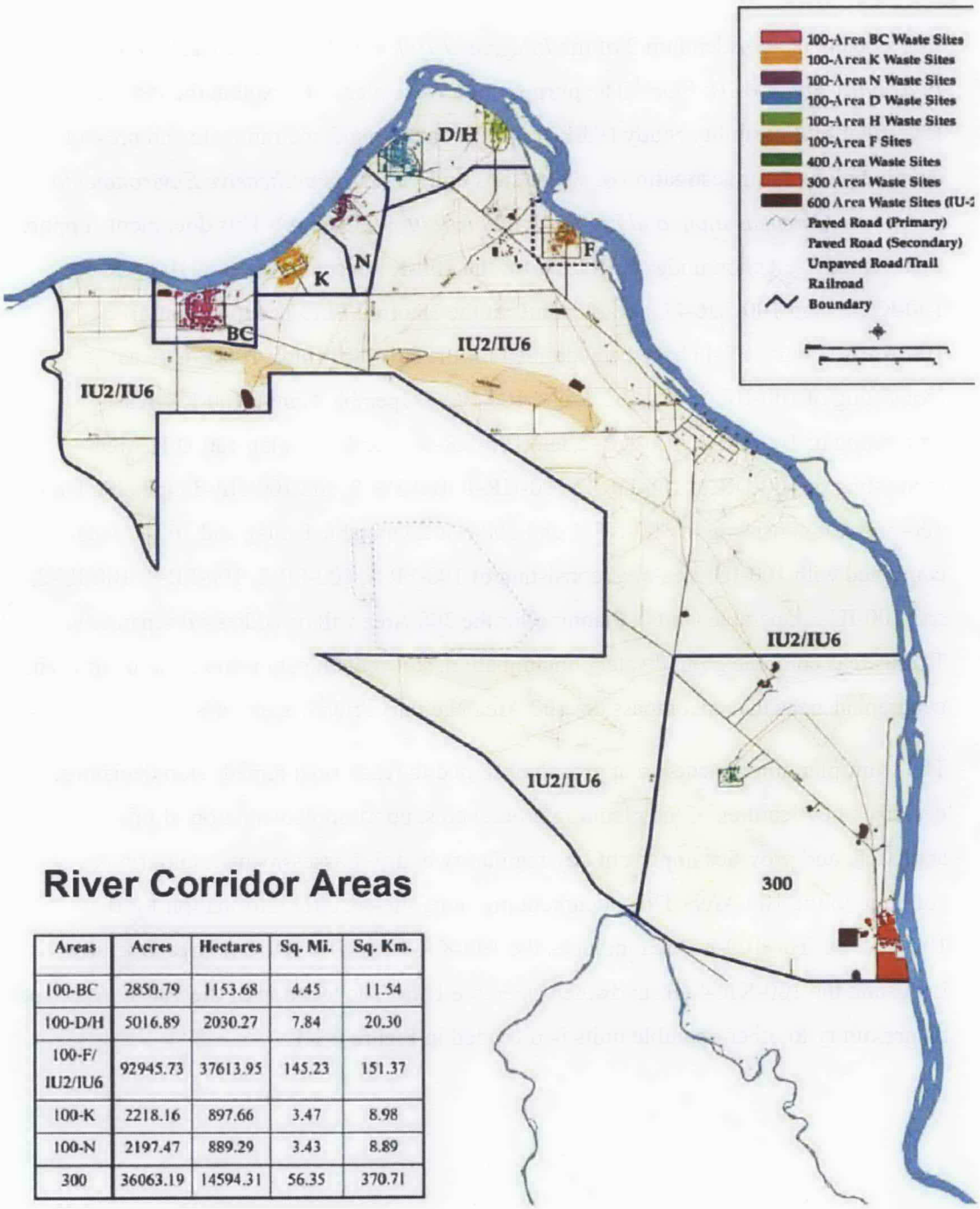
This document is Addendum 2 of the *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan.*[1] The purpose of a work plan is to explain the Remedial Investigation/Feasibility Study (RI/FS) project background and rationale and present detailed plans for investigation of waste sites under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[2] (CERCLA). This document supports final remedy selection under CERCLA for the 100-K Area composed of 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units at the Hanford Site. The following five 100 Areas (Figure ES-1) have been defined for the River Corridor: 100-B/C Area (consisting of 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units), 100-K Area (consisting of 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units), 100-D/H Area (consisting of 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units), 100-N Area (consisting of 100-NR-1 and 100-NR-2 Operable Units), and 100-F Area combined with 100-IU-2/6 Area (consisting of 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units). Planning for the 300 Area will be addressed separately. These areas combine groundwater contamination, soil contamination sites, and facilities in geographic areas that encompass the 100 Area National Priority List[3] sites.

The work plan implements an approach designed to reach final remediation decisions, describes key features of the planning process to support implementation of this approach, and provides important key regulatory and risk assessment assumptions common to the 100 Area. This document provides site-specific information for the 100-K Area. The 100-K Area includes the 100-KR-1 and 100-KR-2 Source Operable Units and the 100-KR-4 Groundwater Operable Unit. The location of the 100-K Area and its proximity to other operable units is provided in Figure ES-1.

1 DOE/RL-2008-46, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

2 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq. http://www4.law.cornell.edu/uscode/42/usc_sec_42_00009601----000-.html.

3 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations.* http://www.access.gpo.gov/nara/cfr/waisidx_08/40cfr300_08.html.



River Corridor Areas

Areas	Acres	Hectares	Sq. Mi.	Sq. Km.
100-BC	2850.79	1153.68	4.45	11.54
100-D/H	5016.89	2030.27	7.84	20.30
100-F/ IU2/IU6	92945.73	37613.95	145.23	151.37
100-K	2218.16	897.66	3.47	8.98
100-N	2197.47	889.29	3.43	8.89
300	36063.19	14594.31	56.35	370.71

Figure ES-1. River Corridor Boundaries

A systematic planning process was used to develop a program for data collection and analysis to support final remediation decisions at 100-K Area. The following key elements were identified during this systematic planning process.

- **Information was identified and collected to define the existing site conditions.**

  Collected information includes past operational history of the facilities (with an emphasis on disposal practices), the nature and extent of groundwater and soil contamination, geohydrologic information, source and groundwater interim actions and their effectiveness, and the results of any treatability and characterization studies.

  Chromium contamination is the primary risk driver at 100-K; however, other groundwater plumes exist. Appendix B presents maps of the facilities, source sites, and groundwater plumes. To date, 16 facilities and 13 waste sites have been remediated. In addition, three groundwater pump-and-treat systems are operating at a rate of approximately 2,650 L/min (approximately 700 gal/min) to treat hexavalent chromium.

- **A conceptual site model (CSM) was developed.**

  The conceptual site model (CSM) examined what was known about the levels and location of contamination and information needed to support final decisions on remediation. A CSM is a representation of a site that organizes the information available and provides a summary of the site conditions. The CSM was used to identify data and information gaps, establish data needs, and design a field program to address the gaps.

  An important feature of the CSM was identifying the potential sources of chromium and providing alternative explanations regarding chromium plume persistence after many years of active groundwater remediation. Alternative concepts to explain the persistence include the following:

  - Dissolved chromium simply covers a large area and the pump-and-treat systems have not removed sufficient water.
  - A dissolved source of chromium remains in the variably wetted zone above the unconfined aquifer.
  - Chromium is diffusing into the unconfined aquifer from the fine particles in the Ringold Upper Mud (RUM) Unit.

- Chromium product remains in pockets on low-permeable material within the unconfined aquifer or the RUM Unit.
- Source of hexavalent chromium may remain in the vadose zone and may continue to impact groundwater.

- **Data gaps, or uncertainties, were identified as part of the CSM development process.**

  A list of data gaps, or statement of uncertainty, was identified as part of the systematic planning process. These data gaps included recognition of the need for additional information to better define the following:

  - Assess risk for direct exposure, protection of groundwater, and protection of the Columbia River at unremediated waste sites.
  - Potential effects of residual soil contamination following interim action on human health, groundwater, and the environment.
  - Extent of contamination in the unconfined aquifer.
  - Extent of contamination in and below the RUM Unit.
  - Continued persistence of chromium contamination in the groundwater.
  - Hydraulic properties of the RUM Unit.
  - Potential adverse affects from remaining undiscovered sites.

  A total of 13 data gaps were defined during the systematic planning process and are presented in Chapter 4.

- **Data needs were defined to address each of the data gaps or uncertainties.**

  Each of the 13 data gaps are defined by a data need that, when filled, provides information to reduce or eliminate the uncertainty associated in the data gap. Table 4-4 and DOE/RL-2008-41 present the data needs and how they will be filled for 100-K Operable Units. An important consideration in Table 4-4 is that several ongoing programs (e.g., facility demolition, waste site remediation, and the pump-and-treat systems) are expected to provide data that will resolve many of the uncertainties identified for 100-K Operable Units. The sampling and analysis plan (SAP)[4] identifies only those data collection activities that these ongoing programs will not address. The RI/FS report prepared for the 100-K Area will take full advantage of data and information obtained by ongoing remediation programs

[4] DOE/RL-2009-41, 2009, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

that are available during the development of the report. The results of ongoing deactivation, decontamination, decommissioning, and demolition, and waste site and groundwater interim remediation actions, in addition to proposed investigations will be used in the selection of final remedies and will be incorporated into a proposed plan that will lead to a final record of decision. Table ES-1 summarizes the characterization field program proposed under this addendum. Table ES-2 presents the number of field samples and analytes that would be collected.

Table ES-1. Proposed 100-K Characterization

Type	Number
Source waste sites to be characterized and/or remediated	110
New boreholes (vadose zone)	2
New wells (unconfined aquifer)	9
New wells (extending into the RUM Unit)	4
New aquifer tube locations	1
Current monitoring wells (sampling to support risk characterization)	18

Table ES-2. Number of Field Samples and Analytes Proposed for the 100-K

Source	Soil Samples	Groundwater Samples	Analyses
New boreholes (vadose zone)	15	2	178
New wells (unconfined aquifer)	117	117	2,042
New wells (extending into the RUM Unit)	64	60	1,152
New aquifer tube locations	0	9	36
Current monitoring wells (sampling to support risk characterization)	0	54	486

NOTE: Table does not include field, quality control, or archive samples.

* Includes both chemical and physical property analysis.

- **A SAP was developed as the implementing document for the field program.**

  The SAP also contains a list of target analytes for use with soil samples, and a list of contaminants of potential concern for use with groundwater samples. The current methodology defines analyses for soil characterization and for groundwater samples to address River Corridor Baseline Risk Assessment groundwater risk uncertainty. This SAP is based on the premise and observation that, after 13 years of active remediation and study, a limited number of uncertainties remain that should be addressed to support final remediation decisions.

In the 100-K Area, substantive work to remediate groundwater contamination, remove contaminated soils, and remove facilities has been completed over the past decade or is planned over the next few years. The results of these activities provide the basis for identifying the few remaining uncertainties needed to be addressed to make final remediation decisions. The completed and planned work for the 100-K Area is provided in Section 1.2.

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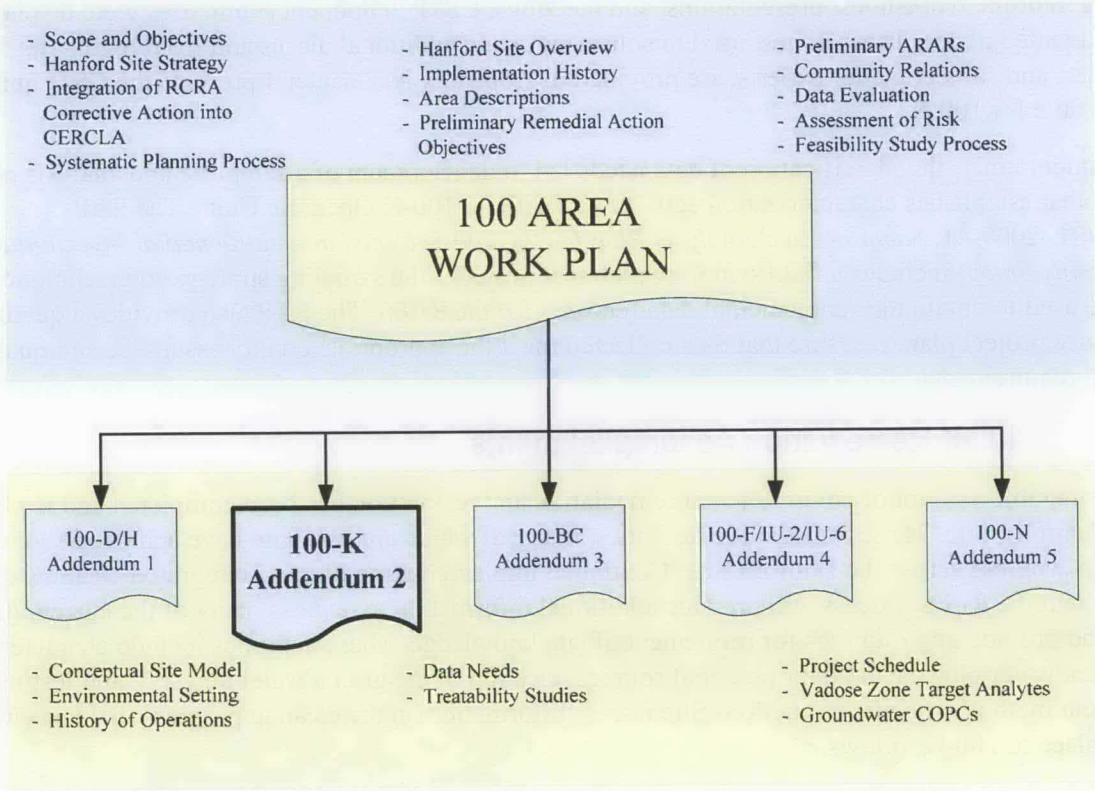
Terms

ASTM	American Society of Testing and Materials
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
COPC	contaminant(s) of potential concern
CrVI	hexavalent chromium
CSM	conceptual site model
DOE	U.S. Department of Energy
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FS	feasibility study
LFI	limited field investigation
MCL	maximum contaminant level
NEPA	*National Environmental Policy Act*
NRHP	National Register of Historic Places
OSE	orphan site evaluation
OU	operable unit
QRA	qualitative risk assessment
RAO	remedial action objective
RCBRA	River Corridor Baseline Risk Assessment
RCRA	*Resource Conservation and Recovery Act of 1976*
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
ROD	record of decision
RTD	remove, treat, and dispose

RUM	Ringold Upper Mud (Unit)
SAP	sampling and analysis plan
TPH	total petroleum hydrocarbons
Tri-Party Agreement	Ecology et al. 1989a, *Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and disposal
WIDS	Waste Information Data System

1 Introduction

This document is Addendum 2 to the *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (DOE/RL-2008-46), hereafter referred to as the "Work Plan." This addendum describes the 100-K Area and planned efforts to conduct a remedial investigation (RI) in support of a final record of decision (ROD) for the 100-K Operable Units. The 100-K Area includes the 100-KR-1 and 100-KR-2 Source Operable Units (OUs) and the 100-KR-4 Groundwater OU. The work plan contains the planning elements that are common to all of the Hanford Site 100 Area source and groundwater OUs and a summary of the RI/feasibility study (FS) tasks. Figure 1-1 shows the relationship between the RI/FS work plan and this addendum.



ARAR applicable or relevant and appropriate requirement
CERCLA *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC contaminant of potential concern
RCRA *Resource Conservation and Recovery Act of 1976*

Figure 1-1. Relationship Between the Work Plan and the Addenda

This addendum was developed through multiple interview sessions, workshops, and task team work organized through the Systematic Planning Process with the participation of subject matter experts. The planning process was guided by the needs of the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA).

1.1 Scope

This addendum addresses the data and information needed to support groundwater and waste site remediation decisions associated with the 100-K Area. The location of the 100-K Area and its proximity to other River Corridor areas is provided in Figure 1-2. A useful tool to guide characterization

and identify effective remediation actions for the 100-K Operable Units is the conceptual site model (CSM). A CSM organizes the information available and provides a summary of site conditions. More importantly, a CSM can be used to identify data needs and establish the programmatic priority for sampling and testing hypotheses.

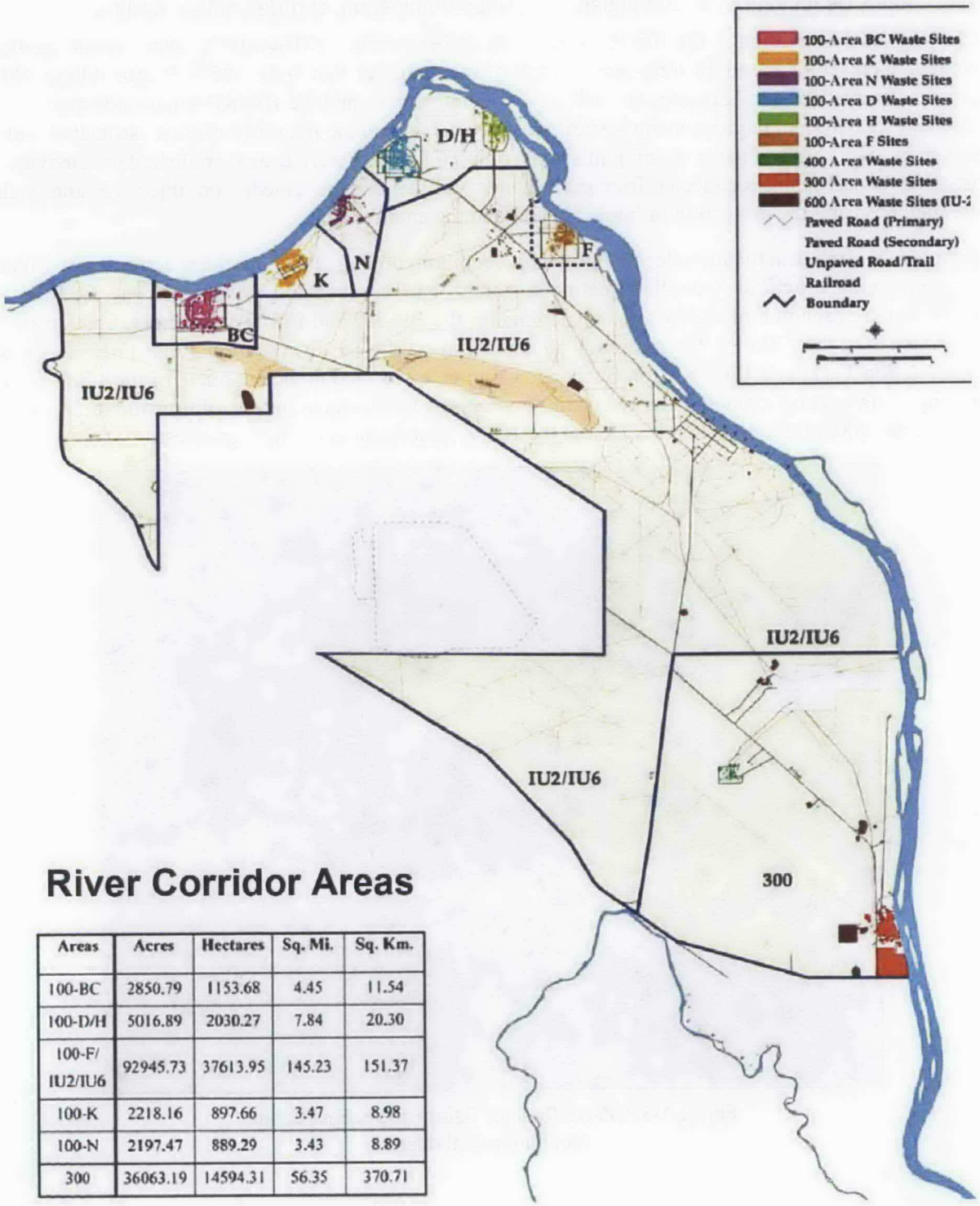
Data gaps are addressed through additional data collection and other investigations. The CSM addresses contaminant sources, contaminant flow and transport, and exposure assessment. It supports risk characterization, remedial action selection, performance monitoring, and site closure. Chapter 2 provides the background and environmental setting information necessary to support the development of the 100-K CSM.

During multiple workshops, presentations, and meetings, CSM component summaries were displayed as wall-mounted plates. These plates, used to solicit input and additional discussion from regulators, agencies, and subject matter experts, are provided in Appendix A. Chapter 4 presents the CSM and a data needs table for 100-K.

Most importantly, the identification of data needs led to development of a sampling and analysis plan (SAP) that establishes characterization activities specific to 100-K Operable Units. The SAP (DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/ Feasibility Study*) includes a field sampling plan that provides the sampling strategy and techniques that will be used to obtain the supplemental data required for the RI/FS. The SAP also provides a quality assurance project plan to ensure that data collected meet the appropriate quality assurance and quality control requirements.

1.2 100-K Remediation Accomplishments

A considerable amount of environmental remediation and restoration has been completed and is planned at the Hanford Site. These remediation activities, many of which are ongoing, have achieved significant cleanup progress across the Hanford Site. Continued implementation of these integrated cleanup actions throughout the RI/FS process will produce additional information to address many of the current data gaps and provide opportunities for refinement of site knowledge. These activities include characterization of groundwater plumes and their potential sources, cleanup of the groundwater and soil, and testing new treatment methods specific to Hanford Site issues. Information on the cleanup progress that has already taken place in 100-K follows.



River Corridor Areas

Areas	Acres	Hectares	Sq. Mi.	Sq. Km.
100-BC	2850.79	1153.68	4.45	11.54
100-D/H	5016.89	2030.27	7.84	20.30
100-F/ IU2/IU6	92945.73	37613.95	145.23	151.37
100-K	2218.16	897.66	3.47	8.98
100-N	2197.47	889.29	3.43	8.89
300	36063.19	14594.31	56.35	370.71

Figure 1-2. River Corridor Boundaries

1.2.1 100-K Deactivation, Decommissioning, Decontamination, and Demolition Actions

Following the deactivation of the 105-KE and 105-KW Reactors in 1970 and 1971, many 100-K facilities have remained active due to the long-term storage of spent nuclear fuel in the 105-K Basins. Many 100-K facilities also provide ancillary support to 100-N Area operations, and the 100-KR-4 Groundwater pump-and-treat system requires using several buildings to support the treatment centers associated with the system. As a result of these ongoing missions, only 16 facilities have been demolished or removed. Post-removal soil samples collected from each facility verified that the remediation objectives and goals were met, ensuring the protection of human health and the environment.

Future 100-K Area deactivation, decontamination, decommissioning, and demolition activities will focus on the remaining structures (including treatment, storage, and disposal [TSD] units) and Interim Safe Storage or the evaluation of earlier removal actions for the 105-KE and 105-KW Reactors. Specifically regarding TSDs, the 1706-KE Condensate Collection Tank, 1706-KE Evaporation Tank, 1706-KE Waste Accumulation Tank, and 1706-KE Ion Exchange Column are located in the basement of the 1706-KER Building. This facility, including the TSD tanks and piping, is scheduled for demolition and removal by mid-summer 2009. Figures 1-3 and 1-4 show the 105-K East Basin demolition progress.

Figure 1-3. 100-KE Reactor Before 105-K East Basin Demolition Activities

Figure 1-4. Workers Demolishing the 105-KE Basin Located Approximately 400 Yards from the Columbia River

1.2.2 100-K Waste Site Remediation

Since 2002, 13 waste sites in the 100-K Area have been remediated, including the "Mile-Long Trench" shown in Figure 1-5. Roughly 940,000 metric tons of soil and debris have been removed from 100-K Area waste sites and disposed in the Environmental Restoration Disposal Facility (ERDF). Approximately 500 vadose zone samples (about 15,000 records) have been collected as part of waste site remediation.

A significant waste site remediation achievement was the completion of the 116-K-2 Trench in 2006. This waste site was regarded as the most highly contaminated liquid waste disposal site in the 100 Area. It was the principal liquid waste disposal site for the 100-K Area and received a range of reactor effluents while operating from 1955 to 1971. It is estimated that about 2,100 Ci (almost one-half of the radionuclide inventory of the 100 Area) and about 300,000 kg (~661,000 lb) of sodium dichromate were discharged to this trench. In remediating the trench, an area roughly 21,521 m^2 (70,610 ft^2) was excavated, backfilled, and revegetated.

A second major waste site remediation effort was the 118-K-1 Burial Ground, the primary solid waste disposal area for the 100-K Area. Figures 1-5 and 1-6 illustrate remedial actions for 118-K-1, where the primary radionuclides were tritium, carbon-14 (C-14), cobalt-60 (Co-60), nickel-63 (Ni-63), strontium-90 (Sr-90), cesium-137 (Cs-137), silver-108m (Ag-108m), europium-152 (Eu-152), europium-154 (Eu-154), and europium-155 (Eu-155). Site excavation work began in 2007 and is expected to be completed by 2011.

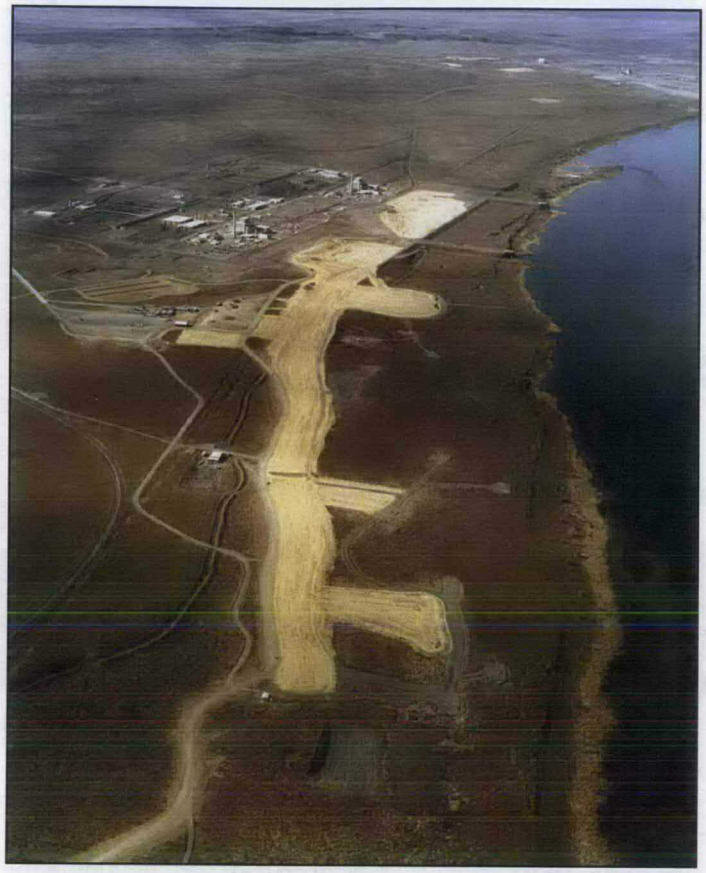


Figure 1-5. Mile-Long Trench – Backfilled and Ready for Revegetation

Figure 1-6. Track-Mounted Probe Sorting Radioactive Materials at the 118-K-1 Burial Ground

1.2.3 100-K Orphan Site Evaluation

A comprehensive orphan site evaluation (OSE) of the 100-K Area was conducted from January 2007 through August 2008. The OSE encompassed historical reviews, field investigation, gap analyses, and integration of results, all of which are documented in OSR-2008-0003, *100-K Area Orphan Sites Evaluation Report*. A summary of the OSE subtasks for the 100-K Area is provided in Table 1-1. The field investigation portion of the OSE covered 329 ha (813 ac), including about 225 km (140 mi) of walking surveys (Figure 1-7). The 16 orphan sites discovered during the OSE will be evaluated to determine their impact (if any) on the environment, because orphan sites are considered known or suspected sources of contamination.

Table 1-1. 100-K Area Orphan Site Evaluation Summary

Historical Resource Type	Quantity Screened	Quantity Reviewed
Historical Review – January 2007 to September 2007		
Documents	345	132
Drawings	20,000	700
Photographs	142	142
Field Investigation – September 2007 to January 2008		
Area Investigated	329 ha (813 acres)	
Gap Analysis and Integration Results – January 2008 to August 2008		
Orphan Sites	16 (6 are in the 100-K Exclusion Area)	
Potential New Discovery Sites	19 (all are in the 100-K Exclusion Area)	
Stewardship Locations	72	
Miscellaneous Restoration Locations	10	
Updated WIDS Locations	20	
Geophysical Investigations	2	
Physical Hazard Locations	2	
Pipelines	9,093 m (5.65 mi) of pipelines were discovered during the historical review of construction drawings and were mapped into the GIS database	

GIS = Geographic Information System
WIDS = Waste Information Data System

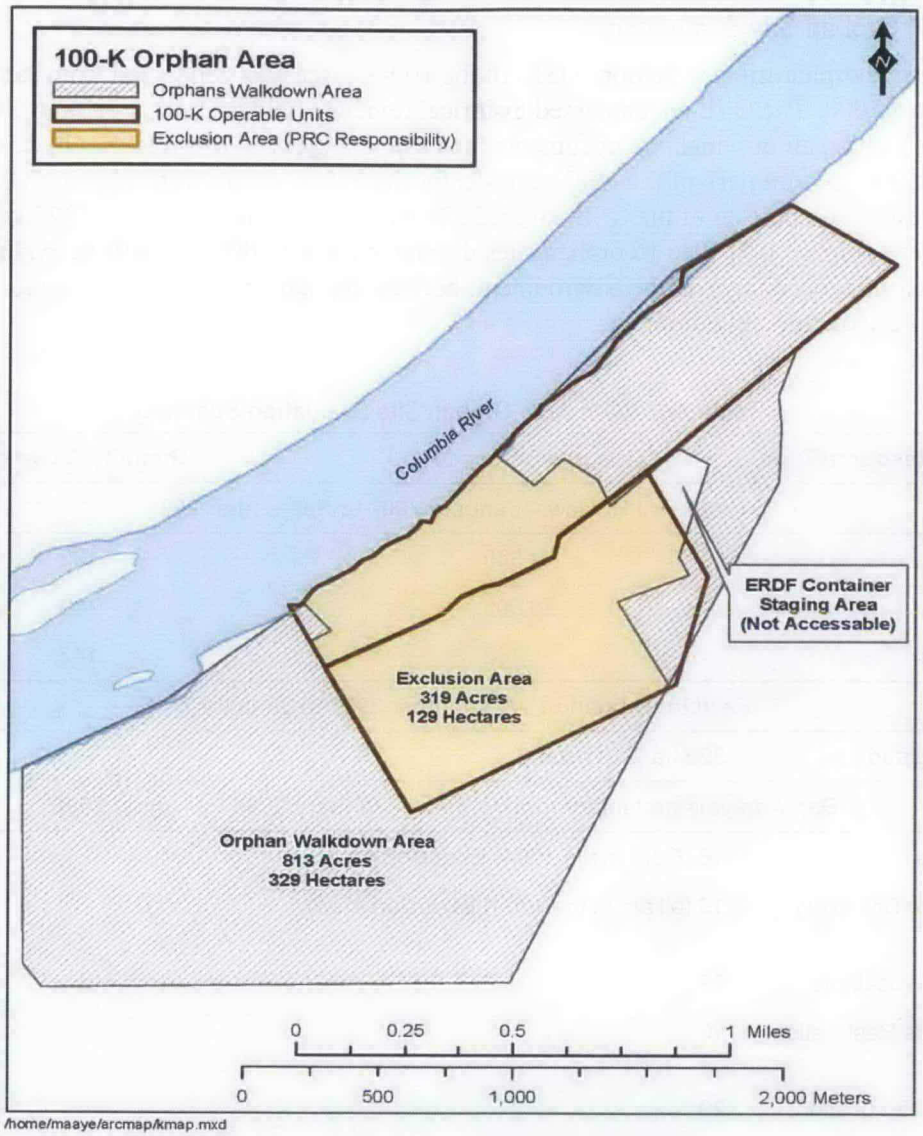


Figure 1-7. 100-K Area Orphan Site Coverage

The 100-K Area OSE is unique because a portion of the area was being transitioned from the River Corridor Closure Contractor to the Plateau Remediation Contractor. The work scope being transitioned includes all activities within the exclusion area (i.e., inside the fence) of the 100-K Area. Because of the transition and access issues associated with the exclusion area, it was decided that only the historical evaluation would be performed in the exclusion zone. The sites will be accepted as waste management units and then characterized to determine if they should be added to the scope of the existing 100-K Area Interim ROD and remediated. The opportunity for additional discoveries will continue throughout cleanup of the 100-K Area, including activities conducted after final RODs are issued (e.g., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA] 5-year reviews).

1.2.4 100-K Pump-and-Treat Systems

From January 1997 through January 2007, the 100-KR-4 Pump-and-Treat System treated more than 3.8 billion L (1 billion gal) of groundwater and removed 272 kg (600 lbs) of hexavalent chromium (CrVI) from the 100-KR-4 Aquifer. The network of 13 extraction wells and seven injection wells draws the groundwater from the aquifer, processes it through an ion-exchange system that removes CrVI, and returns the treated water to the aquifer.

The 100-KR-4 Pump-and-Treat System began operating in 1997 with nine extraction wells and five injection wells. This system is cleaning up groundwater, including the area of the 116-K-2 Trench, which received millions of liters (millions of gallons) of process water from the 100-K Area reactors. Figure 1-8 shows the CrVI plume in 1997 when the 100-KR-4 Pump-and-Treat System started, and in 2007 after 10 years of operation. The 2007 map Figure 1-9, shows the concentration of the plume has been reduced and an area in the middle of the 116-K-2 Trench has been cleaned up below the remedial action goal.

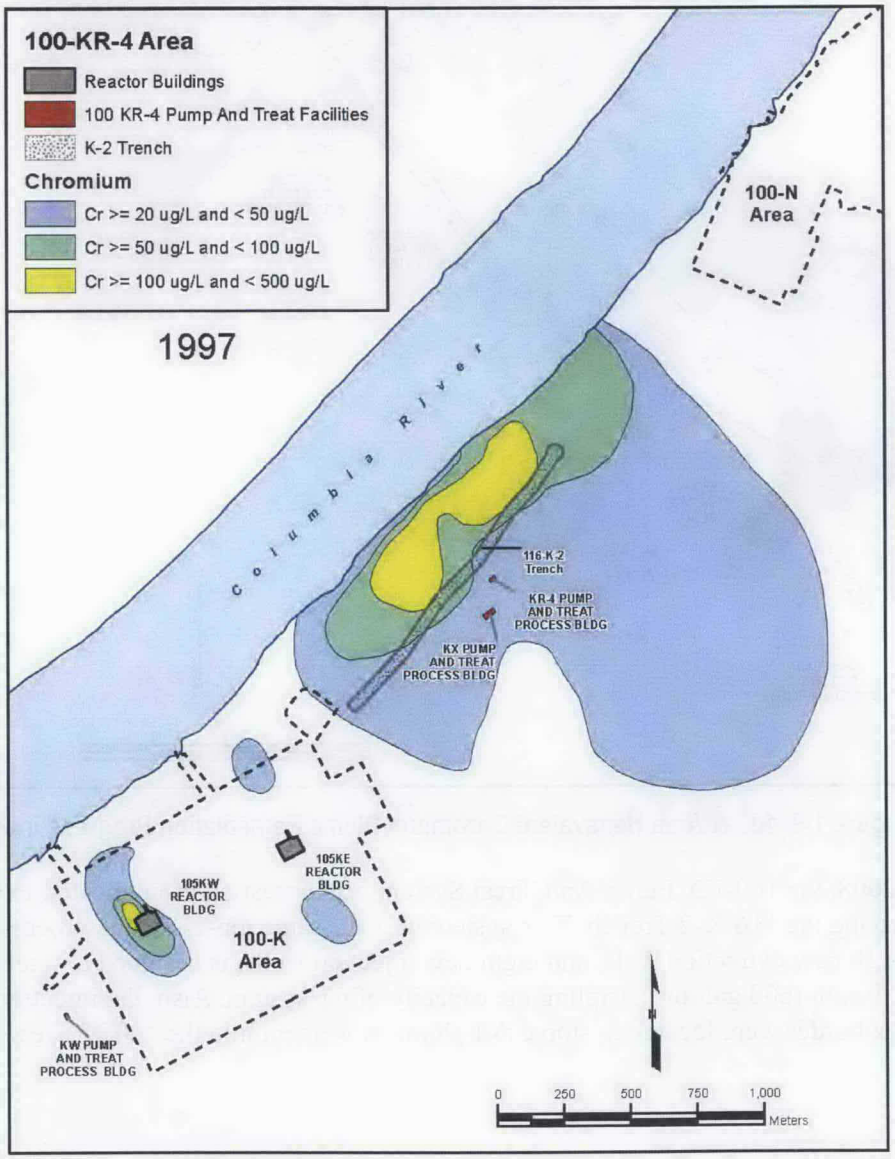


Figure 1-8. 100-K Area Hexavalent Chromium Plume Remediation Progress in 1997

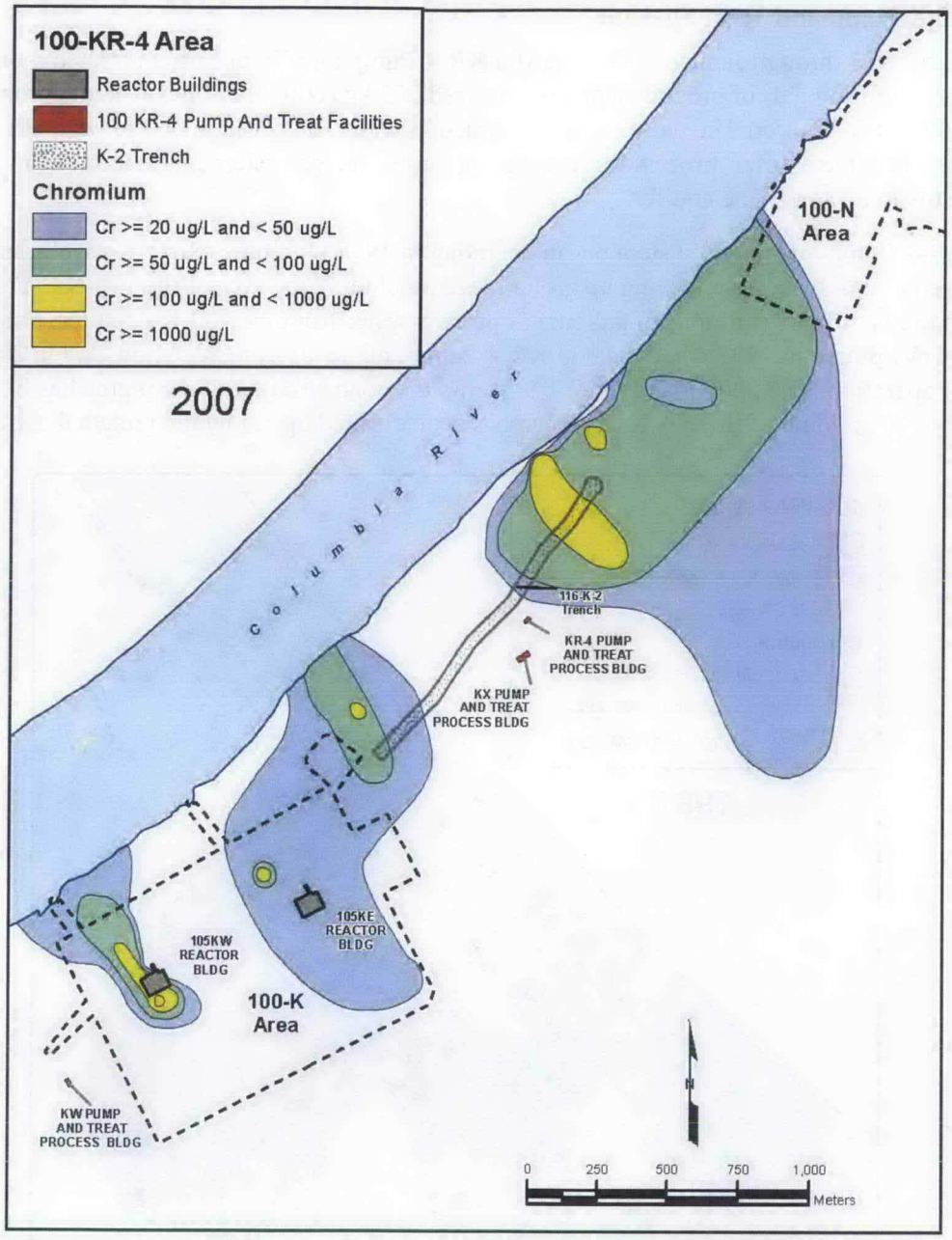


Figure 1-9. 100-K Area Hexavalent Chromium Plume Remediation Progress in 2007

In November 2008, the 100-KX Pump-And-Treat System began treating groundwater, expanding the area of influence around the 116-K-2 Trench. This system uses the same ion-exchange process as 100-KR-4 Well, and with 10 new extraction wells and eight new injection wells, is designed to treat groundwater at a rate of 2,271 L/min (600 gal/min), tripling the capacity of the system. Also, the injection wells on the northeast plume border were located to stop CrVI plume movement into the 100-N Area.

During 100-KX Well development, higher than expected levels of CrVI and tritium were found in some groundwater samples. This information caused the need to realign the wells within the 100-KR-4 and 100-KX Systems. The realignments will maximize plume capture, minimize tritium spread, and increase the groundwater treatment volume. Figure 1-10 shows the proposed location of the 100-KR-4 and 100-KX optimized well network.

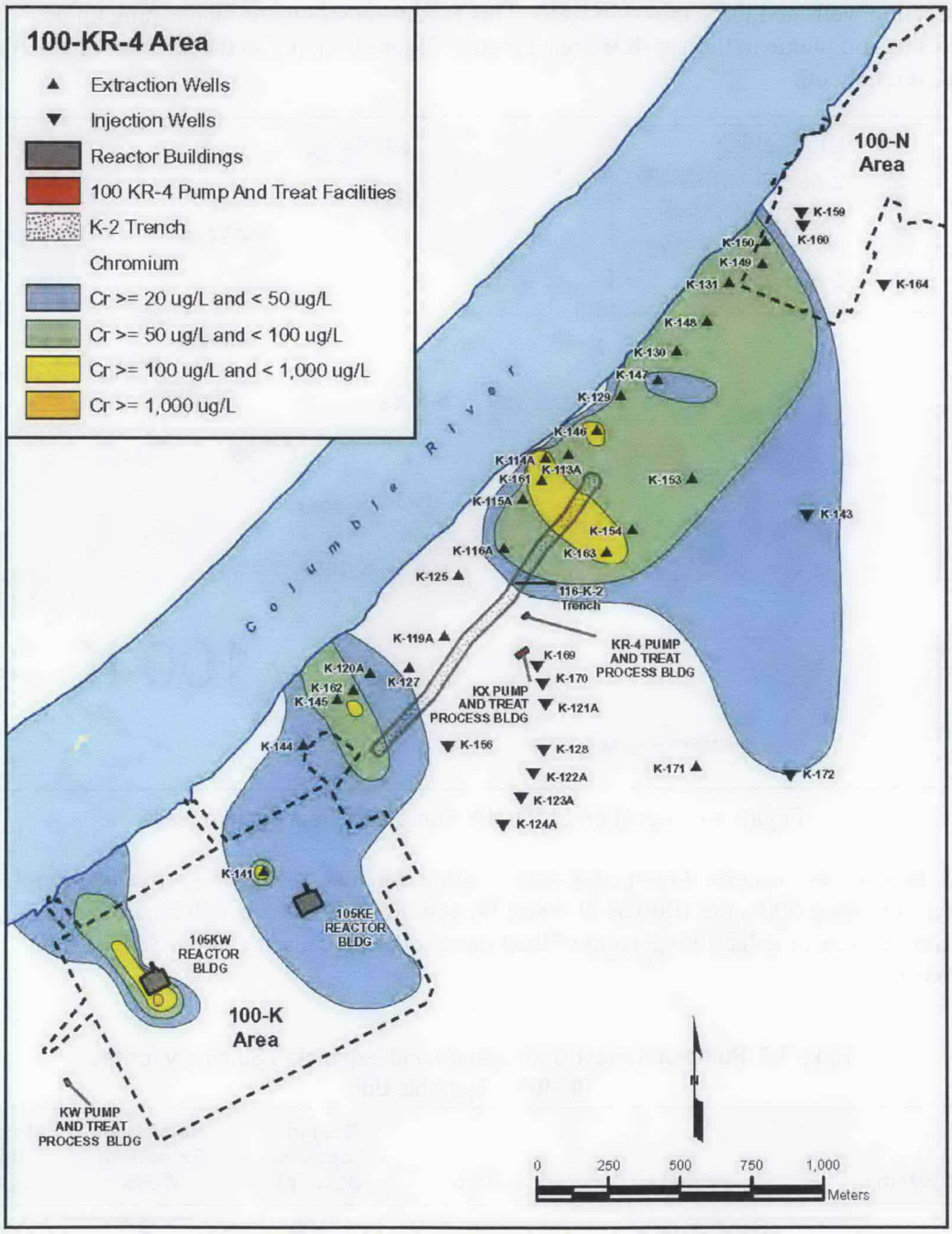


Figure 1-10. Location of the 100-KR-4 and 100-KX Optimized Well Network

In January 2007, the 379 L/min (100 gal/min) capacity 100-KW Pump-and-Treat System began treating the CrVI in groundwater near and downgradient of the 105-KW Reactor, using the same ion-exchange process as the 100-KR-4 Well system. During the first year, the 100-KW Pump-and-Treat System removed 21 kg (46 lb) of CrVI and treated 170 million L (45 million gal) of groundwater.
The 100-KW Pump-and-Treat System is being expanded to double the design treatment capacity to 757 L/min (200 gal/min). As part of this expansion, the well network is being modified to connect a total of six extraction wells and three injection wells. This expansion will focus on cleaning up the high-concentration plume in the 105-KW Reactor area. Figure 1-11 shows the location of the 100-KW expanded well network.

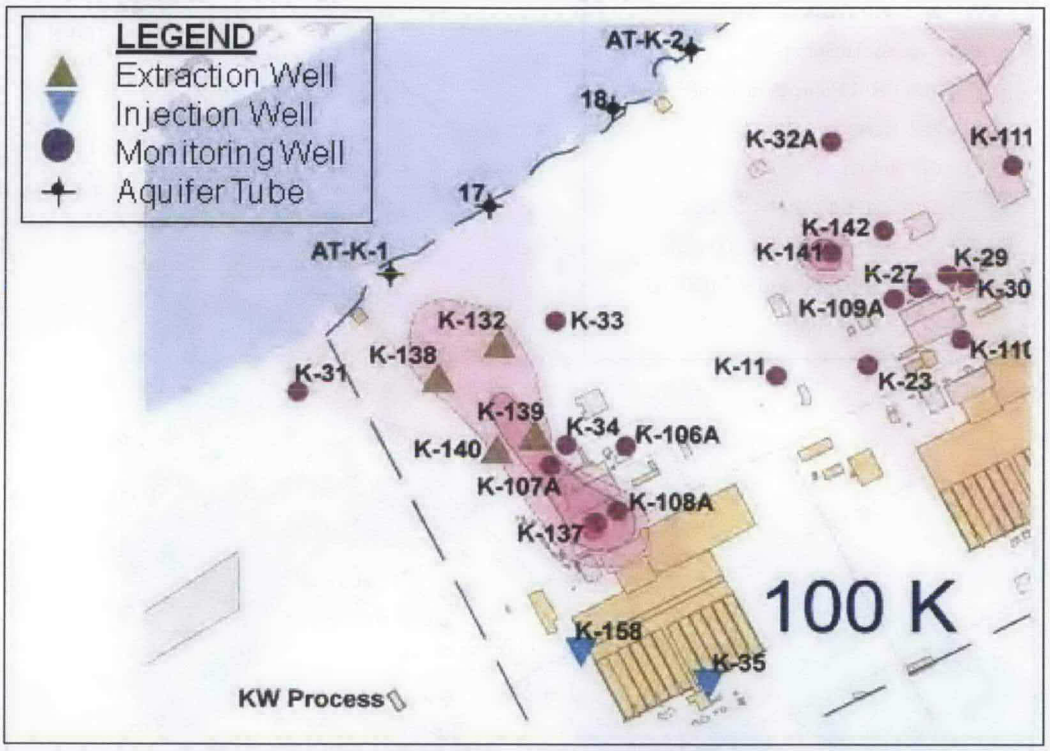


Figure 1-11. Location of 100-KW Pump-and-Treat System Wells

Table 1-2 summarizes the current pump-and-treat systems and their planned improvements and expansions. By spring 2009, the 100-KR-4, 100-KW, and 100-KX systems will be processing groundwater at a rate of at least 90 percent of their current design capacity, about 3,407 L/min (900 gal/min).

Table 1-2. Pump-and-Treat Optimization and Expansion Summary for the 100-KR-4 Operable Unit

System	Actual or Scheduled Start	Design Capacity (gal/min)	Number of Extraction Wells	Number of Injection Wells
100-KR-4	October 1997	300	9	5
100-KX	February 2009	400	10	8
100-KX/KR-4 realign, Phase 1	December 2008, complete acceptance testing in May 2009	~150	3	

Table 1-2. Pump-and-Treat Optimization and Expansion Summary for the 100-KR-4 Operable Unit

System	Actual or Scheduled Start	Design Capacity (gal/min)	Number of Extraction Wells	Number of Injection Wells
100-KX/KR-4 realign, Phase 2	February 2009, complete acceptance testing in January 2010	~50	3	1
100-KW	January 2007	100	4	2
100-KW Expansion	October 2008, complete acceptance testing in May 2009	100	2	1
Totals (February 2010)		**1,100**	**31**	**17**

NOTE: These values are based on current information and may change with future system improvements.

The *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units* (EPA/ROD/R10-96/134) specified three pump-and-treat remedial action objectives (RAOs):

- RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- RAO #2: Protect human health by preventing exposure to contaminants in the groundwater.
- RAO #3: Provide information that will lead to a final remedy.

Institutional controls implemented and maintained along the river corridor have been successful in protecting human health (RAO #2) by limiting access to the site and to groundwater. The pump-and-treat systems have made progress in achieving RAO #1 in the past decade, and the improvements and expansions of the pump-and-treat systems will greatly advance the protection of aquatic receptors. In addition to supporting system efficiencies, evaluating the pump-and-treat systems and their effectiveness will contribute to the FS, and will provide input for the final remedy, thus achieving RAO #3.

1.2.5 Calcium Polysulfide Groundwater Treatability Test

An in situ approach that could be a cost-effective supplement to the present pump-and-treat systems was tested in 2005. The test entailed injecting calcium polysulfide, a strong reducing chemical, into the aquifer. Once in the groundwater, the calcium polysulfide would reduce CrVI to less-toxic and less-mobile trivalent chromium and form a permeable reactive barrier that will continue to reduce CrVI.

This technology effectively reduced CrVI in the aquifer, and the permeable reactive barrier continued reducing CrVI under natural groundwater flow conditions. An analysis of groundwater chemistry before, during, and after the test shows that manganese and iron were mobilized, while arsenic remained near background conditions after the test. The pre- and post-treatment aquifer tests showed that the remediation system did not degrade aquifer permeability.

This test is considered successful, and the data collected are sufficient to scale up the treatment technology. Water in the treatment area continues to be monitored, along with water from a second Well (199-K-130), roughly 200 m (656 ft) downgradient of the test area, to evaluate the persistence of the reducing zone and any adverse effects the test may have on aquifer chemistry.

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2 Site Background and Environmental Setting

Between 1943 and 1963, nine plutonium production reactors were built along the Columbia River. Production of special nuclear materials for national defense was the core function of the 100 Area production reactors. The 100-K Area includes two of these reactors: 105-KE and 105-KW. This chapter provides the background and environmental setting of 100-K and includes information on the waste generated and known and potential contamination.

The information in this chapter primarily derives from WHC-SD-EN-TI-239, *100-K Area Technical Baseline Report*; UNI-946, *Radiological Characterization of the Retired 100 Areas;* DOE/RL-93-78, *Limited Field Investigation Report for the 100-KR-1 Operable Unit;* and other contemporary efforts documenting interim remedial actions (e.g., Waste Information Database System [WIDS] database).

2.1 100-K Overview

To manage the large scope of 100-K remediation activities, the 100-K Area was divided into source and groundwater OUs. Source OUs are concerned with liquid, solid, and radioactive waste disposal sites. The 100-K Area includes the 100-KR-1 and 100-KR-2 source OUs. The 100-KR-4 OU is a groundwater OU located beneath and between the 100-K source OUs.

Construction of the 100-K reactors began in September 1952. The reactors were constructed in tandem to further develop the United States' nuclear deterrent arsenal. Figure 2-1 shows an aerial view of the 100-K Area and the two reactors during construction. Construction was completed and operations commenced at the two reactors in 1955. The reactors initially operated at 1,850 MW and gradually increased output over time to 4,400 MW in 1961, their maximum authorized power. Operation of the 105-KE and 105-KW Reactors continued until their decommissioning. The 105-KW Reactor was decommissioned in 1970, and the 105-KE Reactor was decommissioned in 1971.

2.2 Environmental Setting

The 100-K Area covers an area of approximately 3.1 km^2 (1.2 mi^2). It includes groundwater (100-KR-4 OU) beneath the 100-KR-1 and 100-KR-2 source OUs, and the adjacent surface water, saturated sediment, and aquatic biota affected by operations associated with the reactors (EPA/ROD/R10-96/134). The Columbia River section along 100-K defines a portion of the Hanford Reach, an important ecological, cultural, historical, and recreational feature.

2.2.1 Meteorology

The Hanford Site is characterized by a semiarid, shrub-steppe climate in the driest and warmest portion of the Columbia Basin. Its large size and complex topography can accommodate substantial spatial variations in wind, temperature, precipitation, and other meteorological parameters, which are further affected by mountain barriers (PNNL-6415, *Hanford Site National Environmental Policy Act [NEPA] Characterization*). The Cascade Range to the west creates a rain shadow effect over the Hanford Site's climate, while the Rocky Mountains and ranges in southern British Columbia protect it from the more severe polar air masses from Canada (PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*).

Figure 2-1. 100-K Area Construction (1954; 2675-Neg)

Surface winds blow predominantly from the northwest during winter and summer and from the southwest during spring and fall. In the 100 Area and along the Columbia River, local winds are strongly influenced by near-river topography (PNNL-6415). Strong winds can disperse contamination while waste sites are exposed during excavation or demolition. To minimize this hazard, a variety of methods are employed, including applying dust-suppression water and soluble adhesives to soil as part of remedial activities.

Average monthly wind speeds are lowest during winter, averaging 10 km/h to 11 km/h (6 mi/h to 7 mi/h). The highest average wind speeds, ranging from 14 km/h to 16 km/h (8 mi/h to 10 mi/h), have been reported during summer. Climatologic data are monitored at the Hanford Meteorological Station and other locations throughout the Hanford Site. From 1946 through 2004, the recorded maximum temperature was 45°C (113°F) during July 2002 and August 1961, and the recorded minimum temperature was -30.6°C (-23°F) during February 1950 (PNNL-6415). The monthly average temperature ranged from a low of -0.24°C (31.7°F) in January to a high of 24.6°C (76.3°F) in July. The annual average relative humidity is 54 percent (PNNL-6415).

Annual precipitation measurements historically recorded at the Hanford Site have varied from approximately 8.7 cm to 28.8 cm (3.4 in. to 11.3 in.) since 1947, with an average of 19.5 cm (7.7 in.). Most precipitation occurs during late fall and winter, with more than half of the annual amount occurring from November through February. Snowfall accounts for approximately 38 percent of precipitation from December through February (PNNL-6415). Winter monthly average snowfall ranges from 0.8 cm to 13.5 cm (0.3 in. to 5.3 in.) (March and January, respectively).

2.2.2 Topography

The 100-K Area is situated on relatively flat and level terracing near the river with elevations generally between 120 m and 150 m (394 ft and 492 ft) above mean sea level. Except near the river, the 100-K Area is characterized by low relief and gentle slopes. Topography changes are greatest in the vicinity of the river where surface elevations drop to approximately 116 m (380 ft) above mean sea level. The area has been disturbed and graded extensively by human activity since reactor construction began in the 1950s through present-day waste site remedial activities.

2.2.3 Geologic Setting

The Hanford Site lies within the Pasco Basin, a sub-basin of the Columbia River Basin. The Columbia River Basin comprises much of eastern Washington and northeastern Oregon and is framed by the Cascade Mountains to the west and the Rocky Mountains to the east. An overview of the regional geology of the 100 Area is provided in the work plan (Chapter 2).

An extensive series of flood basalts and sedimentary interbeds form the Columbia River Basalt Group defining the basement rock of the Hanford Site. A sequence of fine- to coarse-grained sedimentary units grouped as the suprabasalt sediments overlie the Columbia River Basalt Group. From deepest to shallowest, the suprabasalt sediments at the 100-K Area are composed of the Ringold Formation, overlain by the Hanford formation, and Holocene surficial deposits (Figure 2-2) (PNNL-14202, *Mineralogical and Bulk-Rock Geochemical Signatures of Ringold and Hanford Formation Sediments*).

In the 100-K Area, in order from deepest to shallowest, the following suprabasalt sediments are of particular interest:

- The Ringold Formation (coarse- to fine-grained sediment) and its various components
- Ringold Upper Mud
- Ringold Unit E
- The Hanford formation (coarse- to fine-grained sediment)
- Holocene surficial deposits (eolian sediment)

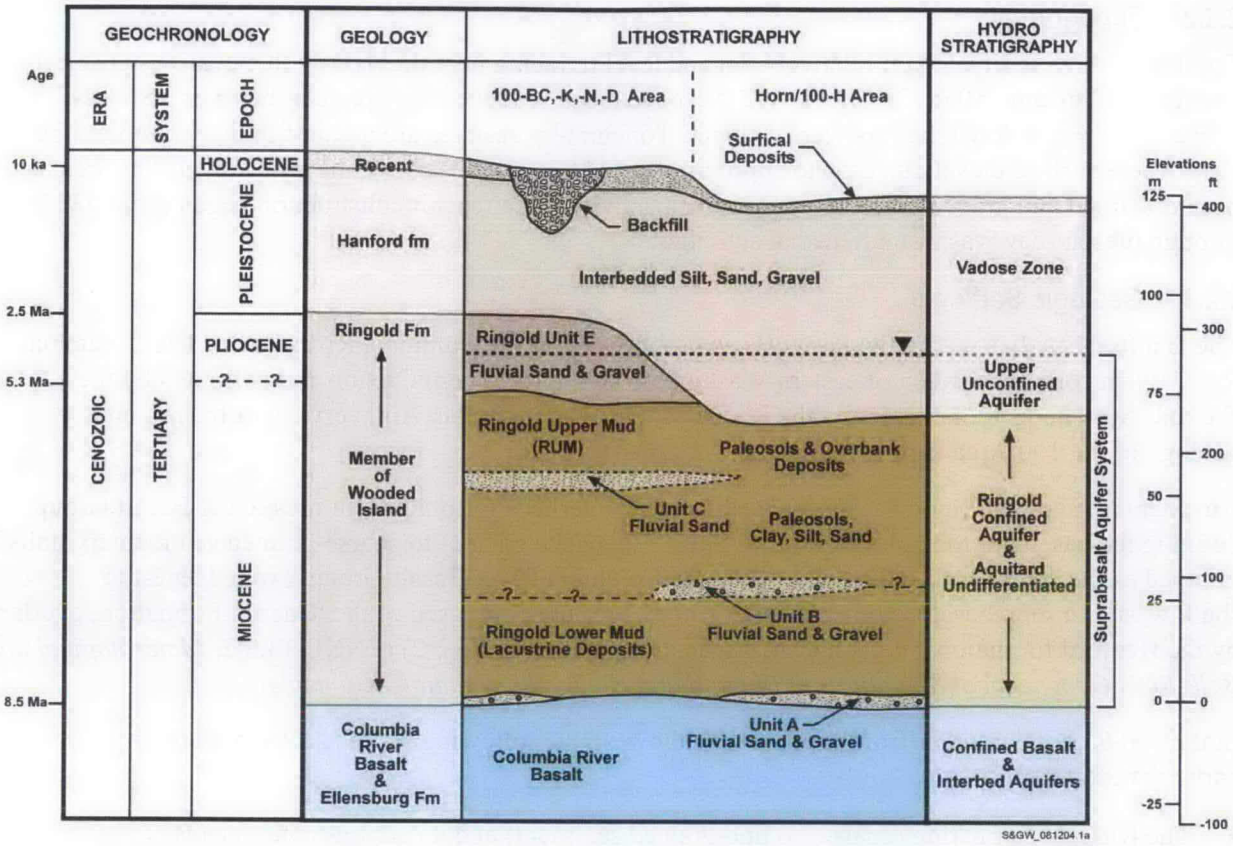

Figure 2-2. Stratigraphic Contacts at the 100-K Area (Generalized 100 Area Hydrogeology)

The geologic and hydrogeologic features and characteristics of most importance to the work plan focus mainly on the prominence, influence, and control over contamination issues relative to the Hanford formation, the Ringold Formation Unit E, the Ringold Upper Mud (RUM) Unit, and to a lesser extent the Ringold Formation Unit B and Ringold Lower Mud, where present (Figure 2-3).

2.2.3.1 *Ringold Formation*

The Ringold Formation[5] consists of six lithofacies units distinguished by grain-size laboratory data and borehole geophysical responses (WHC-SA-0740-FP, *Sedimentology and Stratigraphy of the Miocene-Pliocene Ringold Formation, Hanford Site, South Central Washington*):

1. Mud
2. Mud and sand
3. Sand
4. Sand and gravel
5. Gravel
6. Cobble and boulder

In terms of contaminant mobility, the most important units in the Ringold Formation are the RUM and Unit E.

5 The Ringold Formation initially was described as five laterally traceable lithostratigraphic units of an interstratified sequence of unconsolidated clay, silt, sand, and granule-to-cobble gravel (DOE/RW-0164, *Consultation Draft: Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*; RHO-BWI-ST-4, Geologic Studies of the Columbia Plateau: A Status Report).

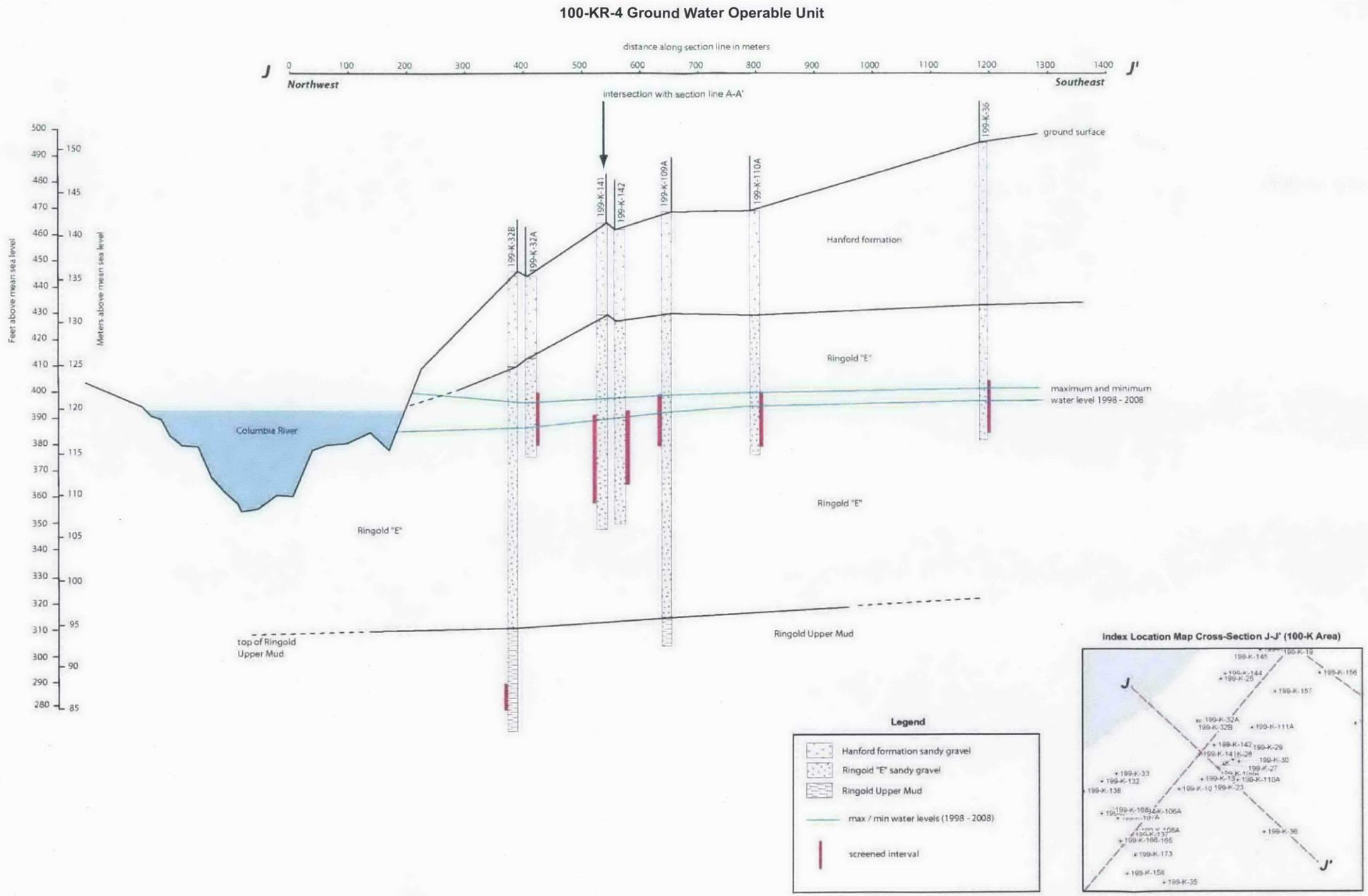

Figure 2-3. Northwest to Southeast Cross Section of the Vadose Zone and Unconfined Aquifer Between the 100-K Area and the Columbia River

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RUM Unit. The RUM Unit is a fine-grained, low-permeability unit (aquitard) that forms the base of the unconfined aquifer at the Hanford Site. Above the basalt, the RUM Unit is the thickest layer present at 100-K, with a maximum thickness of 64 m (209 ft). In 2007 and 2008, several new wells confirmed the depth of the RUM Unit at ~15 m (~49 ft) near the river and greater than 52 m (170 ft) farther inland. This considerable relief difference may be explained as the magnitude of substantial erosional features of the RUM Unit surface.

At 100-K, the bottom of the Columbia River is well above the RUM Unit. Therefore, it is not likely that potential contaminants in the RUM Unit could affect the river or pose a possible threat to ecological receptors.

Ringold Unit E. The extensive Unit E sand and gravel sequence overlies the RUM Unit. Unit E is the most important Ringold unit when evaluating the nature and extent of groundwater contamination. The late-stage catastrophic flooding that deposited the Hanford formation eroded the underlying Ringold Formation. In some areas at 100-K, the Hanford formation has been entirely eroded away. In other areas, scouring created an irregular surface with occasional channel-like features. These channel features are important to understanding contamination fate and transport via these flow paths.

The contact between the Ringold Unit E and the underlying RUM Unit does not intersect the river adjacent to the 100-K Area, based on borings completed beneath the riverbed and interpolation with data from inland borings (WHC-SD-EN-TI-155, *Geology of the 100 K Area, Hanford Site, South-Central Washington*). The Hanford formation/Ringold Formation contact is encountered at an elevation of approximately 135 m (443 ft) (DOE/RL-93-79). The exposure of the Ringold Unit E along the shoreline up to 366 m (1,200 ft) inland is distinct to 100-K (DOE/RL-93-79).

2.2.3.2 Hanford Formation

The water table generally lies near the base of the Hanford formation, where deep vadose zone contaminants have contacted groundwater within the periodically rewetting zone. The Hanford formation is the dominant material in the 100 Area vadose zone and is composed of coarse-grained sand-to-boulder gravel in massive bedding. The unsaturated zone ranges in thickness from zero at the river shoreline to approximately 30 m (100 ft) near the southeastern boundary of 100-K. The Hanford formation coarsens eastward from 100-K (WHC-SD-EN-TI-011, *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas*). It is absent along the shoreline, where the Ringold Formation is exposed from along the riverbank to 366 m (1,200 ft) inland.

The Hanford formation at 100-K is compared to a sand and gravel wedge that increases in thickness away from the river. Being gravel-dominated in the 100-K Area, its sand-dominated intervals have been logged locally, but the information is insufficient to correlate between boreholes (WHC-SD-EN-TI-155; EPA/ROD/R10-96/134; DOE/RL-93-79).

2.2.3.3 Holocene Surficial Deposits

Holocene surficial deposits are composed of silt, sand, and gravel that were deposited by a mix of eolian and alluvial processes. No thicker than 5 m (16 ft), these deposits are observed as a thin veneer across much of the Hanford Site, where the surface has not been disturbed or altered by construction activities.

2.2.3.4 100-K Cross Sections

The two major stratigraphic units in 100-K that comprise the vadose zone and the unconfined aquifer are the Hanford formation and the Ringold Formation. These units vary in thickness depending on the location, as do the thicknesses of the vadose zone and unconfined aquifer. Figure 2-3 shows a cross section close to the northern end of the 100-KW/KE Facilities that is roughly parallel to the river shore and perpendicular to the 100-KW Facilities.

Figure 2-4 shows a second cross section roughly perpendicular to the Figure 2-3 cross section that runs through the 100-KW Facilities.

The vadose zone and unconfined aquifer configuration to the north of the 100-K Area are shown in Figure 2-5, a cross section that runs parallel to 116-K-2 Trench beginning south of the 116-K-2 Trench and extending 100 m (328 ft) to the north. The portion of the cross section that parallels the 116-K-1 Crib is also shown. The vadose zone is made of varying thicknesses of the Hanford formation and the Ringold Unit E, and the unconfined aquifer is contained almost entirely in the Ringold Unit E.

The variation in the RUM Unit surface elevation causes substantial changes in the unconfined aquifer thickness, not only along this cross section but further inland as well. Unconfined aquifer thickness contours are shown in Figure 2-6. These contours largely reflect the surface contours of the RUM Unit. From this map view perspective, the steep decline in the RUM surface elevation shown in Figure 2-5 is a relatively deep channel running across the southern end of the 116-K-2 Trench (perpendicular to the trench and the long axis of the Columbia River).

A secondary channel also is present toward the north end of the 116-K-2 Trench. Generally speaking, the aquifer thickens to the southwest and is about twice as thick under the 116-K-2 Trench compared to the area northeast of the 116-K-2 Trench.

2.2.4 Hydrogeology

The groundwater flow system beneath the Hanford Site remains a primary pathway for contaminants to migrate away from source areas and, for some contaminants, to discharge into the river. Characterization of hydrogeology at the 100 Area requires understanding of the properties and behavior of the vadose zone, groundwater, and surface water sources, interfaces, and interactions. The hydrogeology of the Hanford Site reflects a balance and interdependence of surface water (Columbia River), the unconfined and confined aquifers, and the vadose zone.

2.2.4.1 Vadose Zone Transport

Contaminant transport through the vadose zone may occur in multiple types of phases over intermittent time frames. Contaminant materials may: enter soil periodically in rainwater solutions, precipitate within the upper portions of the soil as solids, deposit as airborne particulates, transport in the subsurface by biomechanical transport mechanisms (burrowing animals), or exist part of an infrastructure loss (leaks and spills) and move across pore spaces by gaseous diffusion.

100-KR-4 Ground Water Operable Unit

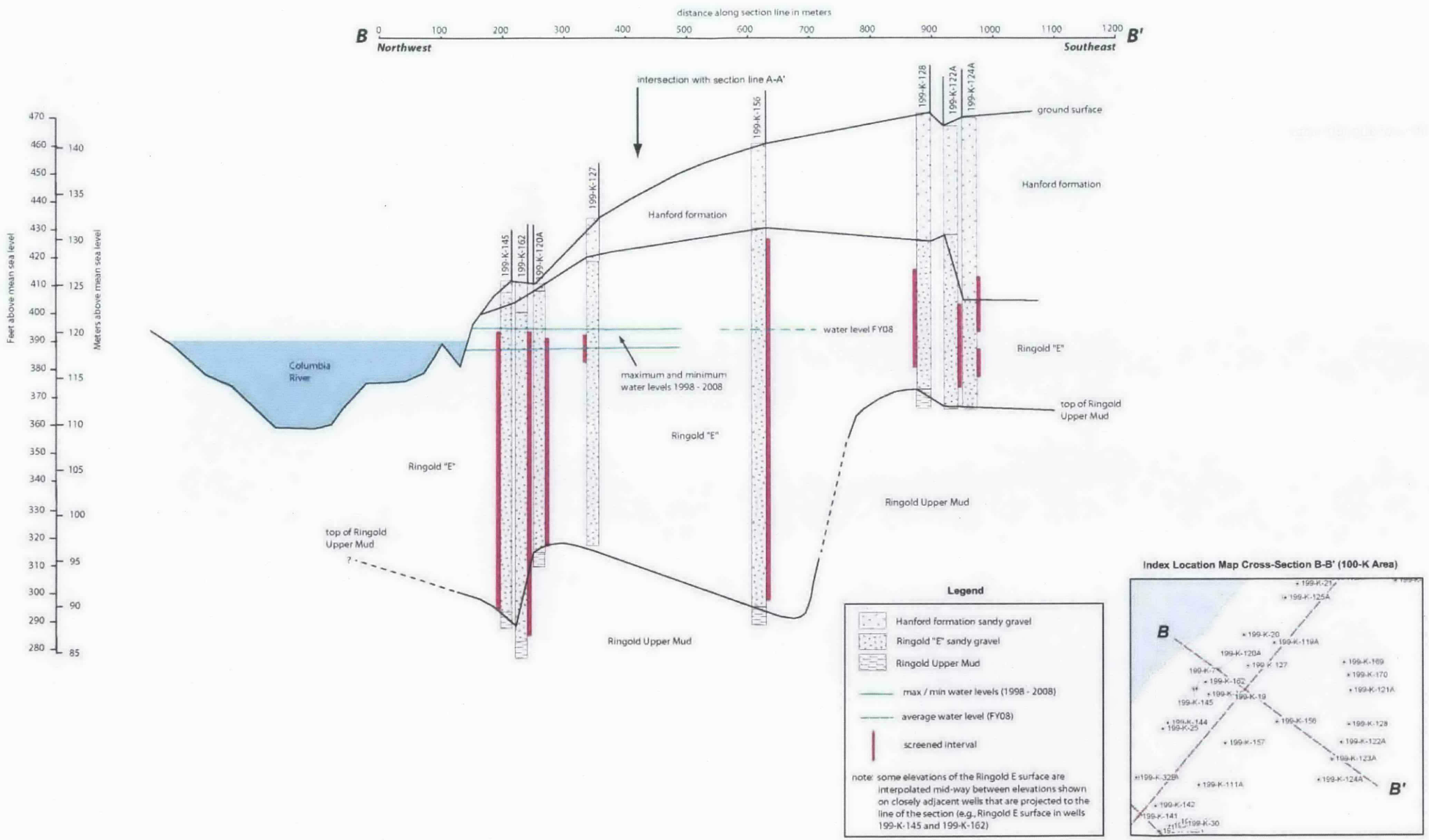

Figure 2-4. Northwest to Southeast Cross Section of the Vadose Zone and Unconfined Aquifer Perpendicular to the Columbia River and Across the 100-KW Facilities

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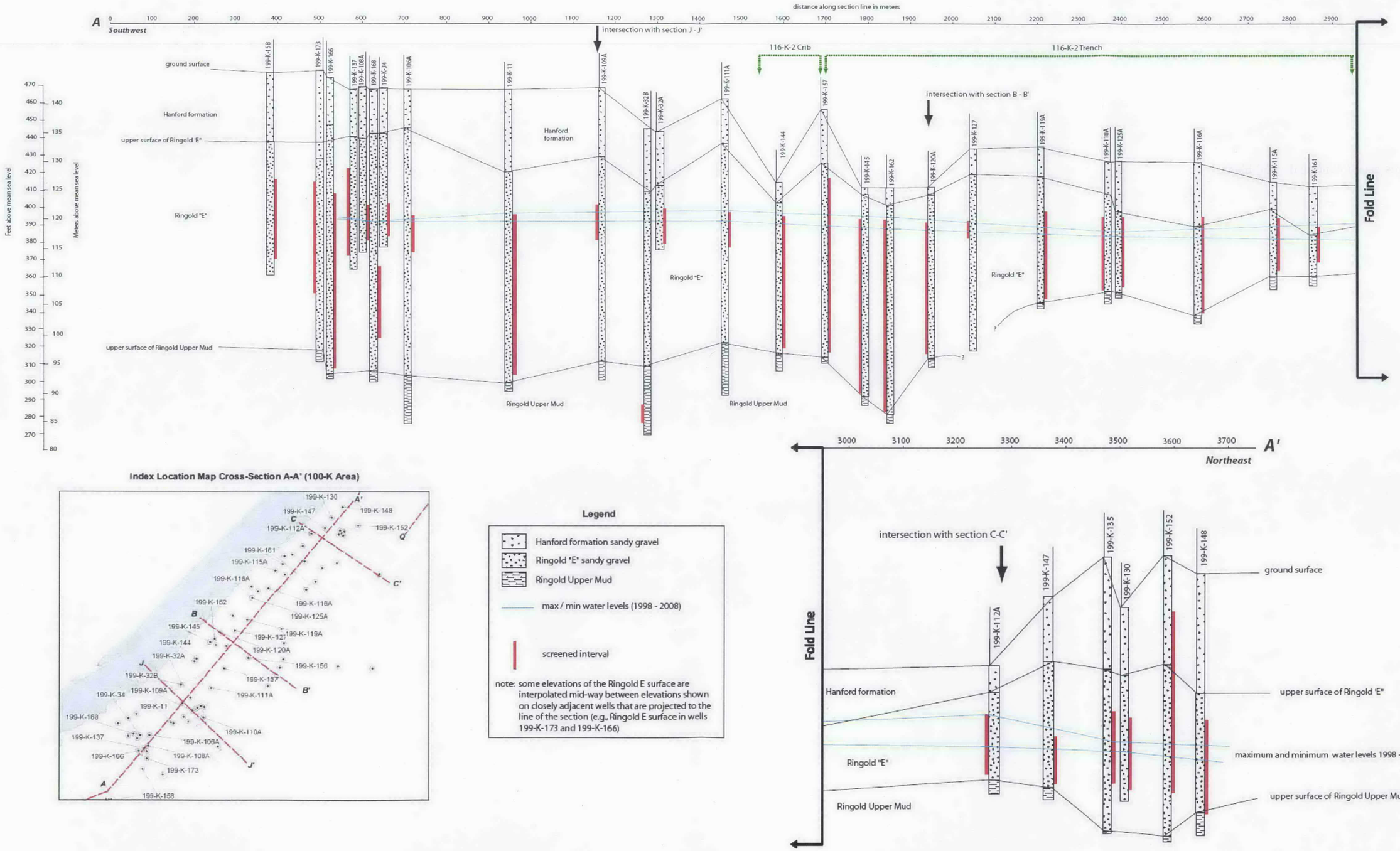

Figure 2-5. Southwest to Northeast Cross Section of the Vadose Zone and Unconfined Aquifer Between the 116-K-2 Trench and the Columbia River

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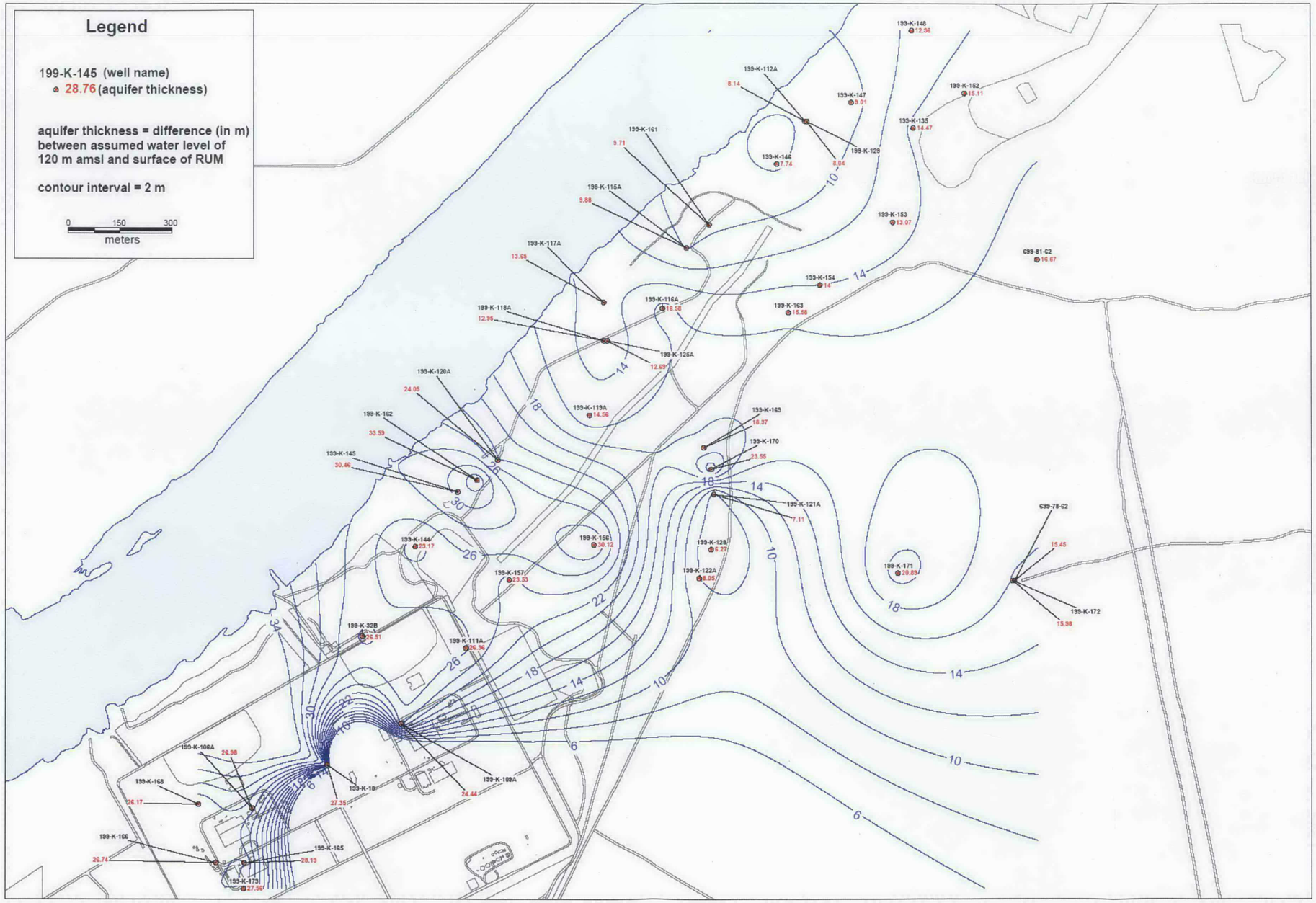

Figure 2-6. Unconfined Aquifer Thickness in the 100-K Area

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Vadose zone moisture content changes with location along with changes in soil matrix potential, and the corresponding anisotropy (ratio of horizontal to vertical hydraulic conductivity) varies in unsaturated flow. Thus, as saturation decreases, anisotropy increases, resulting in a dominance of lateral flow over vertical flow. This condition is unlike saturated flow where, with no changes in saturation (saturation is constant), anisotropy is a constant (saturation-dependent anisotropy). Extensive moisture content data have been collected that show evidence for variable anisotropy for unsaturated media. The gravels of the Hanford formation promote a relatively high transmissivity rate, and therefore an elevated rate of contaminant migration is expected in its highly permeable gravels (WHC-SD-ER-TI-003, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*).

2.2.4.2 Hydrologic Conditions

Both natural and manmade hydrologic processes have influenced groundwater flow patterns and contaminant distribution in the subsurface underlying the 100-K Area. The effects of natural processes on contaminant migration are ongoing, while the effects of manmade operations (e.g., the high-volume liquid discharges into the 116-K-2 Trench) have diminished over time with the cessation of reactor operations. However, some residual effects have not completely dissipated and other manmade processes continue to influence contaminant migration, particularly ongoing pump-and-treat operations.

Groundwater flow patterns for the unconfined aquifer are shown in Figure 2-7. Generally, 100-K groundwater flows southeast to northwest and perpendicular to the Columbia River. To the northeast, beyond the 116-K-2 Trench, flow transitions to a more northeasterly direction parallel to the Columbia River.

Groundwater flow is influenced by river stage. During the fall when river stage is relatively low, groundwater flow is toward the river. In spring, when river stage is high, groundwater can flow away from or parallel to the river to the northeast. High river stages can be more than 3 m (10 ft) higher than low river stage. River stage can also fluctuate several meters (several feet) over short time periods (i.e., hours to days) based on Columbia River dam operations (DOE/RL-96-84, *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*). Changing river stage influences groundwater elevations several hundred meters (several hundred feet) inland from the river. The groundwater level response to changes in river stage is more delayed and attenuated that farther inland from the river.

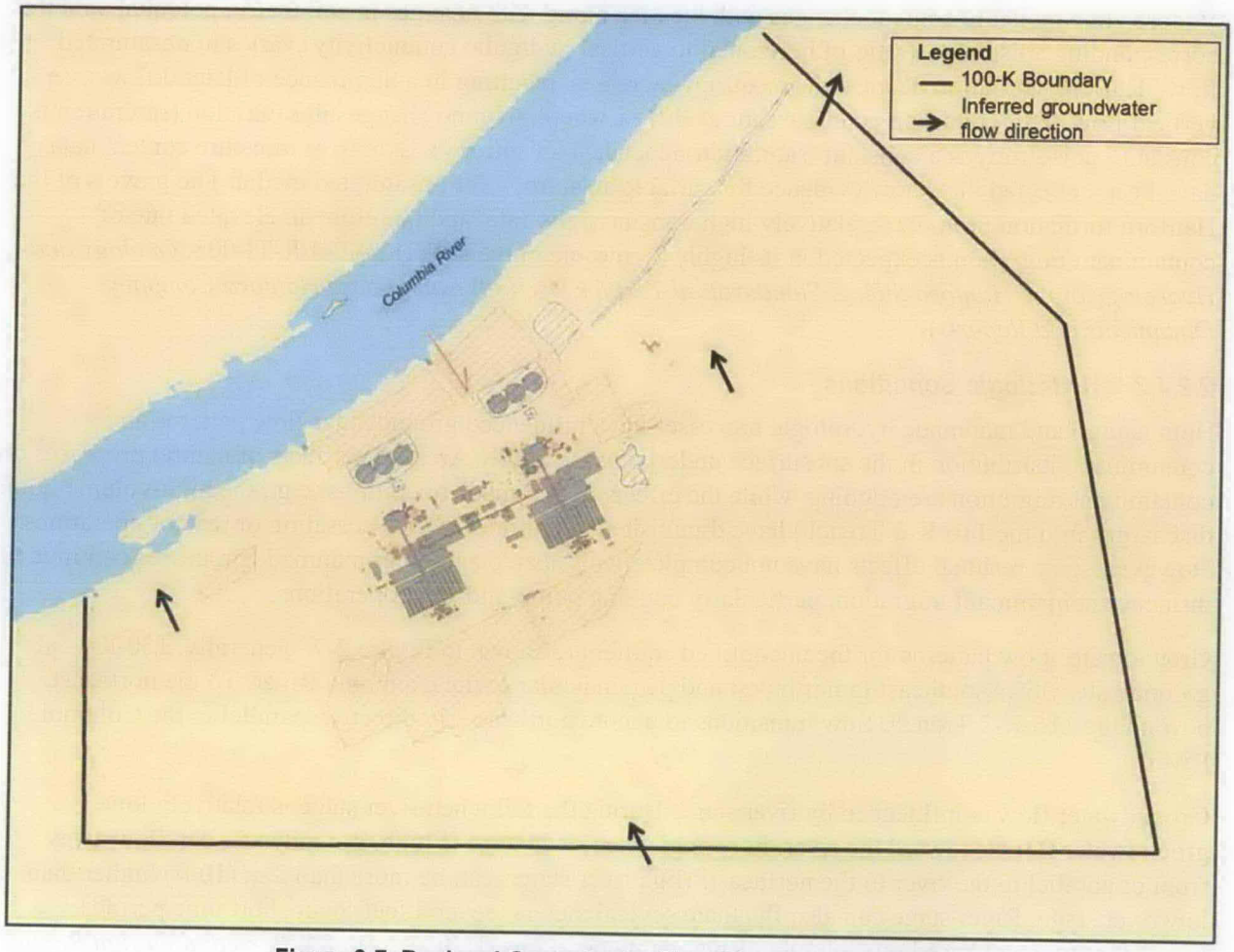


Figure 2-7. Regional Groundwater Flow Directions in 100-K

In the 100-K Area, the primary man-made influence on groundwater flow patterns was discharge of reactor coolant to the 116-K-2 Trench, which created a large groundwater mound. The impact to the water table from these discharges is illustrated in Figures 2-8, 2-9, and 2-10. Head data for three wells are shown in Figure 2-8. These wells are located south, southwest, and west of the 116-K-2 Trench and show similar trends. Of these wells, the most complete record is available for monitoring Well 699-70-68 beginning in August 1955. Head elevation at this well, located about 1.6 km (1 mi) southwest of the 116-K-2 Trench, rose steadily to a peak in April 1968 before beginning to drop. From these data it is clear the groundwater mound began developing shortly after discharge to the 116-K-2 Trench began and expanded until the late 1960s. Figure 2-9 shows the groundwater mound effects on the water table in 1967. Given the head data shown in Figure 2-8, this figure demonstrates nearly the maximum areal influence of the groundwater mound in the 100-KR-4 groundwater OU. After discharges to the trench ceased, the groundwater mound began to contract, and by the mid-1970s the groundwater mound had greatly dissipated. The 1989 water table map (Figure 2-10) shows a regional gradient rather than groundwater mound effects.

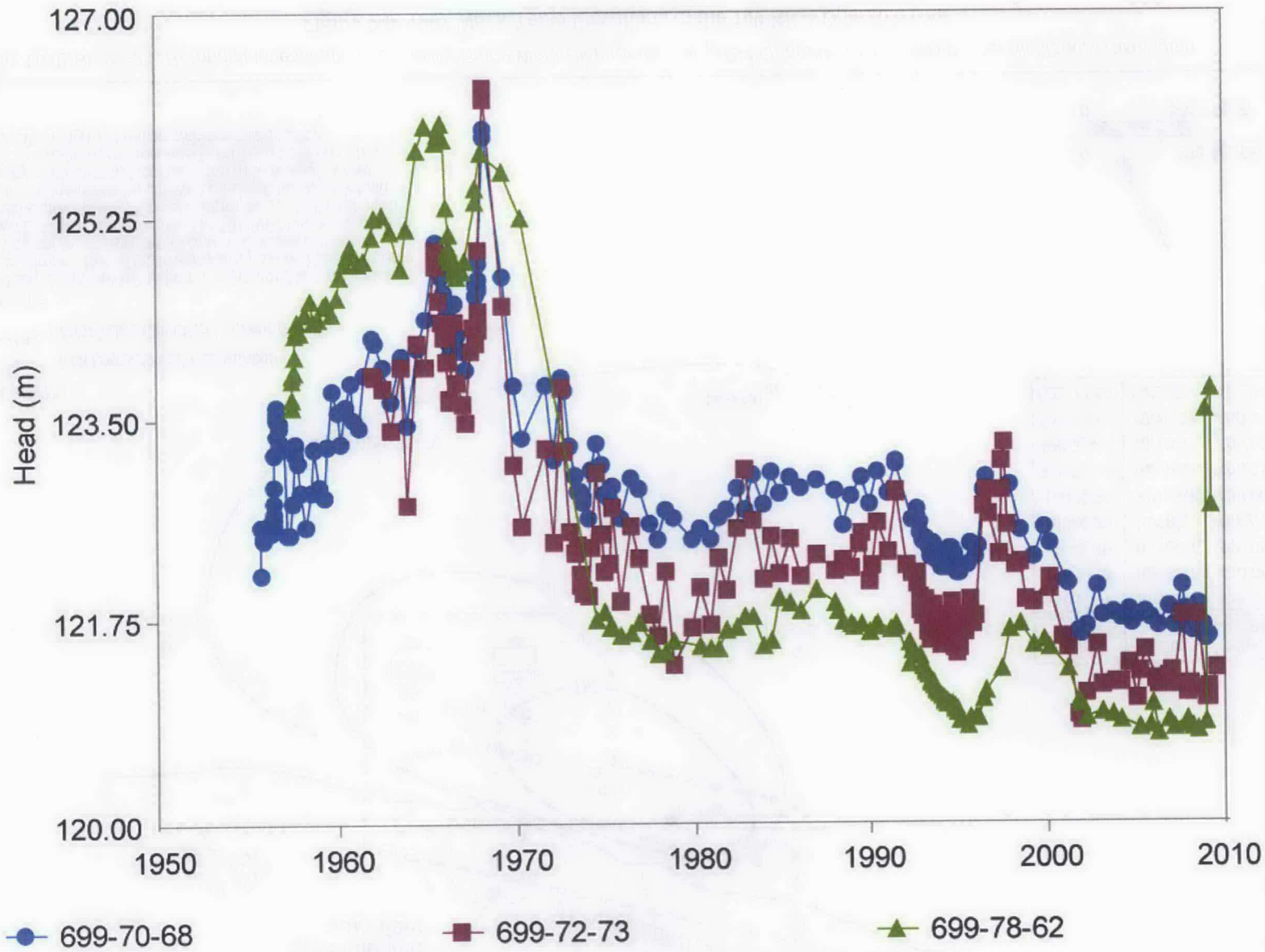
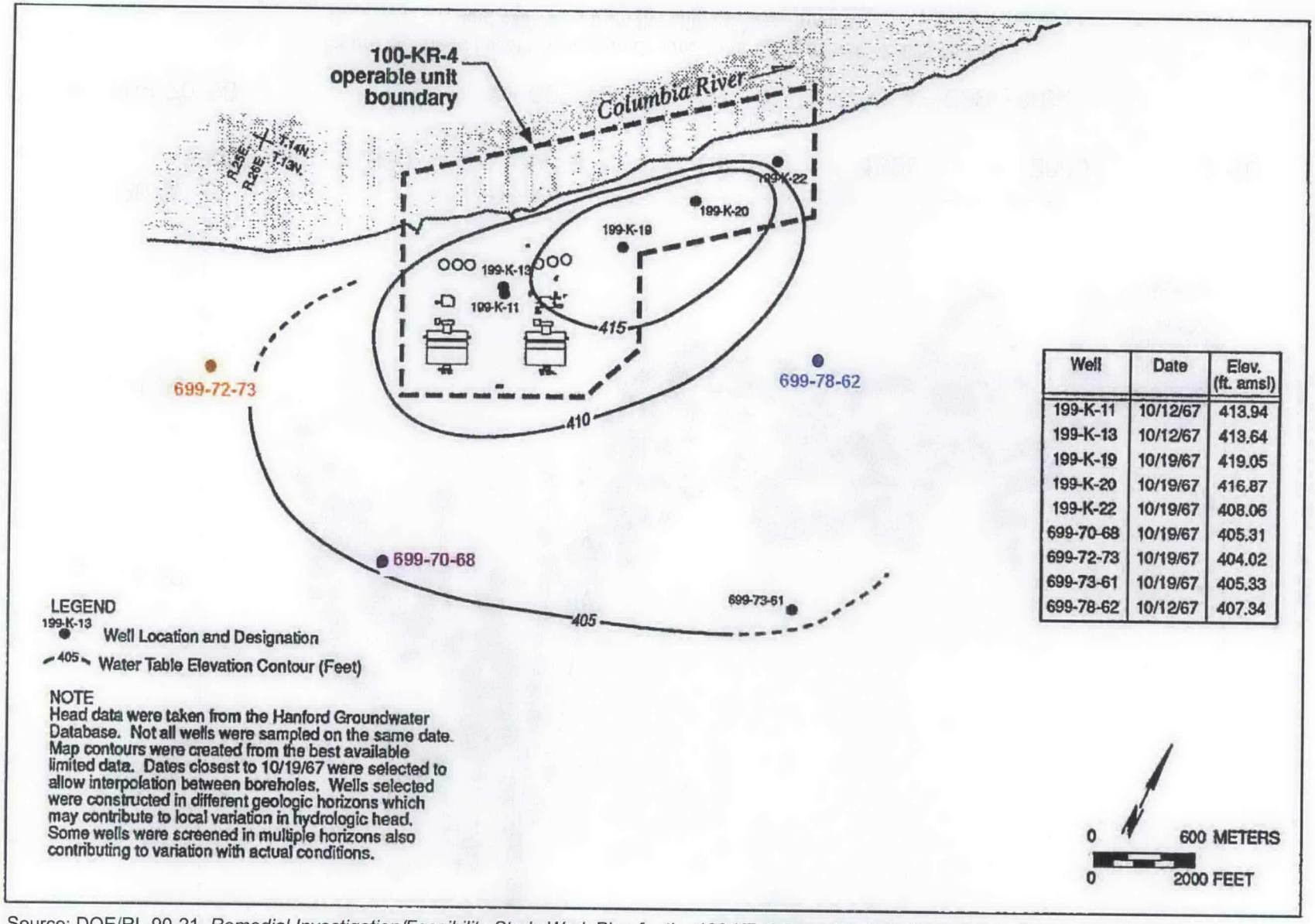


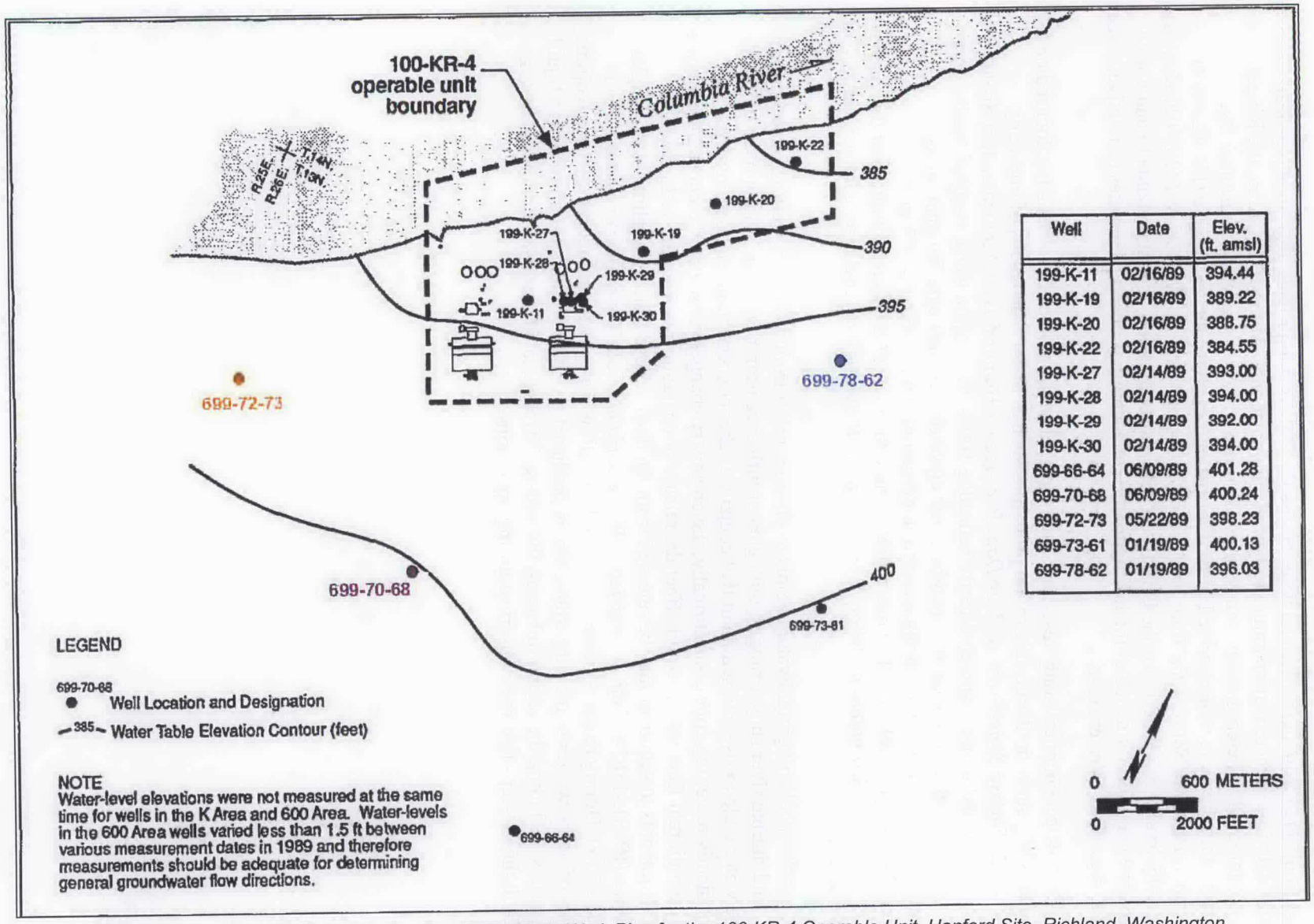
Figure 2-8. Head Level Changes in Groundwater Wells 699-78-62, 699-70-68, and 699-72-73 from the Mid-1950s to Present



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

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

Figure 2-9. 1967 Water Table Elevations in the 100-KR-4 Operable Unit



Well	Date	Elev. (ft. amsl)
199-K-11	02/16/89	394.44
199-K-19	02/16/89	389.22
199-K-20	02/16/89	388.75
199-K-22	02/16/89	384.55
199-K-27	02/14/89	393.00
199-K-28	02/14/89	394.00
199-K-29	02/14/89	392.00
199-K-30	02/14/89	394.00
699-66-64	06/09/89	401.28
699-70-68	06/09/89	400.24
699-72-73	05/22/89	398.23
699-73-61	01/19/89	400.13
699-78-62	01/19/89	396.03

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

Figure 2-10. 1989 Water Table Elevations in the 100 KR-4 Operable Unit

2.2.4.3 Hydrogeologic Characteristics

Data were collected from boreholes and wells across the 100 Area to provide area-wide physical properties data for characterization and to initiate cleanup planning. At the 100-K Area, the Ringold Unit E is composed of heterogeneous sandy gravel deposits of low-to-moderate transmissivity. The contact with the more transmissive Hanford formation lies above the water table (PNNL-14031, *Evaluation of Potential Sources for Tritium Detected in Groundwater at Well 199-K-111A, 100-K Area*). The lower hydraulic conductivity of the Unit E soil delays the migration of contaminants to and within the unconfined aquifer. Evidence of the low hydraulic conductivity is observed in areas of relatively steep gradients, regardless of river stage.

The 100-N Area geochemical study results, considered applicable to other 100 Area sites, focused on contaminants that show moderate adsorption properties such as Sr-90. The results of one study (PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assess*) indicated that Sr-90 in the vadose zone is bound to the sediment directly beneath a 100-N Area liquid waste disposal facility in a relatively thin layer that corresponds to depths of the elevated water table during operations. Alternatively, contaminants with strong adsorption properties (i.e., Co-60, Cs-137, and plutonium-239/240 [Pu-239/240]) had not migrated more than 1 m (3 ft) from the bottom of the disposal facility (PNL-10899, *Strontium-90 Adsorption-Desorption Properties and Sediment Characterization at the 100-N Area*).

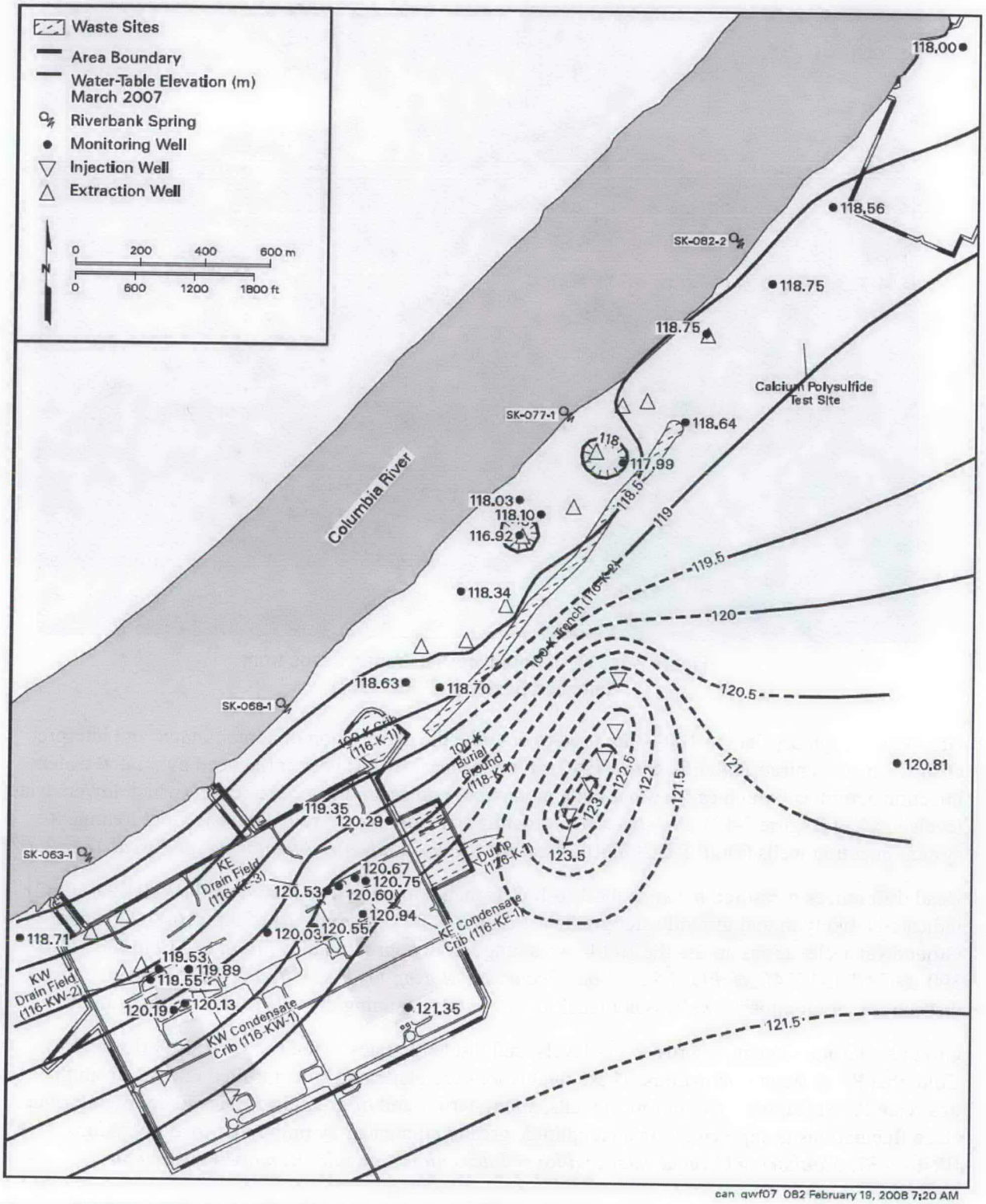
Further, geochemical and groundwater chemistry changes result from constant rewetting of soil during seasonal and diurnal river stage changes, with greater influence nearer the river. A high river stage can cause the water table to rise into sediment that contains higher concentrations of contaminants (the periodically rewetting zone). Additionally, the chemistry changes caused by the constant rewetting of the soil from diurnal fluctuations could affect the release of contaminants from the vadose zone. Thus, contaminants in sediment may be released from the deep vadose zone by washing during higher water events (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River*). During reactor operations, groundwater flow was greatly influenced by large-volume discharges of liquid wastes to the subsurface, which produced groundwater mounds around high liquid discharge sites, including the retention basins, the 116-K-2 Trench, and the 100-K-56 Process Sewer. Figure 2-11 shows seeps that were observed during operations.

Figure 2-11. 100-K Shoreline, Illustrating Seeps from Retention Basins (107-KE; 1967)

Groundwater quality data in 100-K are used to describe the distribution of contaminants and interpret changes in concentration trends. Since 1997, groundwater flow has been influenced by treated water injection activities (which cause water table mounding) and groundwater extraction (which lowers water levels locally) (Figure 2-12). Post-operation groundwater flow moves radially away from treatment system injection wells (DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*).

Head differences measured between the 116-K-2 Trench bottom and an inland well (Well 699-78-62) indicated a likely inland groundwater gradient 1,220 m (4,003 ft) southeast of the 116-K-2 Trench. Groundwater elevations across the 100-K Area range from approximately 116 m to 119 m (381 ft to 390 ft) (PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*). However, the distribution of monitoring wells is not ideal for accurately mapping the water table configuration.

Groundwater movement patterns, water levels, and discharge rates to the river are also affected by Columbia River stage fluctuations. These fluctuations are generated by controlled releases from the upstream Priest Rapids Dam. For most wells, a long-term trend of groundwater levels following river stage fluctuations is apparent, with an amplitude greatly attenuated by pump-and-treat operations (PNL-9437, *Monitoring Groundwater and River Interaction Along the Hanford Reach of the Columbia River*).



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

Figure 2-12. 100-K Area Water-Table Map, March 2007

River water infiltrates the banks during periods of high river stage, and contaminant concentrations in near-river groundwater may become diluted before their eventual release to the river through riverbed sediment and riverbank seeps. River stage also affects the elevation of the water table beneath the 100-K Area. Higher-than-typical contaminant concentrations were noted during the seasonal high river conditions in 1996 and 1997, near liquid waste disposal sources (DOE/RL-2008-05, *Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operation*).

Groundwater flows are driven by a steeper gradient near the 105-KE Reactor. A plausible explanation is that the aquifer material is sufficiently variable and of relatively low hydraulic conductivity. The low hydraulic conductivity found at the 100-K Area indicates that the former groundwater mounding beneath the 116-K-2 Trench was substantial during its use. Further, acknowledgement of the low hydraulic conductivity at the 100-K Area is evident by the extensive length of the trench necessary to accommodate inflow liquid waste during operations without breaching the trench (DOE/RL-93-79).

Reasonable hydraulic property assumptions for the aquifer at the 100-K Area are based on published reports and various datasets. The 100-K Area horizontal hydraulic conductivity is estimated at 2 m/day to 30 m/day (6.6 ft/day to 98.4 ft/day). An effective porosity range has been estimated at 10 percent to 20 percent. Hydraulic gradient estimates range from 0.003 to 0.006 (PNNL-14031). Groundwater flows at an average rate of 0.1 m/day to 0.3 m/day (0.024 ft/day to 0.072 ft/day), as estimated from hydraulic gradients, and from migration rates of plumes (PNNL-14031). The best-supported estimate for groundwater flow rate between the 105-KE Reactor and the river is 0.12 m/day (0.4 ft/day) and is based on the migration of a plume created by a leak from the 105-KE Basin in 1993 (PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*). Faster flow is observed beneath the 105-KW Reactor than below the 105-KE Reactor (PNNL-14031). This rate suggests a 10- to 12-year travel time for tritium and other mobile contaminants from the vicinity of the 105-KE Reactor to the river. Waste constituents that interact with sediment, such as Sr-90 and C-14, travel more slowly (DOE/RL-2008-05).

Because of an inferred seasonal change in flow direction, changes in contaminant concentrations have been caused by shifts in the positions of plumes (WHC-SD-EN-AP-174, *Groundwater Monitoring and Assessment Plan for the 100-K Area Fuel Storage Basins* and PNNL-12023). Groundwater elevations varied by up to 0.9 m/day (3 ft/day) in some wells nearest the river and up to approximately 1.8m (6 ft) over the season in a few wells (PNL-9437). Artificially induced changes to groundwater flow have also been observed. The appearance of relatively high Sr-90 concentrations near the northwestern corner of the 105-KE Reactor building likely was caused by remobilizing a vadose zone Sr-90 source by infiltration of water from overlying fire-suppression water utility lines and hydrants (PNNL-14031).

2.2.5 Environmental Resources

Environmental resources are widespread across the Hanford Site, with significant cultural and historical heritage resources established from the riverfront environment to the ridge tops (DOE/EIS-0119F, Addendum *[Final Environmental Impact Statement]: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*). The Hanford Reach National Monument was formed to place high priority on shrub-steppe community habitat maintenance and enhancement for native species throughout the Monument. Washington State has designated shrub-steppe communities as priority habitat because of their significance to a number of wildlife species and the scarcity of this habitat type. In addition, the U.S. Department of the Interior has identified native shrub and grassland steppe in Washington and Oregon as an endangered ecosystem.

2.2.5.1 Flora

Native pre-settlement vegetation consisted primarily of shrubs, perennial bunchgrasses, a variety of forbs, and a living soil crust composed of lichens, moss, and algae. Much of the native flora in the 100 Area has been disturbed by agricultural and livestock practices from Euro-American settlement in the early 20th century and later by Hanford Site construction, operation, and post-operation activities, resulting in the introduction of non-native plant species. Large tracts of land adjacent to the 100-K Area and the other reactor areas that were farmed are now dominated by stands of cheatgrass (*Bromus tectorum*). Despite these old fields, many locations on the Hanford Site are relatively free of non-native species and are extensive enough to retain characteristic populations of shrub-steppe plants and animals. Unaffected areas support desert shrubs and drought-resistant grasses and forbs. The predominant plant community in the 100 Area is sagebrush/Sandberg's bluegrass/cheatgrass. Other shrub communities are dominated by bitterbrush, hopsage, and rabbitbrush (PNNL-6415). A relatively narrow riparian zone supports grasses, sedges, and scattered deciduous shrubs and trees such as willow, mulberry, and Siberian elm along the banks of the river.

No plant species on the Hanford Site are currently listed as threatened or endangered under the *Endangered Species Act of 1973*, but two species of plants are candidates for federal protection: Umtanum desert buckwheat (*Eriogonum codium*), which occurs in several small, highly localized populations on Umtanum Ridge, and the White Bluffs bladderpod (*Lesquerella tuplashensis*), which occurs on White Bluffs. Additional plant species are listed as threatened or endangered by Washington State. Several of these, including the awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and persistentsepal yellowcress (*Rorippa columbiae*) are restricted to wetlands in the riparian zone of the Columbia River (PNNL-6415).

2.2.5.2 Fauna

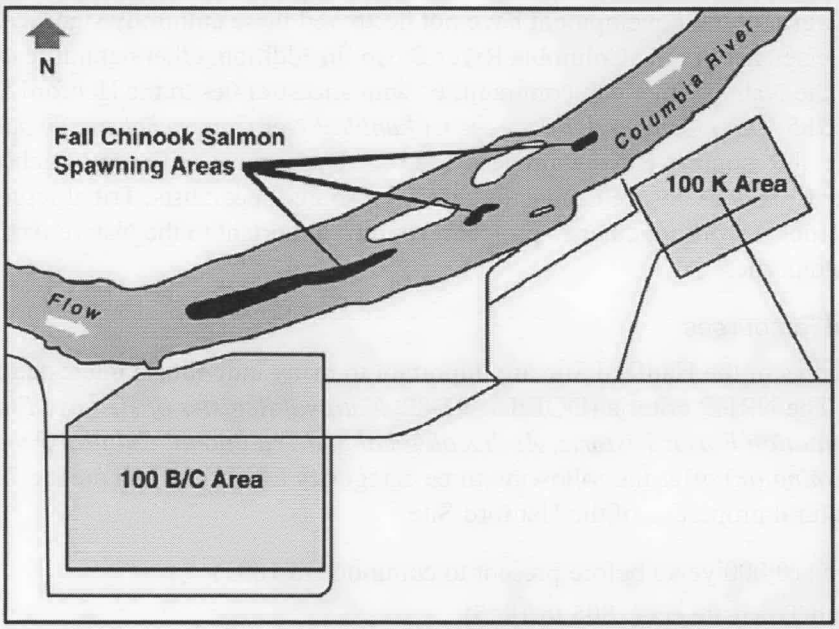
The shrub and grassland habitat of the Hanford Site supports many groups of terrestrial wildlife. Species include large animals such as Rocky Mountain elk (*Cervus elaphus)* and mule deer (*Odocoileus hemionus)*; predators such as coyote (*Canis latrans)*, bobcat (*Lynx rufus)*, and badger (*Taxidea taxus)*; and herbivores including deer mice (*Peromyscus maniculatus)*, harvest mice (*Riethrodontonomys megalotis)*, ground squirrels (*Spermophilus* spp.), voles (*Lagurus* spp., *Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus)*. The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus)*. Many of the rodent species and some predators (badgers) construct burrows on the site. Other nonburrowing animals including cottontails (*Sylvilagus nutalli)*, jackrabbits, snakes, and burrowing owls (*Athene cunicularia)* may utilize abandoned burrows of other animals.

The height of the steep bluffs along the river in the 100 Area and the location of most of the facilities back from the edge of the bluff minimize the line-of-sight effect that human activity might otherwise have on eagles and other nesting birds (DOE/RL-94-150, *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington*). In addition, few trees remain close to the reactor areas, which further limits the potential of line-of-sight effects. However, the trees immediately upriver of the 100-K Area are an exception, and roosting eagles can be seen in these trees from the west end of the 100-K Area during winter months.

Human occupancy at the Hanford Site has had a great effect on wildlife populations. To support agricultural development, wildlife species (i.e., mule deer and coyote) were believed to threaten crops and livestock and were targeted for population reduction. On the other hand, trees planted for use as windbreaks by early settlers have since survived to provide much-needed nesting and perch sites for

raptors and some waterfowl (Rickard et al., 1982, "The Non-Fisheries Biological Resources of the Hanford Reach of the Columbia River"). Seasonal populations of Canada geese and other birds forage in the riparian zones and old (cultivated) fields that are now dominated by cheatgrass (Eberhardt et al., 1989, "Survival of Juvenile Canada Geese During the Rearing Period").

Important game species that inhabit the Columbia River are Chinook salmon, steelhead, Coho salmon, sockeye salmon, smallmouth bass, largemouth bass, sturgeon, walleye, yellow perch, and channel catfish. Most importantly, the river supports a healthy population of fall Chinook salmon (Figure 2-13), whose spawned-out carcasses attract bald eagles in the fall and winter (DOE/EIS-0113, *Final Environmental Impact Statement for Disposal of Hanford Defense High-Level, Transuranic and Tank Waste*).



Source: DOE/RL-2005-40, *100-B/C Pilot Project Risk Assessment Report*.

Figure 2-13. Approximate Location of Fall Chinook Spawning Areas

2.2.5.3 Critical Habitats

Two species of federal-endangered fish, the Upper Columbia River spring-run Chinook salmon and 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, adjacent to the downstream edge of 100-B/C, near mid-channel gravel bars. 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*).

Although the bald eagle has been removed from the list of federal-endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. Also, DOE has decided to continue to protect nest and roost sites on the Hanford Site under DOE/RL-94-150. This plan is currently under revision to account for the de-listing of the bald eagle. Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 m to 400 m (2,625 ft to 1,312 ft). One of the protected roost sites is located in a grove of large trees at the northwest corner of the 100-K Area.

2.2.5.4 Sensitive Environments

Potential remedial activities may affect the Columbia River's importance as a recreational resource; drinking and irrigation water resource; and habitat for waterfowl, fish, and transitory endangered and threatened wildlife. Because of critical bald eagle habitat, many areas of the Hanford Site may be declared a federal sensitive environment (40 CFR 300, Appendix A, "The Hazard Ranking System").

2.2.6 Human Resources

The Hanford Site contains some of the most important archaeological sites in the region. Many of these sites are listed on the National Register of Historic Places (NRHP) as individual sites or as archaeological districts. Restricted access to the Hanford Site has facilitated the preservation of these sites. Furthermore, hydroelectric and agricultural development have not destroyed these culturally significance sites, as has been experienced elsewhere in the Columbia River Basin. In addition, other natural resources and sacred sites important to the Native American communities with ancestral ties to the Hanford Site also have been preserved (PNL-9785, *Data Compendium for the Columbia River Comprehensive Impact Assessment*). Through the Cultural Resources Review process, the U.S. Department of Energy, Richland Operations Office (RL), River Corridor Closure Contactor cultural resource specialists, Tribal representatives, and project and site planners work together to protect resources important to the Native American community and other interested parties.

2.2.6.1 Cultural Resources

The cultural resources of the Hanford Site are important to many individuals interested in their protection and preservation. The NRHP criteria (DOE/RL-97-02, *National Register of Historic Places Multiple Property Documentation Form: Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington*) offer the following three categories for chronicling archaeological, historic, and traditional cultural properties of the Hanford Site:

- Prehistoric era (10,000 years before present to common era 1805)
- Homestead and Townsite era (1805 to 1945)
- Manhattan Project and Cold War era (post-1945 to 1990)
- These categories are represented across the 100-K Area

2.2.6.2 Prehistoric Archaeological Resources

The 100-K Area is located within a culturally sensitive area with both historic and prehistoric Native American use.

The 100-K Area encompasses sections of both the Coyote Rapids Archaeological District and the Ryegrass Archeological District, each listed on the NRHP. Archaeological investigations suggest the 100-K Area supported human occupation from approximately 10,000 years ago through the mid-19th century (PNL-8143, *Fiscal Year 1991 Report on Archaeological Surveys of the 100 Areas, Hanford Site, Washington*; Relander, 1986, *Drummers and Dreamers*; Rice, 1968, *Archaeological Reconnaissance Hanford Atomic Works*; BHI-01556, *Archaeological Excavation Report for Extraction Well C3662 in Support of the 100-KR-4 Pump-and-Treat Project*; PNL-8819, *Fiscal Year 1992 Report on Archaeological Surveys of the 100 Areas, Hanford Site, Washington*). It is evident there is high potential to impact extremely sensitive cultural resources in the area.

2.2.6.3 Traditional Cultural Resources

The 100-K Area is reported to be the area where a 19th century Wanapum prophet, Smowhala, may have held the first *Washat* (Relander, 1986). This ceremony became a central feature of the Dreamer (Seven Drums) religion, which spread throughout the interior Northwest and continues to be practiced today. Because of its association with Smowhala and the origins of the Dreamer religion, the area has special significance to the Indian peoples of the Pacific Northwest.

Coyote Rapids, located along the upstream portion of the 100-K Area, was reported as being occupied by the Wanapum in winter because of the abundance of driftwood (Relander, 1986). Coyote Rapids continued to be an important Wanapum site into the 20th century, and is ethnographically reported as being a village location and fishing area. This area is also believed to have been frequented by other area Tribes that include the Nez Perce, Umatilla, and Yakama.

2.2.6.4 Historic Archaeological Resources

The Hanford Irrigation Canal (45BN309), determined eligible for listing on the NRHP, and the former Chicago, Milwaukee, St. Paul, and Pacific Railroad, are two important features associated with the Early Settler/Farming landscape, present within the 100-K Area. Additionally, the Allard Pump House, at the head of the irrigation canal near Coyote Rapids, and a number of historic farmstead sites are located west of the 100-K Area.

2.2.6.5 Cold War Resources

Thirty-eight buildings and structures have been inventoried in the 100-K Area. Of that number, 13 were selected as representative examples of building and structures eligible for the NRHP as contributing properties within the Hanford Site Manhattan project and Cold War Era Historic District. These buildings include the 105-KE Reactor, 105-KW Reactor, 107-KW Retention Basin, 181-KW River Pump House, 183-KW Filter Plant, and 190-KW Main Pump House (DOE/RL-97-56, *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*).

2.3 Process History

Liquid wastes from reactor operations and associated facilities were released to the soil column and the Columbia River. Potential ongoing sources of contamination include liquid waste sites, burial grounds, unplanned release sites, facilities/structures, and pipelines/outfalls. These site types are defined in Chapter 2 of the work plan. The locations of 100-K Area waste sites are shown in Appendix B. A complete listing of 100-K facilities and waste sites, including descriptions, histories, and classifications, is provided in Appendices C and D. Appendix C, Table C-2 shows a crosswalk of facilities and related waste sites within the facility footprint.

2.3.1 Facilities History and Description

One hundred and seven facilities were used or constructed in 100-K to support nuclear reactor processes and operations. The majority of the reactor ancillary and support facilities have not been removed. This section provides the description and history of facilities used in 100-K and identifies the current status of these structures.

Construction of the 100-K Reactors (105-KE and 105-KW) began in September 1952. The reactors were constructed in tandem to further develop the United States' nuclear deterrent arsenal. Construction was completed and operations commenced at the two reactors in 1955. Operation of the 105-KW and 105-KE Reactors continued until their decommissioning in 1970 and 1971, respectively. Once the plutonium production and other missions at the reactors ended, a ROD for the decommissioning of eight surplus production reactors at the Hanford Site was issued by the DOE (58 FR 48509, "Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington").

Facilities that were used during the operation of the reactors comprise most of the demolished or removed facilities and consist of the retention basins, reactor stacks, office and storage buildings, maintenance shops, process plants, electric substations, storage tanks, and pump stations. Active facilities in the 100-K Area include office and storage buildings, several electric substations, process plants, maintenance shops, and control structures. Many of the active facilities support the various treatment centers for the 100-KR-4 Pump-and-Treat Program. Inactive facilities remaining within 100-K include the reactor buildings, an outfall structure, and mobile offices. Table 2-1 identifies facilities and their current status. A 1966 aerial photograph of the 100-K Area during operations in shown in Figure 2-14.

Table 2-1. Status of 100-K Facilities

Status	Facility Code	Total
Demolished	107-KE, 107-KW, 150-KE, 150-KW, 1702-KE, 1702-KW	6
Removed	1701-KA, 1704-K, 1733-K, MO-205-K, MO-420, MO-474-K, MO-495, MO-767-K, MO-827-K, MO-854	10
Active	142-K, 142-KA, 1506-K1, 151-K, 151-KE, 151-KW, 1604-K, 1605-KE, 1605-KW, 1606-K, 1607-K, 165-KE, 1709-K, 1711-K, 1713-KE, 1713-KER, 1713-KW, 1714-KE, 1714-KW, 1717-K, 1718-K, 1719-K, 1722-K, 1723-K, 1724-K, 1725-K, 1726-K, 1728-KW, 1729-KW, 1730-KE, 1731-KW, 1732-KW, 1733-KE, 1734-K, 1737-K, 181-KE, 183-KE, 1904-K, 6004-KW, MO-060, MO-214, MO-422-K, MO-506, MO-507, MO-750, MO-751, MO-753, MO-754, MO-755, MO-774, MO-775, MO-795, MO-859, MO-871, MO-917-K	55
Inactive	104-KE, 104-KW, 105-KE, 105-KW, 110-KE, 110-KW, 115-KE, 115-KW, 116-KE, 116-KW, 117-KE, 117-KW, 119-KE, 119-KW, 1614-K, 165-KW, 166-AKE, 166-AKW, 166-KE, 166-KW, 167-K, 1701-K, 1705-KE, 1706-KE, 1706-KEL, 1706-KER, 1720-K, 1721-K, 181-KW, 182-K, 183-KW, 1908-KE, 1909-KE, 1909-KW, 190-KE, 190-KW	36

Notes: This summary is current as of November 12, 2008 (Stewardship Information System, November 12, 2008).

Reclassification Status:

Active: Facility is occupied and in use (supports Hanford Site missions).

Inactive: Facility is no longer in use and is awaiting decommissioning and demolition (D&D).

Demolished: Facility has been removed to grade (slab or foundation remains).

Removed: Facility foundation has been removed and any substructure is 0.3 m to 0.9 m (1 ft to 3 ft) bgs.

Figure 2-14. Aerial View of the 100-K Area (1966; 42216-4CN 051066)

2.3.2 Process History Description

Materials that had passed through the reactor were considered radiologically contaminated. These materials represented the majority of the wastes produced. Small volumes of nonradiologically contaminated waste materials (e.g., solvents, chemicals) were discarded in select facilities and waste sites. Active physical barriers and strong administrative measures were in place to minimize radiological hazards throughout the Hanford Site production areas to protect plant personnel. These measures affected the placement of disposal locations and waste management procedures for various waste streams.

Contaminant categories from the reactor production process include the following:

- Process inputs: Raw materials processed through the reactor, such as uranium fuel and cooling water.
- Process chemicals for water conditioning and inhibiting corrosion (e.g., sodium dichromate) because water management was crucial to the operation of the reactors and represents a major input subsystem.
- Materials used for reactor maintenance, such as acids, solvents, heavy metals.
- Process outputs:
  - Product and waste isotopes, such as plutonium-239 (Pu-239) and Sr-90
  - Radioactively and chemically contaminated materials (solid and liquid wastes)
  - Radioactively and chemically contaminated cooling water
  - Uncontaminated waste materials

Most of the irradiated fuel elements were shipped to the 200 Area for chemical processing, but some metallurgical studies on irradiated fuel were performed in the 100 Area in addition to tritium production and separation. Also during production, fuel element failures and infrastructure failures (e.g., pipe leaks) led to losses of contaminated materials to the environment.

Other substantial infrastructure was installed at the 100-K Area to support reactor maintenance and operation. Wastes resulting from supporting production operations were similarly disposed in each area according to the following:

- Phase
- Quantity
- Radioactivity
- Composition:
  - Liquids
  - Solids
  - High/low mass or volume
  - High-level, low-level
  - Strictly chemical
  - Septic

Thus, liquid and solid disposal locations were constructed and waste management practices were developed to handle these materials consistently.

2.3.2.1 Dichromate Life Cycle

In 100-K, CrVI is a principal contaminant of concern (COC). It is present in the groundwater at the 100-K Area, exceeding both aquatic standards and drinking water standards (DWS). Sodium dichromate, the source of the CrVI, was primarily delivered in concentrated liquid form.

Sodium dichromate was used in aqueous solutions of varying concentrations. The principal use for sodium dichromate was to control corrosion in reactor process tubing. High-concentration (less than 70 weight percent) acidic sodium dichromate solutions were used as the stock material from 1955 until closure of the 100-K Reactors in 1970 and 1971 (Figure 2-15). These materials were received by rail and truck tankers. Records indicate that at the 100-K Area, water treatment processes mixed sodium dichromate with cooling water concentrations to between 1.8 ppm to 2 ppm dichromate concentration initially, with diminishing concentrations implemented at each plant over time (decreased to 1.0 ppm at 105-KW in 1964 and 0.5 ppm at 105-KE in 1968; DUN-4847, *Quarterly Report Contamination Control—Columbia River April - June 1968)*. Sodium dichromate use ranged from about 20,000 kg/month initially for each reactor, to between 5,000 kg/month and 10,000 kg/month near the end of production operations.

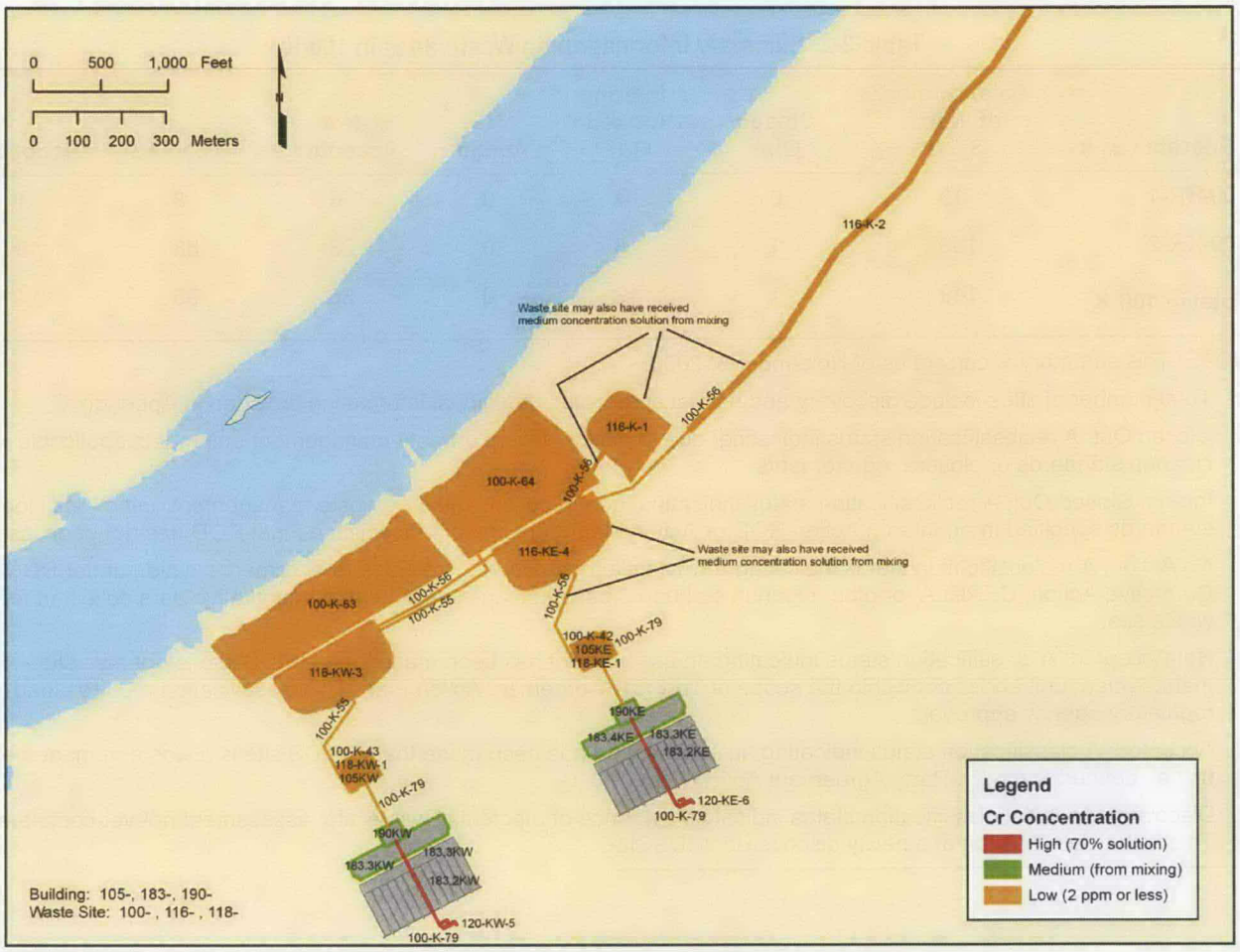


Figure 2-15. Chromium Process and Waste Sites Identified as Receiving a Chromium Waste Stream

2.3.3 Waste Sites Description and History

As of November 5, 2008, 135 waste sites and 14 discovery sites (149 total sites) have been identified within 100-K. These sites consist mainly of inactive *Resource Conservation and Recovery Act of 1976* (RCRA) past-practice sites described as trenches, ditches, cribs, ponds, burial grounds, and unplanned releases. Thirteen sites are within the 100-KR-1 OU and 136 sites are in the 100-KR-2 OU.

Of the 149 sites, 39 have been reclassified as closed out, interim closed out, and not accepted. Only one waste site, the 1607-K4 Septic Tank, has been closed within 100-K. Twelve waste sites have been remediated according to interim RODs. Ninety-six waste sites are being evaluated for interim action, and 26 sites have not been accepted as waste sites. Table 2-2 summarizes the waste site classifications. Tables 2-3 and 2-4 provide the reclassification of waste sites and identify CrVI waste sites and orphan sites. The maps in Appendix B illustrate facility and waste site locations.

Table 2-2. Summary Information on Waste Sites in 100-K

Operable Unit	Total Number of Waste Sites[a]	Closed Out[b]	Interim Closed Out[c]	No Action[d]	Not Accepted[e]	Accepted[f]	Discovery[g]
100-KR-1	13	0	4	0	0	8	1
100-KR-2	136	1	8	0	26	88	13
Total in 100-K	149	1	12	0	26	96	14

NOTE: This summary is current as of November 5, 2008.

a. Total number of sites include discovery and not accepted sites. Additional information provided in Appendix C.

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

c Interim Closed Out: A reclassification status indicating, due to actions taken, a waste management unit meets cleanup standards specified in an Interim Action ROD or Action Memorandum, but for which a Final ROD has not been issued.

d. No Action: A reclassification status indicating a waste site does not require any further remedial action under RCRA Corrective Action, CERCLA, or other cleanup standards based on an assessment of quantitative data collected for the waste site.

e. Not Accepted: A classification status indicating an assessment has been made that a WIDS site is not a waste management unit and is not within the scope of Tri-Party Agreement Action Plan. This classification requires lead regulatory agency approval.

f. Accepted: A classification status indicating an assessment has been made that a WIDS site is a waste management unit as defined in the Tri-Party Agreement Action Plan.

g. Discovery: An initial classification status indicating evidence of a potential waste site; assessment not yet complete. This is the classification of a newly discovered WIDS site.

Table 2-3. Status of 100-KR-1 Operable Unit Waste Sites

Status	Waste Sites	Total
Closed	None	0
Interim Closed	116-K-1,[a] 116-K-2,[a,b] 116-KE-4,[a] 116-KW-3[a]	4
No Action	None	0
Not Accepted	None	0
Accepted	100-K-57, 100-K-63,[a] 100-K-64,[a] 100-K-78,[b] 100-K-80, 100-K-81, 100-K-83, 116-K-3[a]	8
Discovery	**100-K-93**[b]	1

NOTE: This summary is current as of November 5, 2008.

a. Highlighted sites received CrVI waste stream. Bold text denotes an orphan site.

b. Site is the responsibility of River Corridor Closure Contractor. All other sites are the responsibility of the Plateau Remediation Contractor.

Table 2-4. Status of 100-KR-2 Operable Unit Waste Sites

Status	Waste Sites	Total
Closed	1607-K4	1
Interim Closed	100-K-29, 100-K-30, 100-K-31, 100-K-32, 100-K-33, 116-KE-5 , 116-KW-4, 128-K-1	8
No Action	None	0
Not Accepted	100-K-10, 100-K-11, 100-K-12, 100-K-15, 100-K-16, 100-K-20, 100-K-21, 100-K-22, 100-K-23, 100-K-24, 100-K-28, 100-K-39, 100-K-44, 100-K-51, 100-K-52, 100-K-58, 100-K-59, 100-K-7, 100-K-76, 100-K-8, 100-K-9, 126-KE-3, 130-K-1, 130-K-3, 600-4, 600-55	26
Accepted	100-K-1, 100-K-13, 100-K-14, 100-K-18, 100-K-19, 100-K-2,[b] 100-K-25, 100-K-27, 100-K-3, 100-K-34, 100-K-35, 100-K-36, 100-K-37, 100-K-38, 100-K-4, 100-K-42,[a] 100-K-43[a], 100-K-46, 100-K-47, 100-K-48, 100-K-49, 100-K-5, 100-K-50, 100-K-53, 100-K-54, 100-K-55[a], 100-K-56[a], 100-K-6, 100-K-60, 100-K-61, 100-K-62, 100-K-66, 100-K-67, 100-K-68, 100-K-69, 100-K-70, 100-K-71, 100-K-72, 100-K-73, 100-K-74, 100-K-75, 100-K-77, 100-K-79,[a] 100-K-82, 100-K-84, 116-KE-1, 116-KE-2, 116-KE-3, 116-KE-6A, 116-KE-6B, 116-KE-6C, 116-KE-6D, 116-KW-1, 116-KW-2, 118-K-1,[b] 118-KE-1,[a] 118-KE-2, 118-KW-1,[a] 118-KW-2, 120-KE-4, 120-KE-5, 120-KE-6[a], 120-KE-8, 120-KE-9, 120-KW-1, 120-KW-2, 120-KW-3, 120-KW-4, 120-KW-5[a], 120-KW-6, 120-KW-7, 126-K-1,[b] 126-KE-2, 128-K-2,[b] 130-K-2, 130-KE-1, 130-KE-2, 130-KW-1, 130-KW-2, 132-KE-1, 132-KW-1, 1607-K1, 1607-K2, 1607-K3, 1607-K5, 1607-K6, 600-29,[b] UPR-100-K-1[a]	88
Discovery	**100-K-85**,[b] **100-K-86**,[b] **100-K-87**,[b] **100-K-88**,[b] **100-K-89**,[b] **100-K-90**,[b] **100-K-91**,[b] **100-K-92**,[b] **100-K-94**,[b] **100-K-95**,[b] 120-KE-1, 120-KE-2, 120-KE-3	13

NOTE: This summary is current as of November 5, 2008.

a. Highlighted sites received CrVI waste stream. Bold text denotes an orphan site.

b. Site is the responsibility of River Corridor Closure Contractor. All other sites are the responsibility of the Plateau Remediation Contractor.

The 100-K Area includes 21 active (operational) sites. Only three of these active sites (100-K-51 90-Day Waste Accumulation Area, 100-K-52 Wet Fish Studies Laboratory, and 100-K-58 Clean Water Pipelines) are not within an area of known or suspected contamination and therefore were not accepted as waste sites. A "not accepted" designation indicates that DOE, EPA, and the Washington State Department of Ecology (Ecology) concur that the identified site is not a waste management unit. The remaining active sites are being evaluated for interim action.

The DOE has implemented a number of processes to identify new waste sites (e.g., orphan site process). The process of identifying new waste sites increases confidence that waste disposal and release locations requiring characterization and cleanup within a given land parcel on the Hanford Site are addressed. In 1996, 97 waste sites were identified in the WIDS database for the 100-K Area. Between 1996 and 2008, an additional 52 waste sites were identified associated with 100-K, which brings the number of waste sites up to 149 inclusive of 11 new sites identified during the orphan site process (Chapter 3 of DOE/RL-2008-46) that was implemented in 2004.

2.3.3.1 Decommissioning Activities

Initial cleanup activities began in the 100-K Area in 1971 as soon as the reactors were deactivated. The facilities at the 100-K Area were the last to be declared excess after their respective reactors were shut down. Housekeeping and decommissioning activities began at the 100-K Area as part of a site-wide initiative in 1973, after deactivation of the remaining single-pass reactors. This effort progressed as resources allowed from 1974 through 1990, with buildings being demolished, surplus equipment salvaged or redeployed, and active operations maintained at a minimal level (WHC-EP-0478, *Summary of the Hanford Site Decontamination, Decommissioning, and Cleanup FY 1974 Through FY 1990*). However, because of their proximity to the 105-N Reactor, many of the facilities at the 100-K Area remained in service to support the continued operation of the 105-N Reactor. Therefore, relatively little demolition or salvage work has been performed at the 100-K Area.

After termination of reactor operations in the 100-K Area, a number of irradiated uranium fuel elements were found in the basins during removal of fuel storage basin sludge in 1975. These fuel elements were not processed through the Plutonium Uranium Extraction Plant during the final separation runs that occurred from 1983 to 1988. All spent fuel was removed from the basins in 2004, contaminated sludge removal has been completed in the 100-KE Reactor, the basin demolition is underway, and the basin will be completely removed. Significant work to consolidate the KE Basin and KW Basin sludge into the KW Basin has been accomplished. The result is about 23 m^3 (30 yd^3) of sludge temporarily stored in five Engineered Containers in the KW Basin, and about 5 m^3 (6.5 yd^3) of sludge in the Settler Tubes.

2.4 Known and Potential Contamination

This section describes previous investigations and the understanding of the nature and extent of vadose zone and groundwater contamination.

2.4.1 Nature and Extent of Contamination in the Vadose Zone

The description of vadose zone contamination in this section is based mainly on UNI-946; DOE/RL-93-78, *Limited Field Investigation Report for the 100-KR-1 Operable Unit*; and interim remedial actions completed in 100-K.

2.4.1.1 Initial Vadose Zone Radiological Characterization – 1975

Radiological characterization of the 100 Area was initially performed in 1975 (UNI-946). The purpose of the characterization was to establish an estimate of radionuclide inventories, distribution, and concentrations at inactive solid and liquid wastes sites, reactors, and associated facilities.

The focus of the 100-K Area sampling efforts with respect to the vadose zone was mainly the 116-K-1 Crib and the 116-K-2 Liquid Waste Disposal Trench. Other liquid waste sites sampled included the 116-KE-1, 116-KE-2, and 116-KW-1 Cribs. Sampling was performed within and around the 107-KE (116-KE-4) and 107-KW (116-KW-3) Retention Basins as well. Soil samples were collected from shallow boreholes, which were drilled in and adjacent to waste site boundaries to a maximum depth of 14.5 m (47.5 ft). Samples were analyzed for the following constituents: C-14, Co-60, cesium-134 (Cs-134), Cs-137, Eu-152, Eu-154, Eu-155, Ni-63, plutonium-238 (Pu-238), Pu-239/240, Sr-90, tritium, and uranium. Summary information describing the investigation for the 100-K Area is presented in Table 2-5.

Table 2-5. Summary of Characterization Documented in UNI-946

Waste Site[a]	Number of Boreholes	Media	Maximum Depth of Investigation
116-K-1 Crib	5	Soil	25
116-K-2 Trench	30	Soil	30
116-KE-1 Crib	1	Soil	30
116-KE-2 Crib	2	Soil	47.5
116-KW-1 Crib	2	Soil	35
116-KE-4 (107 KE) retention basin	32	Soil and sludge	20
116-KW-3 (107-KW) retention basin	N/A[b]	Soil and sludge	25

Notes:

a. All the waste sites listed (except 116-KE-1, 116-KE-2, and 116-KW-1) have been remediated.

b. Number of boreholes drilled is included in the 107-KE Retention Basin total.

UNI-946, *Radiological Characterization of the Retired 100 Area*.

N/A = not applicable

UNI-946 indicated contamination is present to the maximum depth of 14.5 m (47.5 ft). This depth represents the maximum vertical extent of the investigation and the observed extent of contamination in the upper half of the vadose zone. The majority of the radioactive inventory of the 116-K-1 Crib was in the upper 3 m (10 ft) of the soil column. Maximum 116-K-2 soil contaminant levels were detected 9 m (30 ft) below grade.

Assessment of the lateral extent of contamination indicates lower levels of contamination are present immediately adjacent to waste sites. Contaminants detected in significant concentrations (greater than 1 pCi/g) during this investigation include Sr-90, tritium, europium isotopes, Co-60, Cs-134, Cs-137, Ni-63, and C-14. Pu-238, Pu-239/240, and uranium in soil were not widely distributed and not detected in significant concentrations in the 100-K Area.

It was estimated that approximately 2,100 Ci or almost one-half of the radionuclide inventory of the 100 Area was located in the 116-K-2 Trench. Eu-152 comprised approximately one-half of the total radionuclide inventory (UNI-946). The 116-K-2 Trench contained the highest plutonium inventory of the deactivated radioactive liquid waste facilities in the 100 Area, with approximately 5 Ci of plutonium. Plutonium concentrations up to 130 pCi/g were detected during characterization, with an average of 8.5 pCi/g.

Maximum contaminant concentrations appear to be associated with points of release and beneath the engineered structure of waste sites. For contaminants detected, such as Cs-137 (high contaminant distribution coefficients), concentrations generally decrease with depth below points of effluent release, although concentrations as high as 3,000 pCi/g were present at 8.2 m (27 ft) below ground surface (bgs) in the 116-K-2 Trench.

The maximum horizontal extent of significant Cs-137 contamination (240 pCi/g) was detected at the ground surface adjacent to the 116-KW-3 Retention Basin. Mobile contaminants, such as tritium (470,000 pCi/g at the 116-KW-1 Crib), were also detected near the vertical extent of the investigation. The distribution of europium isotopes and Co-60 in the subsurface varies, and concentrations occasionally decrease with depth. However, elevated levels of contamination are present at or near the maximum extent of the investigation (UNI-946).

2.4.1.2 100-K Area Limited Field Investigations

In the early 1990s, a limited field investigation (LFI) was performed in the 100-KR-1 OU. Results of the investigation are presented in DOE/RL-93-78. Data collection and analysis activities were conducted in accordance with DOE/RL-90-20, *Remediation Investigation/Feasibility Work Plan for the 100-KR-1 Operable Unit, Hanford Site, Richland, Washington.* No LFI for the 100-KR-2 OU has been performed.

In the 100-KR-1 OU the following were identified as high-priority waste sites: the 116-K-1 Crib, 116-K-2 Trench, 116-K-3 Outfall Structure, 116-KW-3 Retention Basin, 116-KE-4 Retention Basin, and the process effluent pipelines. No low-priority waste sites are located in the 100-KR-1 OU. Based on the work plan, four of the six high-priority waste sites were investigated during the LFI: the 116-K-1 Crib, 116-K-2 Trench, 116-KW-3 Retention Basin, and 116-KE-4 Retention Basin.

The sites were investigated using cable-tool drilling of boreholes; backhoe excavation of test pits; field screening for evidence of volatile organic compounds, metals, and synthetic radionuclides; sampling for geological and physical properties; sampling for radiological and chemical constituents; and performing borehole geophysical logging. Table 2-6 summarizes the investigative activities for each waste site.

Table 2-6. Summary of 100-K Area Limited Field Investigation (Vadose)

Waste Site[a]	Radiological Analyte	Metal (Exceeded Hanford Site Background)	Organic and Inorganic Compound	Relevant Information
116-K-1 Crib Depth: 20 ft Investigation depth: 26 ft Number of boreholes: 1 Maximum contamination depth: 4 to 6 ft bgs	Am-241, Cs-137, Co-60, Eu-152, Eu-154 Pu-239/240, K-40, Ra-226, Sr-90, Th-228, Th-232, U-233/234, U-238	None	Toluene	Lack of significant concentrations at crib bottom indicate the facility was probably not used intensively. It is also possible contaminated fill material was used for backfilling. Although detected, no metals or inorganic compounds exceeded the Hanford Site Background 95% UTL. Toluene was the only VOA detected in the sample 0-1 ft deep.
116-K-2 Trench Depth: 25 ft Investigation depth: 30 ft Number of boreholes: 1 Maximum contamination depth: 18 to 20 ft bgs	Am-241, C-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, K-40, Ra-226, Sr-90, Th-232, U-233/234, U-238	Total chromium, copper, mercury, zinc	Methylene chloride, tetrachloroethane, toluene, trichloroethane	The borehole survey reported the calculated values for Co-60 were unusually high for Hanford soil.

Table 2-6. Summary of 100-K Area Limited Field Investigation (Vadose)

Waste Site[a]	Radiological Analyte	Metal (Exceeded Hanford Site Background)	Organic and Inorganic Compound	Relevant Information
116-KW-3 Retention Basin Investigation depth: 24 ft Number of boreholes: 1 Number of test pits: 2 Depth of test pit: 20 ft	Cs-137, Co-60, Eu-152, Eu-154, K-40, Ra-226, Sr-90, Th-228, Th-232, U-233/234, U-235, U-238	Cobalt	Tetrachloroethane, Benzo(a)anthracene, benzo(b) pyrene, benzo(b) fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)-pyrene, phenanthrene, pyrene, toluene	The origin of these organic compounds is unknown; there is no record of the use of these compounds in the reactor effluent. Contaminant concentration was generally near the surface, which may be the result of basin leakage during operation, contamination has not migrated to significant depth.
116-KE-4 Retention Basin Investigation depth: 22 ft Number of boreholes: 1 Number of test pits: 2 Depth of test pit: 20 ft	Cs-134, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-239/240, K-40, Ra-226, Sr-90, Th--228, Th-232, U-233/234, U-238	Total chromium	Benzo(a)anthraxcene, benzo(b) fluoranthene, fluoranthene, pyrene, toluene	Maximum concentrations for the radionuclides in the borehole and test pits were generally found in samples collected at or near the surface except for Cs-134. Contaminant concentration was generally near the surface, which may be the result of basin leakage during operation, contamination has not migrated to significant depth.
116-K-3 Outfall Structure	N/A	N/A	N/A	Nonintrusive investigation was performed[b].
Process Effluent Pipelines	N/A	N/A	N/A	Nonintrusive investigation was performed[b].

Notes:

a. All waste sites listed (except 116-K-3 and the process effluent pipelines) have been remediated.

b. Nonintrusive investigations relied on data compiled from a number of different sources including historical data such as past sampling and analysis (UNI-946) and process knowledge.

UNI-946, *Radiological Characterization of the Retired 100 Area.*

Am-241	=	americium-241	Th-232	=	thorium-232
bgs	=	below ground surface	U-233/234	=	uranium-233/234
K-40	=	potassium-40	U-235	=	uranium-235
N/A	=	not applicable	U-238	=	uranium-238
Ra-226	=	radium-226	UTL	=	upper tolerance limit
Th-228	=	thorium-228	VOA	=	volatile organic analyte

Based on the LFI results, the radiological contamination of vadose zone soils resulting from leakage and disposal of reactor cooling effluent to liquid waste disposal facilities is the primary concern.

The principal radionuclides found during the LFI include americium-241 (Am-241), Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-239/240, and Sr-90. The highest radiological contamination was found in soil samples collected from the 116-K-2 Trench.

Metal contaminants that included total chromium, cobalt, copper, mercury, and zinc were found at the 116-K-2 Trench, 116-KW-3 Retention Basin, and 116-KE-4 Retention Basin. Although metal contaminant concentrations exceeded Hanford Site background levels, they were below the potential soil cleanup applicable or relevant and appropriate requirements per the Washington State cleanup criteria (WAC 173-340, "Model Toxics Control Act – Cleanup").

Semivolatile organic compounds (benzo(a)anthracene, benzo(b)fluoranthene, and chrysene) were detected in surface soil samples near the 116-KW-3 Retention Basin at concentrations exceeding the Washington State cleanup criteria (WAC 173-340). Historical records do not indicate these contaminants were disposed to the 100-KR-1 OU, and no source for these contaminants has been identified.

The vertical distributions of contamination beneath the 116-K-1 Crib and 116-K-2 Trench are shown in Figures 2-16 and 2-17, respectively. Conditions at these waste sites appear to represent the worst-case sites based on effluent volumes discharged, sample data, or both. The depth of remedial action is inserted into the profiles as an indicator of soil removed during interim remedial action approximately 8 years after the completion of the LFI.

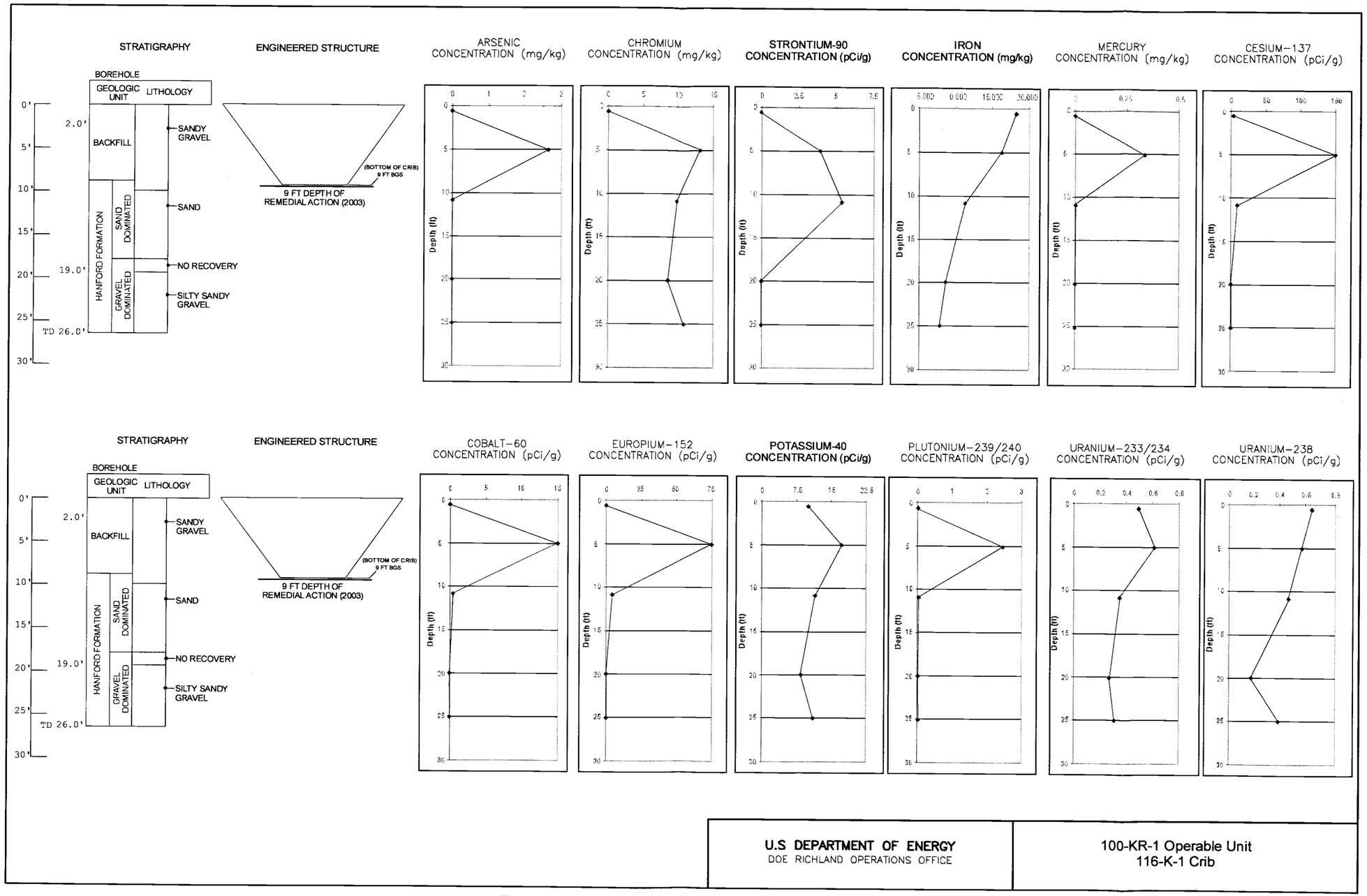
The profile of the 116-K-1 Crib shows contaminant concentrations generally decrease with depth. Higher concentrations are generally present within 1.5 m (5 ft) below the surface. The data indicate contaminant concentrations do not exceed soil concentrations protective of groundwater and the Columbia River at this waste site.

The profile of the 116-K-2 Trench shows contaminant concentrations generally decrease with depth below the depth of remedial action (~7.6 m [~25 ft] bgs). Higher concentrations are generally present about 6 m (20 ft) bgs. However, these constituents decrease with depth and do not exceed background or soil concentrations for groundwater or Columbia River protection (WAC 173-340) beyond the remedial depth (~7.6 m [~25 ft] bgs). All other constituents are below levels for groundwater protection.

2.4.1.3 Interim Remedial Actions and Existing Waste Site Contamination

Remediation and characterization of the 100-K Area waste sites began in 2002 under the authority provided by the interim action ROD (EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-1, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington*) and continues to the present. Remediation consists mainly of removal, segregation, storage, transportation, and disposal of soil, debris, and waste material and backfilling of remediated waste sites. Achievement of RAOs is based on attaining remedial action goals for direct exposure, protection of groundwater, and protection of surface waters. Interim RAOs and goals as described in the work plan were achieved at all interim closed waste sites and no action waste sites.

As a result of the ongoing 100-K Area interim actions, information from previous investigations presented in the UNI-946 and the LFI reports for the OUs are no longer applicable, at least to the depth of remedial action. For example, in Figures 2-16 and 2-17, relationships are shown between the stratigraphy, the engineered structure, the depth of remedial action, and contamination at waste sites. The figures show that all material to the depth of remedial action has been removed. Thus, contaminant distribution has been significantly modified and impact to the environment is mitigated because of the interim action.



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100-KR-1 Operable Unit
116-K-1 Crib

Figure 2-16. Vertical Profile of 116-K-1 Crib Contamination

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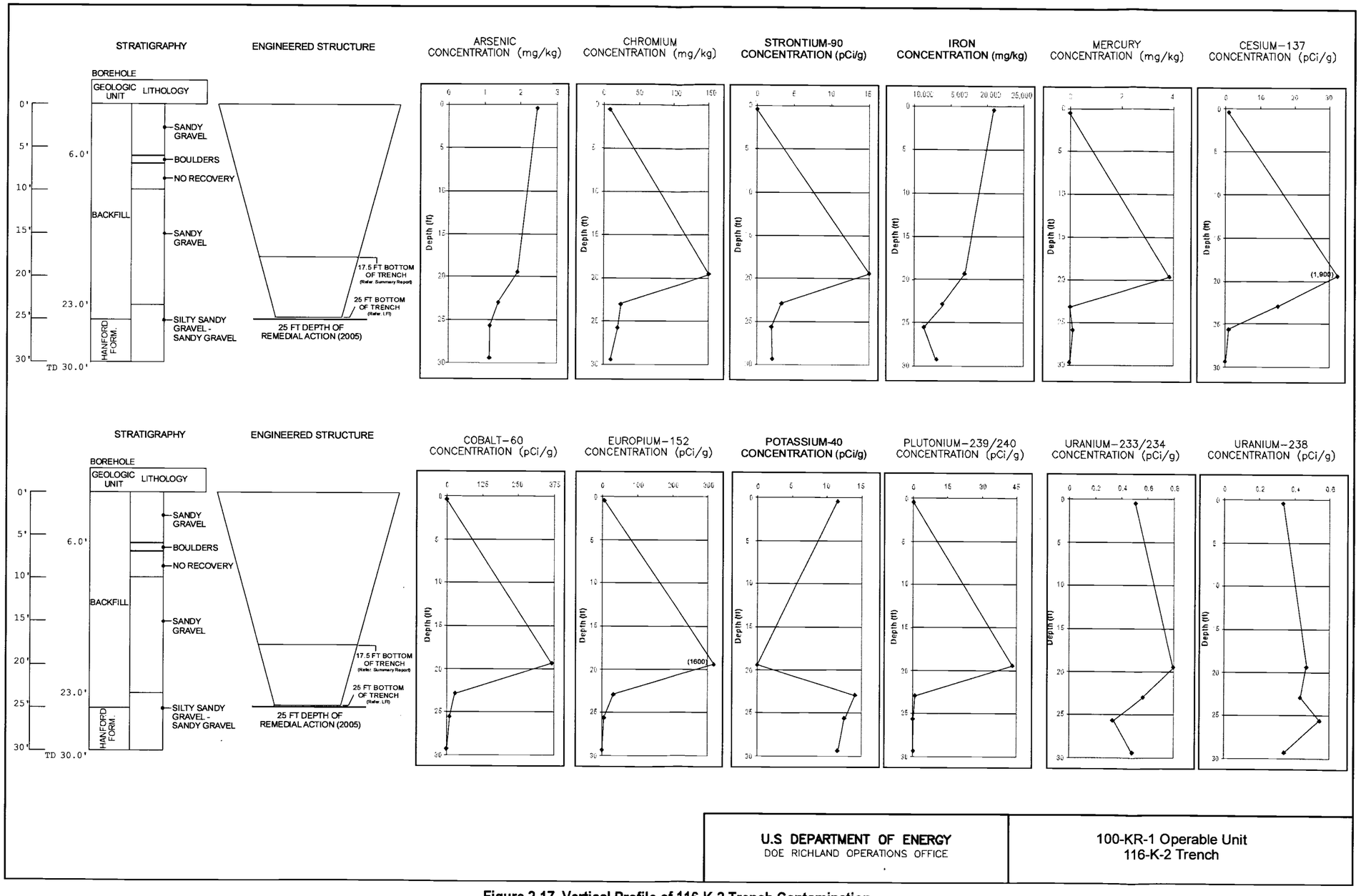

U.S DEPARTMENT OF ENERGY DOE RICHLAND OPERATIONS OFFICE	100-KR-1 Operable Unit 116-K-2 Trench

Figure 2-17. Vertical Profile of 116-K-2 Trench Contamination

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Data used to interim close waste sites are documented in cleanup verification packages and summarized in Appendix D. These data also describe the current nature and extent of contamination at interim closed waste sites. The primary statistical calculation to evaluate compliance with cleanup standards is the 95 percent upper confidence limit on the arithmetic mean of the data. The data in Appendix D generally include the maximum concentrations and/or concentrations representing the 95 percent upper confidence limit of waste site COCs for both the shallow and deep zones (0 to 4.5 m [15 ft] and less than 4.5 m [15 ft] bgs, respectively). With some exceptions, the closeout verification data and background information on the waste sites will be used to support selection of waste sites for additional characterization based on residual concentrations remaining at the site. Characterization data obtained from efforts planned in this addendum will be used to verify the distribution of remaining contamination.

2.4.1.4 Hexavalent Chromium Leach Test Studies

Soil leach studies have not been performed in the 100-K Area. A series of leach tests was conducted to assess the leaching potential of CrVI in soil at the 100-D and 100-H Areas. A discussion on proposed 100-K Area leach test studies is presented in Chapter 4.

2.4.1.5 Soil Data from Groundwater Interim Remedial Actions

During reactor operations, the water table at the 100-KR-4 OU was significantly higher, especially around the 116-K-2 Trench, which received thousands of liters per minute of reactor cooling water. Within the reactor area, equally high water table levels were observed. In order to evaluate potential CrVI in the deep vadose zone, split-spoon samples were collected at intervals through the soil column, most routinely at depths approximately 1.5 m and 3 m (5 ft and 10 ft) above the water table in a number of newer wells for the 100-KW and 100-KX Pump-and-Treat Systems in 2007 and 2008. All samples were collected to evaluate if there was residual CrVI in the vadose zone, whether from spills or losses to the soil from nearby pipelines, or from residual material left by the elevated water table. The coarse nature of the soil often resulted in little or no sample recovery in the split-spoon, and a grab sample was collected from available material.

Table 2-7 summarizes the results from 40 vadose samples in 11 100-KX and four 100-KW Wells. Results suggest that little (if any) CrVI remains in the vadose zone (previously wetted or from more shallow sources) because CrVI was not detected in 35 of the 40 samples (at a detection limit of 0.10 to 0.35 mg/kg). The maximum samples were at concentrations at or slightly above the laboratory CrVI detection limits. These elevated concentrations are between 1.5 m to 3 m (5 ft to 10 ft) above the local water table of the wells.

Table 2-7. Hexavalent Chromium Concentrations in Vadose Zone Samples Collected in 100-KW Expansion Wells

Sample Number	Well Name	Sample Depth (ft)	Water Table Depth (ft)	Date	Value	Analytical Units	Lab Qualifier	Review Qualifier
B1WL25	199-K-165	19.0	82.45	08/26/08	0.10	mg/kg	U	N/A
B1WL29	199-K-165	28 to 31.3	82.45	08/26/08	0.10	mg/kg	N/A	N/A
B1WMD9	199-K-165	66.75 to 68.25	82.45	08/27/08	0.10	mg/kg	U	N/A
B1WMF0	199-K-165	72.0	82.45	08/27/08	0.10	mg/kg	U	N/A
B1WMF1	199-K-165	73.1	82.45	08/27/08	0.10	mg/kg	U	N/A

Table 2-7. Hexavalent Chromium Concentrations in Vadose Zone Samples Collected in 100-KW Expansion Wells

Sample Number	Well Name	Sample Depth (ft)	Water Table Depth (ft)	Date	Value	Analytical Units	Lab Qualifier	Review Qualifier
B1WL37	199-K-166	26.9	79.5	09/10/08	0.10	mg/kg	N/A	N/A
B1WMH7	199-K-166	65.5 to 70	79.5	09/11/08	0.10	mg/kg	U	N/A
B1WMJO	199-K-166	72.5 to 75.0	79.5	09/11/08	0.10	mg/kg	N/A	N/A
B1WMJ3	199-K-166	76.85 to 79.35	79.5	09/11/08	0.10	mg/kg	U	N/A
B1WL42	199-K-167	20.5 to 23	ND	09/09/08	0.10	mg/kg	U	N/A
B1WL46	199-K-167	26.4 to 28.9	ND	09/09/08	0.10	mg/kg	U	N/A
B1WL49	199-K-168	24 to 26	76.9	07/31/08	0.10	mg/kg	U	N/A
B1WPC2	199-K-168	47 to 49.5	76.9	08/04/08	0.10	mg/kg	U	N/A
B1WN00	199-K-168	62.4 to 65.2	76.9	08/06/08	0.10	mg/kg	U	N/A
B1WNO3	199-K-168	69.9 to 70.9	76.9	08/06/08	0.10	mg/kg	U	N/A
B1WN13	199-K-168	72.3 to 75.3	76.9	08/06/08	0.10	mg/kg	U	N/A
B1WPP3	199-K-173	24 to 26	83.0	09/18/08	0.30	mg/kg	U	N/A
BIX5R0	199-K-173	41.6 to 44	83.0	09/18/08	0.30	mg/kg	U	N/A
BIWMK2	199-K-173	60.5 to 70	83.0	09/19/08	0.30	mg/kg	U	N/A
B1WMY1	199-K-173	70.3 to 72.8	83.0	09/19//08	0.30	mg/kg	U	N/A
B1WMY4	199-K-173	76.95 to 79.45	83.0	09/19/08	0.30	mg/kg	U	N/A
B1PYH0	199-K-144	12.6 to 14.6	23.7	02/14/08	0.35	mg/kg	U	N/A
B1PYH1	199-K-144	17.3 to 19.3	23.7	02/14/08	0.35	mg/kg	U	N/A
B1PYH2	199-K-145	12.5 to 14.5	22.5	03/17/08	0.35	mg/kg	U	N/A
B1PYH3	199-K-145	17.7 to 19.7	22.5	03/17/08	0.35	mg/kg	U	N/A
B1PYH4	199-K-146	17.5 grab	31.6	12/11/07	0.35	mg/kg	U	N/A
B1PYH5	199-K-146	20 grab	31.6	12/11/07	0.76	mg/kg	N/A	F
B1PYF4	199-K-148	51.3 to 53.3	66.4	11/01/07	0.35	mg/kg	U	N/A
B1PYF5	199-K-148	56.0 to 58.0	66.4	11/01/07	0.35	mg/kg	U	N/A
B1PYH6	199-K-150	58 grab	68.2	12/20/07	0.35	mg/kg	U	N/A
B1PYH7	199-K-150	64 grab	68.2	12/20/07	0.35	mg/kg	U	N/A
B1RP08	199-K-152	57 to 59	69.5	12/17/07	0.48	mg/kg	N/A	N/A
B1RP09	199-K-152	61.6 to 63.6	69.5	12/17/07	0.35	mg/kg	U	N/A
B1RP10	199-K-156	5.5 to 57.5	68.3	01/16/08	0.35	mg/kg	U	N/A

Table 2-7. Hexavalent Chromium Concentrations in Vadose Zone Samples Collected in 100-KW Expansion Wells

Sample Number	Well Name	Sample Depth (ft)	Water Table Depth (ft)	Date	Value	Analytical Units	Lab Qualifier	Review Qualifier
B1RP11	199-K-156	59.5 grab	68.3	01/17/08	0.35	mg/kg	U	N/A
B1RP12	199-K-157	46.9 to 48.9	61.2	01/14/08	0.35	mg/kg	U	N/A
B1PYF8	199-K-161	18.2 to 20.2	28.5	11/28/07	0.33316	mg/kg	U	N/A
B1PYF9	199-K-161	26 to 28	28.5	11/29/07	0.35	mg/kg	U	N/A
BIPYH8	199-K-162	14 to 16	22.1	02/05/08	0.35	mg/kg	U	N/A
BIPYH95	199-K-162	18 to 20	22.1	02/05/08	0.35	mg/kg	U	N/A

Notes:

CP-16139, *Fiscal Year 2003 CERCLA Groundwater Monitoring Well Summary Report.*

WMP-27726, *Borehole Summary Report for Wells 199-K-133, 199-K-134, 199-K-135 and 199-K-136, FY 2005.*

WMP-31906, *Borehole Summary Report for the Installation of Four Pump and Treat Wells in the 100-KW Area, CY 2006.*

SGW-33232, *Borehole Summary Report for the Installation of Pump and Treat Wells in the 100-KW Area, Calendar Years 2006 and 2007.*

SGW-33258, *Borehole Summary Report for the Installation of Groundwater Monitoring Wells in the 100-KE Area, FY 2007.*

SGW-39635, *Borehole Summary Report for the Installation of Four Groundwater Wells at 100-KW, FY 2008.*

F = Results undergoing further review.

N/A = not applicable

U = undetected

2.4.1.6 Petroleum Hydrocarbon Contamination in the 100-KW Area

While drilling a proposed groundwater Well, 199-K-167 (C6453), a layer of petroleum contamination was encountered within the vadose zone between 8.8 m and 9.4 m (29 ft and 31 ft) bgs. This well was located approximately 24.4 m (80 ft) southeast of the 166-KW Fuel Bunker Facility. After petroleum was encountered, drilling was stopped in the borehole below the petroleum layer at 12.5 m (40.9 ft) bgs and the borehole was decommissioned. No total petroleum hydrocarbons (TPH) were detected in soil samples collected above the petroleum layer from 6.2 m to 7.0 m (20.5 ft to 23.0 ft) and 8.0 m to 8.8 m (26.4 ft to 28.9 ft) bgs. However, readings from an organic vapor monitor showed concentrations of 2.8 ppm to 27.3 ppm from just above the 8.8 m to 9.4 m (29 ft to 31 ft) layer.

The replacement groundwater Well, 199-K-173 (C7016), was drilled approximately 1.8 m (6 ft) to the southwest of 199-K-167. Soil samples were collected within the petroleum layer in the new well to evaluate petroleum impacts to the vadose zone. Sample result showed diesel concentrations were present at 8.7 m to 9.5 m (28.6 ft to 31.1 ft) bgs (670,000 µg/kg TPH-diesel) and at 9.1 m to 9.9 m (30 ft to 32.5 ft) bgs (84,000 µg/kg TPH-diesel). The soil contaminant concentration considered protective of groundwater is 2000 mg/kg for TPH-diesel (Ecology, 2009, "Cleanup Levels and Risk Calculation [CLARC]"). No TPH was detected in soil samples from 20.6 m to 21.3 m (67.5 ft to 70 ft), 21.4 m to 22.2 m (70.3 ft to 72.8 ft), or 23.4 m to 24.3 m (76.9 ft to 79.7 ft) bgs, indicating the petroleum did not migrate to the deeper vadose zone. In addition, groundwater samples from K-173 were analyzed for TPH-diesel, with no detects.

2.4.2 Nature and Extent of Contamination in Groundwater

The principal groundwater contaminant issues include the following:

- A large CrVI plume created by past disposal to the 116-K-2 Trench.
- Localized CrVI plumes of uncertain origin near the 105-KE and 105-KW Reactors.
- Radiological contamination associated with past discharges to the ground near the 105-KE and 105-KW Reactor buildings.
- The historical loss of shielding water from the fuel storage basins.

Groundwater in 100-K is contaminated with radionuclides and inorganic and organic constituents. More detailed information on the groundwater can be found in the annual Hanford Site groundwater monitoring reports (e.g., DOE/RL-2008-01). Figure 2-18 illustrates recent groundwater CrVI plume boundaries and various groundwater well locations.

Several radionuclides that were identified as contaminants of potential concern (COPCs) in the ROD for interim action for the 100-KR-4 Groundwater OU (EPA/ROD/R10-96/134) are discussed below.

Tritium. Groundwater in the 100-K Area has been routinely assessed for tritium since the 1990s. Tritium levels exceeded the maximum contaminant level (MCL) in 2007 and 2008, near the 105-KE Reactor building and the 105-KW Reactor building, respectively, and upgradient and downgradient of the southwest portion of the 116-K-2 Trench. In the qualitative risk assessment (QRA) for the 100-KR-4 OU (WHC-SD-EN-RA-010, *Qualitative Risk Assessment for the 100-KR-4 Groundwater Operable Unit*), tritium was identified as a risk to human health but was not identified as a risk to ecological receptors. In April 2008, tritium was detected at a relatively high concentration of 286,000 pCi/L in groundwater extraction Well 199-K-144. The source area contributing to the relatively high tritium concentration in Well 199-K-144 is uncertain. The extent of tritium in groundwater has not been defined.

Carbon-14. Carbon-14 was identified as a COPC in the QRA (WHC-SD-EN-RA-010) for human health through ingestion of groundwater and as a risk to ecological receptors. C-14 concentrations have exceeded the MCL in several wells in the 100-K Area since 1992. In 2007, C-14 was detected at concentrations greater than the MCL northeast of the 105-KE Reactor building, northeast of the 105-KW Reactor building, and in the northwest corner of the 116-KW-3 Waste Site. The extent of C-14 in groundwater has not been defined to the southeast and west of the 105-KE and 105-KW Reactor areas.

Strontium-90. Strontium-90 concentrations have exceeded the MCL in several wells in the 100-K Area since 1992. In 2007, Sr-90 levels exceeded the MCL downgradient of the northeast portion of the 116-K-2 Trench, northwest of the 105-KE Reactor building, and directly downgradient of the 105-KW Reactor building. The extent of Sr-90 contamination has not been defined to the southeast and west of the 105-KE and 105-KW Reactor areas.

The highest concentrations of Sr-90 were detected in Well 199-K-109A, formerly located on the northeast side of the 105-KE Reactor building. This well was decommissioned in May 2008, and no replacement well was installed. At the time of decommissioning, groundwater samples revealed Sr-90 concentrations at approximately 140 times the MCL.

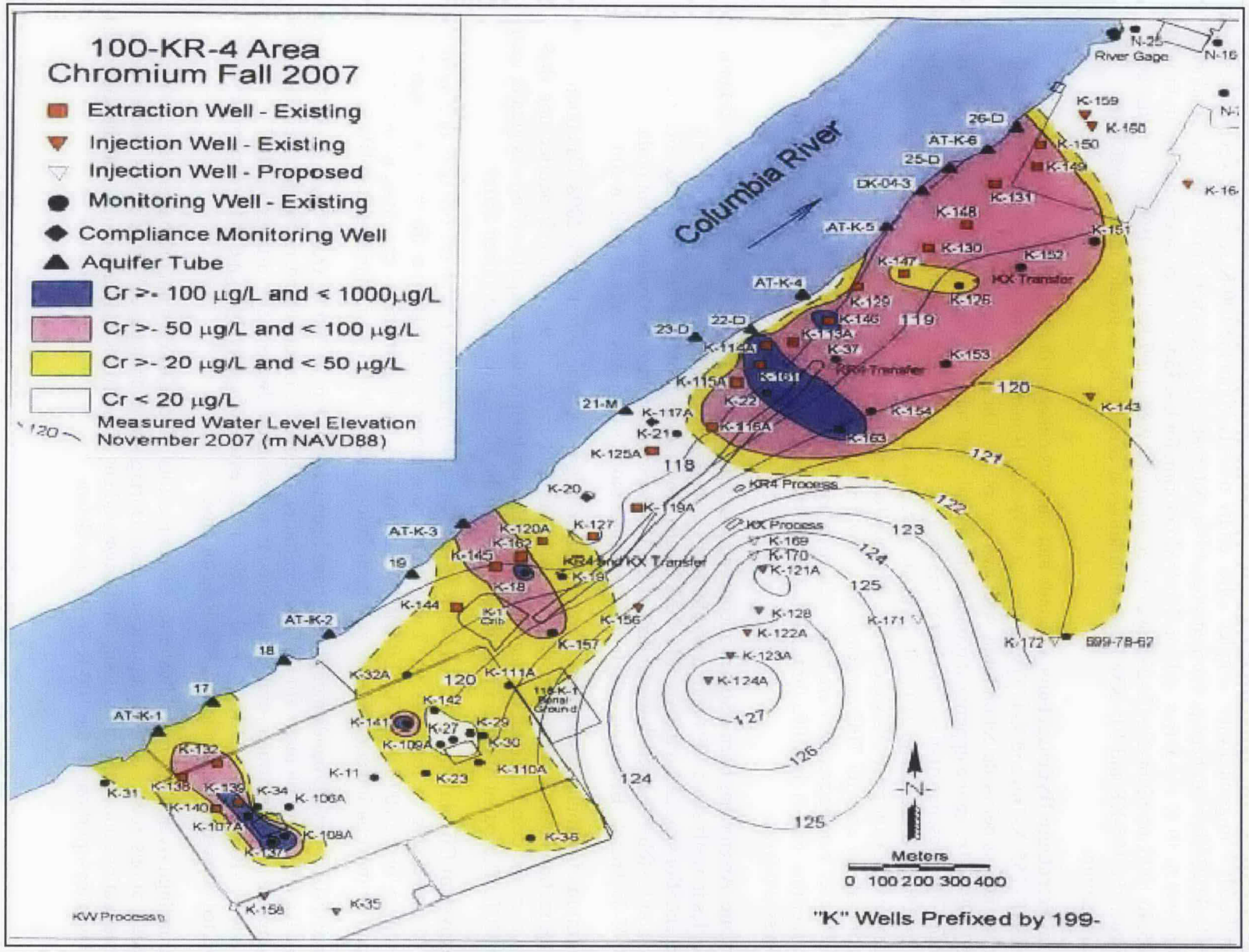

Figure 2-18. 100-K Area Wells, Aquifer Tubes, and Hexavalent Chromium Plume Map

Technetium-99, Uranium-233/234, Uranium-235, and Uranium-238. Technetium-99 (Tc-99), uranium-233/234 (U-233/234), and uranium-238 (U-238) have not been detected at concentrations greater than the MCL in groundwater samples collected from wells within the 100-K Area. However, assessment for U-233/234 has not been performed since 1996. Alternatively, assessment for U-238 was conducted from 1994 to 1998 and at two wells in 2008. Monitoring for U-238 took place intermittently from 1992 to 2005. In 1996, uranium-235 (U-235) was detected in two Wells (199-K-11 and 199-K-13) in the area between the 105-KE and 105-KW Reactor buildings at concentrations greater than the MCL for total uranium.

Total Petroleum Hydrocarbons. Groundwater samples collected during drilling from three Wells (K-165, K-166 and K-173) near the 166-KW Fuel Bunker Facility, generally showed TPH-diesel concentrations below detection limits with two exceptions. Diesel product was reported at Well 199-K-165 in the uppermost groundwater sample, but subsequent groundwater sampling did not confirm the presence of diesel product in the well. At Well 199-K-168, the most downgradient of the new wells, 300 μg/L diesel and 210 μg/L kerosene were reported in the uppermost sample (just below the water level). After the wells were installed, groundwater samples from Wells K-165 and K-168 showed one initial detection for TPH in each well (at low concentrations), but in subsequent samples of TPH-diesel, concentrations were below detection levels. Several inorganics that were identified as COPCs for interim action in the ROD for the 100-KR-4 groundwater OU (EPA/ROD/R10-96/134) are discussed below.

Arsenic. Arsenic has been detected at concentrations greater than the MCL intermittently in groundwater samples in wells since 1994 and in aquifer tubes that were installed in 2007. In 2007, arsenic concentrations exceeded the MCL in wells located downgradient of the 100-N-19 Waste Site, and in two aquifer tubes located downgradient of the 105-KE Reactor area and downgradient of the 100-K-55 Trench. However, only five groundwater monitoring wells were sampled in 2007.

Cadmium. Cadmium assessments were performed in groundwater from 1985 to 2008. Cadmium concentrations were last detected above the MCL in 1998, in Well 199-K-34 and in aquifer tube 18-S. However, the detection limit for many samples collected from wells and aquifer tubes was greater than the MCL. The extent of cadmium in groundwater in the 100-K Area has not been defined.

Hexavalent Chromium. The QRA (WHC-SD-EN-RA-010) identified CrVI as a risk to both human health and ecological receptors. CrVI was identified as the principal risk driver for the interim action identified for the 100-KR-4 OU (EPA/ROD/R10-96/134). CrVI in groundwater routinely has been identified in wells and aquifer tubes at concentrations greater than aquatic standards and DWS.

Three distinct CrVI groundwater plumes have been identified in the 100-K Area (Figure 2-18). However, the lateral extent of plumes with CrVI concentrations above the aquatic standard has not been defined in several areas. Groundwater samples collected from new groundwater wells installed in 2007 (Wells 199-K-141 and 199-K-142) did not define the extent of relatively high CrVI concentrations detected downgradient of the 105-KW Reactor area.

During high river stage, groundwater assessment results indicate CrVI is not discharged to the river at concentrations in excess of the aquatic standard. During low river stage, CrVI discharges to the river at concentrations above the aquatic standard downgradient of the 105-KW Reactor area, and the southwest and northeast portions of the 100-K-56 Process Sewer.

Lead. Groundwater assessments for lead have been performed in monitoring wells intermittently from 1985 to 2007. Previous exceedances of the groundwater MCL were detected downgradient of the central portion of the 100-K-56 Process Sewer (Well 199-K-21), near the northeastern end of the 100-K-56 Process Sewer (Well 199-K-37), and downgradient of the 105-KW Reactor building in Well 199-K-34. Sampling and analysis for lead has been performed at irregular intervals in aquifer tubes in the 100-K Area; however, exceedances of the MCL have not been noted in aquifer tube samples.

Nickel. Nickel has been detected at levels in excess of the MCL in several wells. In 2007, nickel concentrations were greater than the MCL south of the 105-KW Reactor building in Well 199-K-137. Nickel concentrations have not exceeded the MCL in aquifer tube samples from the 100-K Area.

Silver. Silver concentrations have not exceeded the MCL in 100-K Area wells and aquifer tubes.

Zinc. Groundwater has been assessed for zinc in monitoring wells in the 100-K Area since 1987 and in aquifer tubes since 1998. One 1994 unfiltered sampled collected from Well 199-K-106A, located to the northeast of the 105-KW Reactor building, exceeded the MCL.

Nitrate. Nitrate has been detected at concentrations greater than the MCL in several portions of the 100-K Area since groundwater sampling was initiated. In 2007, nitrate exceedances were reported for groundwater samples from near the 105-KE and 105-KW Reactor buildings, downgradient of the southwest portion of the 100-K-56 Process Sewer, and in one aquifer tube downgradient of the 105-KW Reactor area. Nitrate is recognized as a site-wide contaminant at the Hanford Site, and sources of nitrate to groundwater results from both Hanford and pre-Hanford operations.

The organic contaminants identified as COPCs for interim action in the ROD for the 100-KR-4 Groundwater OU (EPA/ROD/R10-96/134) are discussed below.

Chloroform. Chloroform concentrations have not exceeded the MCL in 100-K Area wells and aquifer tubes.

Trichloroethene. Groundwater samples have not been collected and evaluated consistently in the wells and aquifer tubes for trichloroethene (TCE). The last monitoring well TCE concentration to exceed the MCL was from Well 199-K-132 (April 2008). As of 2008, Well 199-K-132 is operated as a groundwater extraction well and is located downgradient of the 105-KW Reactor area. Several monitoring wells in the 105-KW Reactor area have revealed excessive TCE levels in past sampling rounds, but these wells were sampled for only a limited period of time.

2.4.3 Groundwater Contamination beneath the Unconfined Aquifer

Underlying the upper aquifer in 100-K is the RUM Unit. The RUM Unit is generally recognized as the base of the upper unconfined aquifer in 100-K; one Well (199-K-32B, see Appendix B for well location) in 100-K has been completed beneath the unconfined aquifer .

Groundwater in the RUM Unit has been sampled for organics, inorganics, and radionuclides, including the contaminants of interest for the 100-KR-4 OU (DOE/RL-94-48, *100-KR-4 Operable Unit Focused Feasibility Study*; EPA/ROD/R10-96/134).

Several radionuclides that were identified as COPCs in the ROD for interim action for the 100-KR-4 Groundwater OU (EPA/ROD/R10-96/134) are discussed below for sampling from Well 199-K-32B.

Tritium. Tritium has been sampled since 1992. The highest concentration of tritium detected in Well 199-K-32B was 270 pCi/L in 1994 (which is below the MCL of 20,000 pCi/L).

Carbon-14. Carbon-14 was analyzed in groundwater samples from Well 199-K-32B from 1992 to 1996; it was not detected in any of the samples.

Strontium-90. Strontium-90 was analyzed in groundwater samples from Well 199-K-32B from 1992 to 1996; it was only detected in one sample, at a concentration of 1.4 pCi/L, which is below the MCL of 8 pCi/L.

Technetium-99. Technetium-99 was analyzed in groundwater samples in 1992 and 1993, and was not detected in any of the samples.

Uranium-233/234. Uranium-233/234 was analyzed in groundwater samples from 1992 to 1994; it was detected at relatively low concentrations in the samples ranging from 1.6 to 2.1 pCi/L.

Uranium-238. Uranium-238 was analyzed in groundwater samples from 1992 to 2003; and it was detected in groundwater samples from 1992 to 1996 at relatively low concentrations up to 1.89 pCi/L. Uranium-238 was not detected in the samples collected after 2006.

Several inorganics that were identified as COPCs for interim action in the ROD for the 100-KR-4 Groundwater OU (EPA/ROD/R10-96/134) are discussed below.

Arsenic. Arsenic was analyzed in groundwater samples from 1992 to 1995. It was detected at a maximum concentration of 2.9 μg/L, which is below the federal MCL of 10 μg/L.

Cadmium. Cadmium was analyzed for in groundwater samples from 1992 to 2008. The highest concentration of cadmium detected in a groundwater sample from Well 199-K-32B was 15.2 μg/L, which is above the MCL of 5 μg/L.

Hexavalent Chromium. Hexavalent chromium has been sampled once in Well 199-K-32B, and was detected at a concentration of 6.8 μg/L in 2008. Total chromium has been analyzed from well samples since 1992. Filtered total chromium results (inferred to be representative of CrVI) have ranged from 2.6 μg/L to 27.5 μg/L. The 27.5 μg/L result was from a sample collected in 2008. The 27.5 μg/L result is below the Washington cleanup criteria (WAC 173-340) concentration of 48 μg/L for CrVI for groundwater ingestion, but is above the 22 μg/L concentration considered protective of aquatic receptors. For a more detailed discussion regarding the potential impacts of groundwater beneath the unconfined aquifer on aquatic receptors, see Chapter 4.

Lead. Groundwater samples for lead were analyzed from 1992 to 1999. The highest concentration of lead detected was 6.7 μg/L, which is below the MCL of 15 μg/L.

Nickel. Groundwater samples for nickel have been analyzed since 1992. The highest concentration of nickel detected was 97.5 μg/L in 1998.

Silver. Groundwater samples for silver have been analyzed since 1992. The highest concentration detected was 16.3 μg/L in 2008, which is well below the secondary MCL for silver of 100 μg/L.

Zinc. Groundwater samples for zinc have been analyzed since 1992. The highest concentration detected was 54.3 μg/L in 2006, which is well below the secondary MCL for zinc of 5,000 μg/L.

Nitrate. Groundwater samples for nitrate have been analyzed since 1992. The highest concentration detected was 11.1 mg/L in 2000, which is well below the MCL for nitrate of 45 mg/L.

The organic contaminants identified as COPCs for interim action in the ROD for the 100-KR-4 Groundwater OU (EPA/ROD/R10-96/134) are discussed below.

Chloroform. Chloroform was analyzed in groundwater samples from 1992 to 1994, and was not detected in any of the samples.

Trichloroethene. Trichloroethene was analyzed in groundwater samples from 1992 to 1994, and was not detected in any of the samples.

Groundwater samples have not been collected from the confined aquifer beneath the RUM Unit. However, groundwater contamination is not expected beneath the unit in the unconfined aquifer in the 100-K Area for the following reasons:

- Net groundwater movement in the RUM Unit is upward, based on upward hydraulic gradients, measured from 1993 to 2008, between Well 199-K-32A (completed in the upper unconfined aquifer) and Well 199-K-32B (completed in the RUM Unit).
- The RUM Unit in the 100-K Area is up to 61 m (200 ft) thick, and due to the relatively low permeability of the unit, contaminants are not expected to migrate vertically through the RUM Unit to the confined aquifer.

Additional data (Section 4.7) are being proposed as part of this RI/FS work plan addendum to define the vertical extent of contamination and hydraulic properties of the RUM Unit.

2.5 Assessment of Baseline and Residual Risks in the 100 Area

Several different risk assessments have been conducted in support of remedial decision making, covering specific timeframes, OUs, or geographical areas within the 100 Area. The results from these prior risk assessments are presented in Section 3.6 of DOE/RL-2008-46. The results of these risk assessments, particularly the River Corridor Baseline Risk Assessment (RCBRA), will support the development of remedial alternatives and final cleanup levels.

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3 Identification of Investigation Requirements

This chapter is included for completeness to satisfy CERCLA requirements for this RI/FS work plan addendum. The following sections of the work plan (DOE/RL-2008-46) are included by reference.

- Assessment of Baseline and Residual Risks in the 100 Area (Section 3.6).
- Preliminary Remedial Action Objectives (Section 4.1).
- Preliminary Remediation Goals (Section 4.2).
- Potential Applicable or Relevant and Appropriate Requirements (Section 4.3).
- Preliminary Remedial Actions (Section 4.5).

For this work plan addendum, there are no exceptions to the sections of the work plan.

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4 Conceptual Site Model

This chapter describes the current CSM for 100-K. The CSM expresses the current understanding of site conditions and allows for the identification of data gaps and data needs in conjunction with the systematic planning process). The CSM identifies waste site key features, distills known information, and captures potential decisions. It describes sources, receptors, and the interactions linking them. The CSM is used to identify uncertainties and provide a framework to identify data and information needed to resolve each uncertainty. The CSM evolves as new data and information are developed. The goal of the CSM is the synthesis of knowledge in a manner that supports project needs, and addresses decision-making requirements (including the design of remedial actions). The CSM is presented here as a discussion of contaminant sources (including release mechanisms), contaminant distribution, contaminant fate and transport, and exposure pathways and receptors.

Table 4-1 describes the data gaps and the CSM component relating to each data gap. Table 4-5 and Section 4.6 summarize each identified CSM data gap specific to 100-K, proposed scope of work for the data gap, and justification for the proposed scope of work.

Table 4-1. Data Gap Summary

Data Gap No.	Data Gap	Section No.	Section Title
1	Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath non-remediated waste sites.	4.2.2	Secondary Sources of Contamination and Release Mechanisms
2	Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath remediated waste sites.	4.3.1	Vadose Zone Contamination
3	Vadose zone contaminant nature and extent needed to assess protection of human health, ecological resources, and groundwater around reactor structures.	4.3.1	Vadose Zone Contamination
4	Unidentified waste sites (orphan/discovery sites) may exist.	4.2.2	Secondary Sources of Contamination and Release Mechanisms
5	The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been defined in select areas.	4.3.2	Groundwater
6	The level of groundwater contamination entering the Columbia River is not well known.	4.4.3	Groundwater/River Interactions
7	The fate and transport of contaminants beneath the unconfined aquifer has not been evaluated.	4.4.2.1	RUM and Lower Hydrogeologic Units
8	It is unknown if contamination within the RUM will adversely affect aquatic receptors in the Columbia River.	4.4.2.1	RUM and Lower Hydrogeologic Units
9	The rate of exchange between the groundwater and the river is unknown.	4.4.3	Groundwater/River Interactions
10	The mechanism to explain the persistence of the CrVI plume is unknown.	4.3.3	Significant Waste Release Events Causing Environmental Contamination

Table 4-1. Data Gap Summary

Data Gap No.	Data Gap	Section No.	Section Title
11	Potential alternative remedial technologies have not been sufficiently investigated.	4.4.4	Potential Alternative Remedial Technologies
12	Insufficient data are available to support fate and transport modeling.	4.3.3	Significant Waste Release Events Causing Environmental Contamination
13	Data are needed to better define the spatial and temporal distribution of groundwater contamination.	4.3.2	Groundwater

CrVI = hexavalent chromium
RUM = Ringold Upper Mud

4.1 Contamination Sources and Release Mechanisms

Sources of contamination include spills, leaks, and past liquid and solid waste disposal sites. Contamination is found in the vadose zone, groundwater, and has migrated to the Columbia River.

4.1.1 Primary Sources of Contamination and Release Mechanism

The primary sources of contamination in 100-K are two water-cooled nuclear reactors (105-KE and 105-KW) and the structures (e.g., fuel storage basins) and processes (e.g., sodium dichromate process) associated with reactor operations. The reactors were built to irradiate uranium-enriched fuel rods from which plutonium and other special nuclear materials could be extracted. The reactors and processes associated with operations generated large quantities of liquid and solid wastes. Effluent generated during operations consisted primarily of contaminated reactor cooling water, fuel storage basin water, and decontamination solutions. Cooling water consisted of river water treated to remove dissolved solids and enhanced with chemicals to reduce corrosion. Cooling water contaminants consisted of fuel materials, fission and irradiation byproducts, and CrVI (used as a corrosion inhibitor). CrVI is recognized as a primary COC in groundwater because of its mobility, widespread presence, and potential impact to human health and the environment. Solid wastes consisted of sludge, reactor components, and various other contaminated items. Waste generated from reactor operations was contaminated with radionuclides, hazardous chemicals, or both. The SAP (DOE/RL-2009-41) provides a complete description of the chemical and radionuclides associated with area operations.

The primary release mechanisms are planned and unplanned releases. Liquid contaminants were released to the environment by discharging effluent to temporary surface impoundments, cribs, ditches, and the Columbia River. Solid waste was placed in burial grounds.

4.1.2 Secondary Sources of Contamination and Release Mechanisms

Wastes released to the environment created secondary sources of contamination such as ponds, ditches, and cribs; burial grounds; and unplanned release sites. Releases from secondary sources also can affect the environment through the following processes:

- Re-suspension of contaminated soils through wind or excavation activities.
- Direct contact with contaminated soils.

- Biotic uptake of contaminants via direct contact with soils or ingestion of soils, vegetation, or other animals.
- Migration of contaminated liquids through the soil column via infiltration or percolation.
- External radiation.

Contaminant sources (i.e., facilities and waste sites) are listed in Appendices C and D. Contaminant sources for CrVI are provided in Tables 4-2 and 4-3. Table C-2 in Appendix C shows a crosswalk of facilities and the associated waste sites related to the facility footprint. Process knowledge and historical research (including the OSE process) have identified primary and secondary sources across most of 100-K.

Data Gap 1: *Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath unremediated waste sites.*

Table 4-2. 100-K Chromium Disposal Sites

Site Name	Description
100-K-42 (Fuel Storage Basin)	The site is the concrete fuel storage basin that served as a collection, storage, and transfer facility for the irradiated fuel elements discharged from the 105-KE Reactor. No recorded inventory. Associated facility: 105-KE Fuel Storage Basin.
100-K-43 (Fuel Storage Basin)	The site is the concrete fuel storage basin that served as a collection, storage, and transfer facility for the irradiated fuel elements discharged from the 105-KW Reactor. No recorded inventory. Associated facility: 105-KW Fuel Storage Basin.
100-K-55 (piping)	Piping transported process effluents treated with sodium dichromate. No recorded inventory.
100-K-56* (Piping)	Piping transported process effluents treated with sodium dichromate. No recorded inventory.
100-K-63 (Retention Basin Flooding)	The waste is contaminated soil related to the leakage of cooling water from the 107-KW Retention Basins (116-KW-3 Waste Site). Leakage flowed onto the floodplain between the tanks and the river. COPCs include CrVI.
100-K-64 (Retention Basin Flooding)	The waste is contaminated soil related to the leakage of cooling water from the 107-KE Retention Basins (116-KE-4 Waste Site). Leakage flowed onto the floodplain between the tanks and the river. COPC includes CrVI.
100-K-79 (Piping of 70%)	The waste is residual sodium dichromate (chromium 6) and mercury (from sulfuric acid) in the pipes and potential leaks from the offloading station.
100-K-82	Fuel storage basin effluent that included debris from fuel cladding failures. The release is analogous to the release at the 105-KE Basin under UPR-100-K-1.
116-K-1 Crib (1955)	The site received reactor coolant water from the 107-K Retention Basins during reactor outages due to fuel ruptures. Documented that effluent volume received was 40,000,000 L and inventory includes 40 kg (88 lb) of sodium dichromate or 14 kg of total chromium. The COC for this site included CrVI and total chromium (1 mg/L of NaCr).
116-K-2 Trench (1955-1971)	The site received all contaminated effluent from floor drains in the 105-KE and 105-KW Reactors (low volume). The site received approximately 1,893 L/min (500 gal/min) (995,000,000 L/yr or 17 billion L over 17 years) of 105-KE and 105-KW Reactor water retention basin overflow as well as occasional tanks of process cooling water collected after a fuel cladding failure. Inventory included 300,000 kg (661,000 lb) of sodium dichromate or (105,000 kg of total chromium). The waste site COCs included 300 billion L of CrVI (PNL-6456).

Table 4-2. 100-K Chromium Disposal Sites

Site Name	Description
116-K-3 Outfall	The unit received reactor coolant water from the 107-K Retention Basins. The inventory content is unknown. Associated facility: 1908-K Outfall Structure.
116-KE-3	The waste is contaminated structures and soil from the fuel storage basin sub-basin drainage system.
116-KE-4	This site received cooling water effluent from the 105-KE Reactor for radioactive decay and thermal cooling prior to release to the Columbia River. The COCs included CrVI. No recorded inventory. Associated facility: 107-KE Retention Basin.
116-KW-2	The waste is contaminated structures and soil from the fuel storage basin sub-basin drainage system.
116-KW-3	The basins received 105-KW Reactor effluent. The COCs included CrVI. No recorded inventory. Associated facility: 107-KW Retention Basin.
118-KE-1	The treated water pipelines between the 165-KE and 105-KE Buildings contained dilute sodium dichromate. No recorded inventory. Associated facility: 105-KE Reactor Building.
118-KW-1	The treated water pipelines between the 165-KW and 105-KW Buildings contained dilute sodium dichromate. No recorded inventory. Associated facility: 105-KW Reactor Building.
120-KE-6	No documented releases; however, there is evidence of residual sodium dichromate in the soil that has accumulated from many years of unloading and handling.
120-KW-5	No documented releases; however, there is evidence of residual sodium dichromate in the soil that has accumulated from many years of unloading and handling. Staining from sodium dichromate is evident in the soil near the concrete pad.
UPR-100-K-1	Unplanned release of effluents associated with the fuel storage basin effluent that included contaminants from fuel cladding failures.

Notes:

Highlighted site code denotes waste site locations from which high concentration (less than70 weight percent) acidic sodium dichromate solutions could have been released into the subsurface from related facilities that produced, stored, or transferred liquid sodium dichromate solutions.

PNL-6456, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford: Volume 3 – Unplanned-Release Sites (HISS Data Base).*

* 100-K-56 (north of 105 KE, 116-K-1, and 116-K-2) has been reported as receiving blended solution that, at times, may have been higher than 2 ppm (low concentration material).

COC = contaminant of concern

COPC = contaminant(s) of potential concern

CrVI = hexavalent chromium

Table 4-3. 100-K Liquid Disposal Sites

Site Name	Description
116-K-1 Crib	The site received reactor coolant water from the 107-K Retention Basins during reactor outages due to fuel ruptures. The site received 107-K Basin cleanout slurry from February 1955 to May 1956. Effluent volume received was 40,000,000 L.
116-K-2 Trench	The site received all contaminated effluent from floor drains in the 105-KE Reactor and 105-KW Reactor (low volume) and approximately 1,893 L/min (500 gal/min) of 105-KE Reactor and 105-KW Reactor Water Retention Basin Overflow as well as occasional tanks of process cooling water collected after a fuel cladding failure.
116-K-3 Outfall	Process sewer wastes and reactor cooling water collected and temporarily stored in the 116-KE-4 and 116-KW-3 Retention Basins were pumped to the river via the outfall structure. No recorded volume. Associated facility: 1908-K Outfall Structure.
116-KE-1	The site received condensate and other waste from reactor gas purification systems. Effluent volume was 800,000 L. Associated facility: 115-KE Condensate Crib.
116-KE-2	The site received wastes from cleanup columns in the 1706-KER Loop. Effluent volume received was 3,000,000 L. Associated facility: 1706-KER Waste Crib.
116-KW-1	The 115-KW Condensate Crib and Pipeline received condensate and other wastewater from reactor gas purification systems. Effluent volume was 800,000 L. Associated facility: 115-KW Condensate Crib.
116-KE-4 Retention Basin	This site received cooling water effluent from the 105-KE Reactor for radioactive decay and thermal cooling prior to release to the Columbia River. No recorded volume. The retention basin tanks and associated effluent pipelines developed leaks during their operating life. Varying amounts of losses from 116-KE-4 were observed. The leakage rate from the basin itself was estimated to be 37,854 to 75,708 L/min (10,000 to 20,000 gal/min); the leakage rate from butterfly valves that allowed flow to an adjacent trench was estimated to be 18,927 to 37,854 L/min (5,000 to 10,000 gal/min) (WHC-SD-EN-TI-239). Associated facility: 107-KE Retention Basin.
116-KW-3 Retention Basin	The basins received 105-KW Reactor effluent. The COCs included CrVI. No recorded volume. Associated facility: 107-KW Retention Basin.
118-KE-1	The treated water pipelines between the 165-KE and 105-KE Buildings contained dilute sodium dichromate. Associated facility: 105-KE Reactor Building.
118-KW-1	The treated water pipelines between the 165-KW and 105-KW Buildings contained dilute sodium dichromate. Associated facility: 105-KW Reactor Building.

Source: WHC-SD-EN-TI-239, *100-K Area Technical Baseline Report.*

COC = contaminant of concern

CrVI = hexavalent chromium

Data Gap 4: *Unidentified waste sites (orphan/discovery sites) may exist.*

The orphan site process for outside the fence line is complete and the process will continue for inside the fence line. The discovery site process will continue until waste site and facility removal are complete.

4.2 Contaminant Distribution

The principle environmental threat in 100-K is CrVI. The target analytes and COPCs associated with the vadose zone are identified in the SAP (DOE/RL-2009-41). The lists of target analytes and COPCs were developed using the methodology described in Chapter 3 of the work plan.

4.2.1 Vadose Zone Contamination

The CSM is supported by field data (described in Chapter 2) and indicates that contaminant distributions at high volume, remediated liquid waste disposal sites for contaminants (e.g., arsenic, total chromium, mercury, CrVI, lead, Cs-137, Co-60, Eu-152, Ni-63, Pu-239/240, U-238, and U-233/234) are highest at the bottom of the disposal facility and generally decrease with depth. Soil samples collected and analyzed during interim remedial actions indicate residual contamination is located well above the water table and periodically re-wetted zone. Table 4-3 provides a list of high-volume liquid waste sites. Appendix B provides waste site locations.

Wastes sites that received small amounts of liquid are generally found to have soil contamination extending limited distances into the vadose zone beneath the waste sites (i.e., burial ground, some unplanned releases, and liquid sites). Adverse impacts to groundwater are not expected from these sites.

Contaminated soil at interim closed and no action waste sites (Chapter 2) has been removed and/or confirmed to meet remedial action goals for direct exposure, protection of groundwater, and protection of the Columbia River based on the requirements in EPA/ROD/R10-96/134. The inventory of contaminants remaining in the soil column has been significantly reduced by interim remedial actions. Contaminated soil removal and disposal in ERDF for the remaining source sites will continue. Data collected from these remaining source sites will provide information to assess the potential for adverse impacts through direct exposure or transport to groundwater pathways from remaining residual contamination.

Data Gap 2: *Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath remediated waste sites.*

Contaminated soil was removed from remediated waste sites. Modeling analyses suggest the residual contaminants in the soil column below the remediated waste sites are protective of the groundwater and the Columbia River. Soil samples have not been collected below remediated waste sites to the depth of the current water table to confirm this portion of the CSM. Little or no contaminant data have been collected at unremediated waste sites.

Data Gap 3: *Vadose zone contaminant nature and extent needed to assess protection of human health, ecological resources, and groundwater around reactor structures.*

Limited characterization has been performed around reactor structures.

4.2.2 Groundwater

Facilities and waste sites in the 100-K Area discharged or received chemicals and radionuclides from the 1940s to the 1960s. Previous groundwater investigations indicate contaminants have reached the groundwater from vadose zone sources at concentrations in excess of cleanup standards (Chapter 2). Three distinct CrVI groundwater plumes have been identified within 100-K (Figure 4-1). The groundwater contaminants are generally found near the 105-KE and 105-KW Reactor buildings (and associated support infrastructure) and the 116-K-2 Trench.

In addition, contaminants such as aluminum, iron, and manganese exceed secondary DWS. Federal secondary DWS are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (e.g., skin or tooth discoloration) or aesthetic effects (e.g., taste, odor, or color) in drinking water. As such, the focus of this section (and the CSM) is contaminants that pose a health risk to humans or ecological receptors.

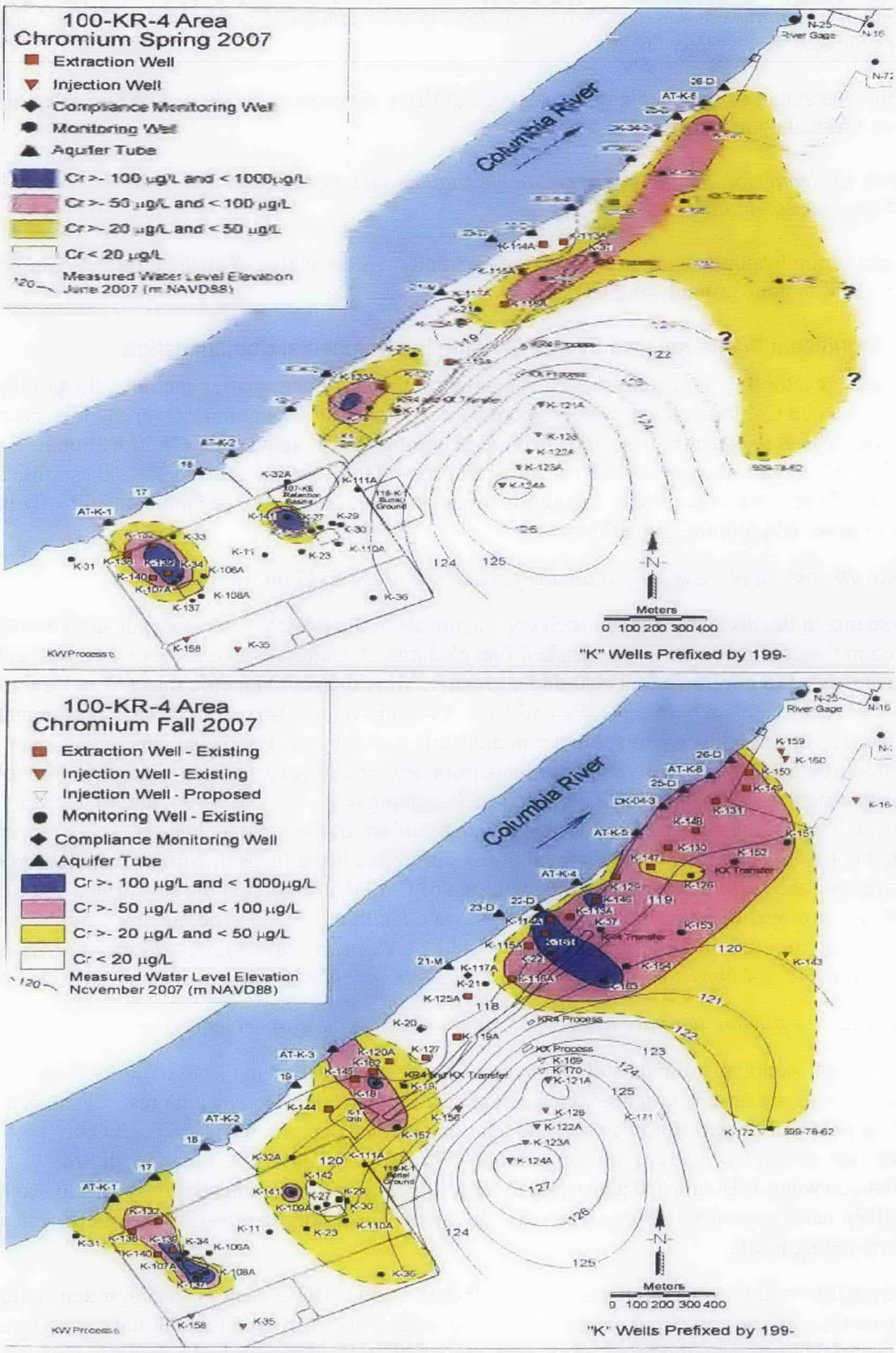


Figure 4-1. Map View of Recent Chromium Contamination Levels in the Unconfined Aquifer Underlying the 100-K Area

Data Gap 5: *The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been defined in select areas.*

Determine the extent of select contaminants (e.g., CrVI) at concentrations above DWS in select locations of the unconfined aquifer in 100-K.

Data Gap 13: *Data is needed to better define the spatial and temporal distribution of groundwater contamination.*

Additional groundwater data are needed that are spatially representative of an area, reflect river stage influence, and include groundwater COPCs.

4.2.3 Significant Waste Release Events Causing Environmental Contamination

The primary reactor operation activities causing environmental contamination included the production and use of treated Columbia River water to cool the reactors during operations. Over the lifetime of the 105-KE and 105-KW Reactor operations from 1955 through 1971, approximately 13 trillion L (about 3.5 trillion gal) of coolant were produced and passed through these reactors. As these fluids were produced and used, both intentional and unintentional discharges released contaminants directly into the Columbia River and into the soil column.

Data Gap 10: *The mechanism to explain the persistence of the CrVI plume is unknown.*

Contaminants in the discharged water included chemicals in the treated water and radioactive isotopes dissolved in the cooling water from breached fuel cladding. A major element in this water was sodium dichromate added to minimize fuel cladding corrosion. More than 6,000 metric tons (13 million lbs) were used in the reactor coolant between 1955 and 1971. Cooling waters also received other contaminants during passage through the reactors, other contaminants including activated elements in the water (e.g., chromium-51 [Cr-51]), activation products from reactor components (e.g., tritium, C-14, Co-60), and fission products released through breached fuel cladding (e.g., Cs-137, Sr-90, and plutonium isotopes). However, the mass and environmental distributions of the radionuclides are relatively small compared to CrVI. Therefore, CrVI removal in the subsurface is the focus of current remediation efforts. For this reason, the CSM is focused on the evolution of CrVI distribution in the subsurface since the startup of reactor operations in 1955. The processes and facilities used to generate, use, and discharge reactor coolant after use are described in DOE/RL-90-21, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit, Hanford Site, Richland, Washington,* and are summarized below.

Data Gap 12: *Insufficient data are available to support fate and transport modeling.*

On selected soil samples, estimate soil and hydraulic properties, determine level of contamination, confirm contaminant distribution coefficients, and perform batch leach contacting test. Batch leach contacting tests will be performed on soil and aquifer sediment samples using ASTM D3987-85, *Standard Test Method for Shake Extraction of Solid Waste with Water.* The method will use demineralized water (pH adjusted according to EPA's West Coast recommendations) for the leach. The leach will be calculated at 1:1 soil-to-water-weight ratios. The desorption distribution coefficient will support modeling needs.

To generate the cooling water solutions for the 105-KW and 105-KE Reactors, concentrated sodium dichromate feed solutions were processed through an infrastructure system that diluted the higher-strength source materials to achieve the required coolant composition. Each reactor had a dedicated but identical processing infrastructure. To begin the process, concentrated sodium dichromate solutions were brought to the site by railcar and transferred to 158,987 L (42,000 gal) tanks (120-KW-5 and 120-KE-6) next to

the 183-KW and 183-KE Reactor complexes that treated and stored Columbia River water (Figure 4-2). The solution, frequently referred to as the 70 percent solution, had a pH of about 1.5 to 2, CrVI concentrations of about 466 g/L (PNNL-17674, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*), and specific gravity of about 1.7 g/cm^3. Subsequently, some length of piping carried the 70 percent solution to clearwell tanks at the northern end of the 183-KW/KE Facilities containing treated Columbia River water. Beyond this point, no 70 percent solution was present in the coolant production process or discharge infrastructure.

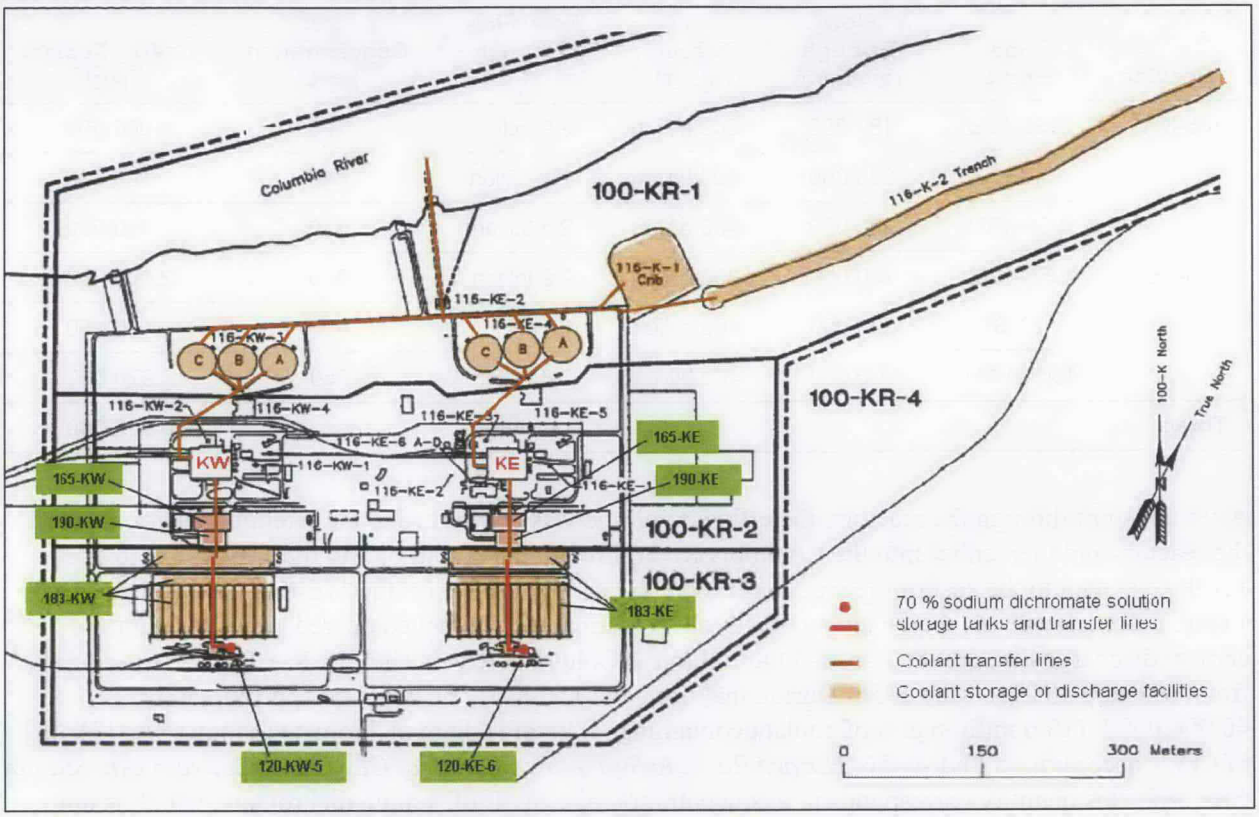


Figure 4-2. Facilities in the 100-K Area that Produced, Stored, or Transferred Liquid Sodium Dichromate Solutions

During transfer from the rail cars to the storage tanks, some sluicing of fluid into a nearby drain must have occurred, as well as unintentional spills. Such losses are indicated by yellow-stained soils around the tanks. The piping beneath the 183-KW/KE Facilities also provided opportunities for leaks into the subsurface. The quantities of solution lost from these initial parts of coolant production infrastructure are unknown, but the locations from which the 70 percent solution could have been released into the subsurface were limited.

The 70 percent solution was metered into 183-KW/KE Clearwell Tanks (located next to the 190-K Buildings) that contained treated Columbia River water and mixed in the appropriate proportions to generate the dilute coolant solution. Initially, a 2-mg/L sodium dichromate coolant solution (about 700 µg/L of CrVI) was generated, but over time, more dilute solutions were used. By 1964, sodium dichromate concentration decreases of about 1 mg/L (350 µg/L of CrVI) were instituted and then decreased further in 1968 to 0.5 mg/L (175 µg/L of CrVI) (DUN-4847). Once these solutions were generated, they were pumped through the 190-KW/KE and 165-KW/KE Buildings to the reactors at a rate of about 681,372 L/min (180,000 gal/min) until about 1962 (HW-70849, *Process Water Pump Operating*

Conditions During Project CGI-883 Pump Modification). At that time, a project to upgrade pumps and increase water flow through the reactor was completed, allowing greater flow, about 75,708 L/min (200,000 gal/min). From these data, an approximate total coolant volume of 12 trillion L (3.2 trillion gal) passed through the reactors containing about 6,300,000 kg (13.9 million lbs) of CrVI (Table 4-4).

Table 4-4. Estimate of Reactor Coolant Volume and Hexavalent Chromium Content Passed Through the 105-KW and 105-KE Reactors

Reactor	Time Period	Flow Through (gal/min)	Flow Through (L/yr)	Total Flow Through (L)	CrVI Concentration (µg/L)	CrVI in Coolant (kg)
105-KW	1955-1962	180,000	360 billion	2.9 trillion	700	2,000,000
	1963	200,000	400 billion	400 billion	490	190,000
	1964-1970	200,000	400 billion	2.4 trillion	350	840,000
105-KE	1955-1962	180,000	360 billion	2.9 trillion	700	2,000,000
	1963	200,000	400 billion	400 billion	490	190,000
	1964-1971	200,000	400 billion	2.8 trillion	350	970,000
Totals				**12 trillion**		**6,300,000**

After transport through the reactors, the effluent volume was discharged to the retention basins north of the reactors and then either into the Columbia River through the outfall or into the 116-K-1 Crib or the 116-K-2 Trench to the east of the reactors (Figure 4-2). The purpose for the 116-K-1 Crib and 116-K-2 Trench was to receive the radioactively contaminated coolant compared to nonradioactive coolant discharge through the 116-K-3 Outfall to the Columbia River. The 116-K-1 Crib was used only from February 1955 to May 1956. During that time, the 116-K-1 Crib received approximately 40,000,000 L (10.6 million gal) of coolant containing 40 kg of sodium dichromate (about 14 kg [31 lbs] of CrVI) according to PNL-6456, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford.* This quantity corresponds to a concentration of 1 mg/L of sodium dichromate, which is not consistent with the use of 2 mg/L in reactor coolant during this period. If the volume of discharge assumed is correct, the quantity of CrVI lost should be about 28 kg (61.7 lbs).

The 116-K-2 Trench was used through the reactor operations period from 1955 until 1971. During this time, discharges were received from a number of sources. The 105-KW/KE Retention Basins were the sources that provided the largest volumes of coolant. Initially, discharges were limited to the radioactively contaminated fluids, but over time the butterfly valves controlling releases into the 116-K-2 Trench degraded, permitting substantial and uncontrolled discharges estimated to be between 37,854 and 75,708 L/min (10,000 and 20,000 gal/min) (UNI-946). At times the 116-K-2 Trench overflowed. Losses beneath the retention basins no doubt also occurred as the piping system degraded. Other lesser sources of discharge included floor drains in the reactors, metal storage basin overflow (1,893 to 2,650 L/min [500 to 700 gal/min]) and drains in research and development facilities (1706-KE/KER), and gas purification buildings. In addition, decontamination fluids were sometimes added to reactor coolant effluent.

Given the uncertainties about sources and discharge rates, total volumes of fluids and quantities of CrVI that discharged into the 116-K-2 Trench are uncertain. PNL-6456 proposed a total volume discharge of 300 billion L (79 million gal). If the estimated losses of 75,700 L/min (20,000 gal/min) indicated by UNI-946 are considered, over a 16-year period, a total discharge of 600 billion L (160 billion gal) is estimated. These volumes are about 2 to 5 percent of the total estimated coolant volume passed through the reactors and appear to be a reasonable rough approximation of subsurface discharge. Knowing that the sodium dichromate concentrations ranged between 2 mg/L and 0.5 mg/L (or 700 μg/L and 175 μg/L of CrVI) and assuming an average value of about 1 mg/L of sodium dichromate (or 350 μg/L of CrVI), a total subsurface discharge of 100,000 kg to 200,000 kg (220,500 lb to 441,000 lbs) of CrVI is estimated.

Leaks or overflows in and around the outfall structure, and releases from small liquid discharge facilities, piping that carried reactor coolant, and some solid wastes (e.g., sludges) comprised other sources of CrVI discharges. Of these, losses around the outfall structure may have been substantial, as apparently more than 90 percent of the reactor coolant discharged through the facility. The other facilities received much smaller volumes of liquids (and solids) compared to the retention basins and 116-K-2 Trench and could only have contributed relatively minor amounts of CrVI to the subsurface.

4.3 Contaminant Fate and Transport

This section discusses the fate and transport of contaminants in the vadose zone and groundwater within 100-K.

4.3.1 Current Field Characterization Summary

Numerous wells have been completed in the unconfined aquifer in the 100-KR-4 OU since 1997 for purposes of measuring contamination levels, extracting contaminants, and injecting treated water back into the aquifer. The majority of measurements have been collected near the water table. With respect to CrVI, the monitoring data generally show contamination levels less than 200 μg/L (Figure 4-1). Reduction in CrVI concentration over time has been observed in most wells, primarily because of the pump-and-treat system placed between the Columbia River and the 100-K Area facilities. However, a few areas of higher CrVI contamination have persisted.

The highest levels of groundwater CrVI contamination occur near the 190-KW and 165-KW Buildings in a small area defined by two wells, 199-K-137 and 199-K-165. CrVI contamination in both wells has been above 3,000 μg/L. Groundwater samples have also been taken as a function of depth in Well 199-K-165. The samples provide initial indication of the vertical extent of CrVI contamination in the aquifer. Between the water table (25 m [81 ft] bgs) and 44 m [143 ft] bgs), CrVI concentrations range from 1,230 μg/L to 3,020 μg/L with the maximum value at 33 m (107 ft) bgs. Conversely, a CrVI concentration of 286 μg/L was measured in the deepest sample at 50 m (163 ft) bgs. Two other nearby wells, 199-K-107A and 199-K-165, have also shown moderately high CrVI levels greater than 300 μg/L (Figure 4-3). CrVI concentrations have dropped since the middle of 2007.

This observation suggests extraction wells between these wells and the Columbia River are partially successful at removing CrVI from the aquifer.

One groundwater well next to the 70 percent solution storage tank at the 105-KE Reactor facility, 199-K-36, also suggests unconfined aquifer contamination from the 70 percent solution used in reactor coolant production for 105-KE. Throughout 2001, CrVI concentrations generally exceeded 800 μg/L and peak at about 1,300 μg/L in August. These concentration levels have not been sustained and no other nearby wells have shown similar CrVI levels.

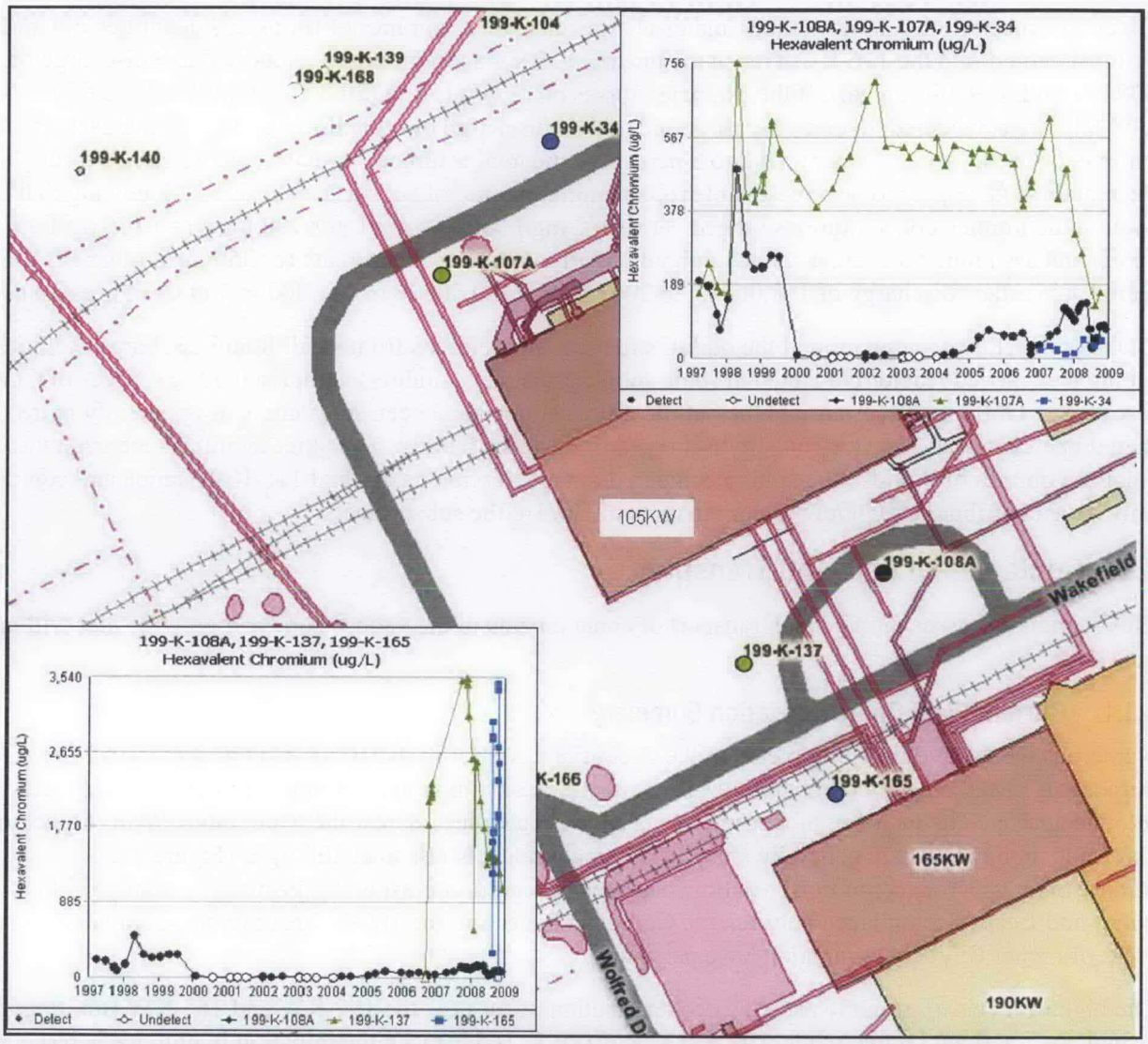


Figure 4-3. Chromium Concentrations in Groundwater Wells near the 190-KW and 165-KW Buildings

Moderately elevated CrVI concentrations are present in three other locations. In each case, one or two wells with relatively high contamination levels are surrounded by nearby wells with considerably lower values. At well 199-K-141 just north of the 105-KE Reactor, CrVI concentrations have ranged between 186 µg/L and 431 µg/L and appear to be rising. At well 199-K-18, at the southern end of the 116-K-2 Trench, concentrations have steadily risen, from about 30 µg/L in 1997 to greater than 150 µg/L in recent measurements. Since late 1999, CrVI concentrations at well 199-K-22 at the north end of the 116-K-2 Trench have typically been close to 150 µg/L and are gradually decreasing.

Soil data collection for CrVI has been largely limited to the near surface, typically less than 6 m (20 ft) bgs and strongly concentrated along the 116-K-2 Trench and beneath the retention basins. Of the 165 samples collected and analyzed showing measurable CrVI, the maximum concentration found was 8.66 mg/kg at a depth of 6 m (21 ft) bgs. Only 19 samples had CrVI concentrations greater than 2 mg/kg, and 134 samples had concentrations less than 1 mg/kg.

In 2007 and 2008, soil samples were collected from the deep vadose zone for analysis of CrVI during well drilling for expansion of the 100-KW and 100-KX Groundwater Pump-and-Treat Systems. Forty soil samples were collected from 14 boreholes at depths approximately 1.5 m (5 ft) and 3 m (10 ft) above the water table in the four new wells. Results suggested that little (if any) CrVI remaining in the deep vadose zone (previously wetted or from more shallow sources) because CrVI was not detected in 35 of the 40 samples (at a detection limit of 0.10 mg/kg to 0.35 mg/kg). The maximum sample concentration was 0.76 mg/kg collected 6 m (20 ft) bgs and 3 m (10 ft) above the water table in borehole 199-K-146.

4.3.2 Conceptual Site Model Description

The following discussion postulates the evolution of CrVI distribution in the subsurface with emphasis on the hydrologic system characteristics and processes controlling contaminant distribution.

The great majority of CrVI was discharged into the surrounding environment as a dissolved species in various liquids. The historical records information described in a previous section shows CrVI was released into the environment primarily as a dissolved species in two types of solutions, the reactor coolant and the 70 percent stock solution used to make reactor coolant and reactor coolant itself. The differences in solution chemistry, associated production facilities, and discharge locations have had a substantial effect on current CrVI distribution in the subsurface.

With regard to ultimate CrVI distribution in the environment, the significant solution properties are CrVI concentration, pH, and specific density. The approximate CrVI concentration was 466 g/L in the 70 percent by weight solution. This solution was acidic (pH about 1.5) and significantly more dense than water (specific gravity of 1.7 g/cm^3). Aquifer contamination from this stock solution occurred in two locations: storage tanks and piping near and under the 183 Complex at each reactor.

Figure 4-2 shows and Chapter 2 describes, the 70 percent solution was shipped by rail car to a 158,987 L (42,000 gal) storage tank next to the 183-KW and 183-KE Facilities and then piped to mixing tanks containing treated Columbia River water. The total amount of 70 percent solution that passed through this system is not known but can be derived from the CrVI content estimates in the reactor coolant. If the reactor coolant volumes and CrVI content provided in Table 4-4 are assumed (6,300,000 million kg; [13.9 million lbs]), a total 70 percent volume of about 13,000,000 million L (3.4 million gal) was stored and transferred from these two tanks. The delivery of the 70 percent solution into the storage tanks was not completely efficient, and yellowish-stained soils around the storage tank location indicate losses to the subsurface. In addition, some leakage in the transfer pipes or connection between the transfer pipes and the mixing tanks is plausible. The fraction of delivered 70 percent solution lost to the subsurface is not known. However, based on a comparison of groundwater contamination condition at the 100-K Area versus the 100-D Area, the fraction lost does not appear to be nearly as much as that lost at the 100-D Area, even though more fluid was used at the 100-K Area. The major difference appears to be the greater simplicity of the 100-K Area 70 percent solution feed system, which involved only the storage tanks and a short transfer line to mixing tanks.

Following discharge of these CrVI-rich dense fluids into the subsurface, vertical penetration occurred. The density of the fluid would have facilitated vertical migration into the subsurface with little lateral movement. However, very little information is available that describes the distribution of CrVI initially from this fluid in the subsurface, and several factors suggest a broad range of possibilities. The vadose zone and the unconfined aquifer are each about 24 m (80 ft) thick beneath the storage tanks and transfer piping and composed primarily of the Ringold E Unit (see Well 199-K-165 in Figure 2-4), which is partially cemented in places. This unit may have provided substantial resistance to vertical migration. The opportunity for recharge would also have been limited because the 183-KW/KE Basins provided partial shielding from precipitation and subsequent recharge. In addition, some sequestration by CrVI reduction via ferrous iron (PNNL-17674) or physical entrapment in occasional silty lenses may have occurred in the vadose zone.

It appears that some fraction of the 70 percent solution has reached the unconfined aquifer because maximum CrVI concentrations in a small number of wells exceed reactor coolant chromium concentrations (up to 700 μg/L). These wells (199-K-137 and 199-K-165) have shown levels up to 3,000 μg/L, concentrations that could not be achieved if the CrVI source were the only reactor coolant. These wells are also appropriately placed just downgradient of the piping that transferred the 70 percent solution to the mixing tanks in the 183-KW Complex. The newly generated depth-specific groundwater data from Well 199-K-165 suggest complete penetration of the 70 percent solution through the unconfined aquifer may not have occurred, given the relatively low groundwater concentration (286 μg/L) near the bottom of the aquifer.

Groundwater monitoring data indicate CrVI from the 70 percent solution discharge has migrated in a narrow band toward the Columbia River along a northwest axis. This direction is consistent with the regional gradient and provides no indication of alteration to the natural gradient in the 105-KE and 105-KW Reactor areas caused by the historical 116-K-2 Trench groundwater mound or the more recent water injection mound about 1.6 km (1 mi) to the northeast. The plume appears to be migrating slowly, given its current limited extent and the small regional gradient that pushes it toward the Columbia River. Future migration is expected to be relatively slow as well, and currently operating extraction wells are both reducing and limiting the spread of high concentrations. Whether the trend will continue depends on the nature and extent of the remaining source term, which is highly uncertain.

Reactor coolant solutions, once passed through the 105-KW and 105-KE Reactors, were routed north to two sets of three retention basins and then piped either to the Columbia River through the 116-K-3 Outfall or to the 116-K-2 Trench. As discussed in Chapter 2, of the approximately 12 trillion L (3 trillion gal) of coolant that passed through the reactors, the greater fraction went through the outfall. The remainder, an estimated 100 million to 600 billion L (264 million to 158 billion gal) (about 2 percent to 5 percent of the total) containing about 100,000 kg to 200,000 kg (220,000 lbs to 441,000 lbs) of CrVI, was piped into the 116-K-2 Trench. For the most part, the CrVI discharged through the outfall entered the Columbia River, with the exception of leaks and spills near the shore.

The long-term releases of large volumes of reactor coolant into the 116-K-2 Trench caused the formation of a large groundwater mound (Figure 2-9) in the mid-to-late 1950s that grew until the late 1960s. The rapid formation of the groundwater mound shortly after discharges to the trench began indicates CrVI migrated quickly through the vadose zone and likely penetrated much if not all of the unconfined aquifer. Relatively quick transport through the vadose zone was facilitated because the majority of the vadose zone beneath the 116-K-2 Trench comprises the more permeable Hanford Formation (Figure 2-5). Given the radial migration of fluid along the trench axis, some portion of the source term, perhaps the majority, discharged into the Columbia River and is no longer present in the subsurface. Figure 2-9 also suggests the 116-K-2 Trench discharges overwhelmed reactor coolant discharges from other locations such as beneath the retention basins.

The remainder of the source, probably thousands of kilograms of CrVI, was pushed inland by the growing groundwater mound. Figure 2-9 suggests the mound influence extended as much as 3 km (2 mi) inland and the highly soluble CrVI would have been present throughout the impacted area at concentration levels less than 700 μg/L, the maximum concentration assumed in the early reactor coolant. At the outer edges of the groundwater mound, dispersion effects would have limited maximum CrVI concentrations to smaller values (e.g., less than 100 μg/L). Mounding during operations from discharge to the 116-K-2 Trench is the most likely cause of the CrVI detected in well 699-78-62, located approximately 1,158 m (3,800 ft) inland from the trench. As the groundwater mound diminished, inland migration of the CrVI also diminished, and by the mid-1970s, the regional gradient was essentially reestablished. At this point, CrVI migration began to reverse and migrate slowly toward the Columbia River.

Figure 4-1shows the current distribution of CrVI in the subsurface from the 116-K-2 Trench discharges is partially defined by the groundwater monitoring, extraction, and injection wells. The CrVI concentration contours show the most highly concentrated zones to be along the 116-K-2 Trench axis, as expected, and the areas containing concentrations greater than 100 μg/L are limited. The existing total area of CrVI contamination is likely considerably larger than that shown in Figure 4-1 and still extends farther inland.

Extraction wells began removing contamination in 1997 at the north end of the 116-K-2 Trench. The wells were expanded in 2007 and 2008 to cover the remainder of the 100-KR-4 OU facilities to the southeast. In addition, a series of injection wells have been operational since 2007 at the southern end of the 116-K-2 Trench and upgradient of the 100-KW facilities to expedite CrVI removal. Approximately 350 kg (772 lb) of CrVI has been removed through 2007 (DOE/RL-2008-05). These operations have decreased the areas of higher contamination (e.g., more than 100 μg/L). The remaining areas of higher contamination at the south and north end of the 116-K-2 Trench (around Wells 199-K-18 and 199-K-22, respectively) may be related to aquifer configuration. These areas are roughly coincident with the thicker aquifer zones created by depressions in the RUM Unit shown in Figure 2-6. These zones may have acted as channels for preferential flow and provided greater storage of reactor coolant. The main group of injection wells has created a zone near the middle of the 116-K-2 Trench below concentrations of 20 μg/L.

Groundwater flows at an average rate of 0.1 m/day to 0.3 m/day (0.33 ft/day to 0.98 ft/day), as estimated from hydraulic gradients and from migration rates of plumes (PNNL-14031). The best supported estimate for the groundwater flow rate between the 105-KE Reactor and the river is 0.12 m/day (0.4 ft/day) (PNNL-13788). Relatively faster flow is observed beneath the 105-KW Reactor than below the 105-KE Reactor (PNNL-14031).

4.3.2.1 Ringold Upper Mud and Lower Hydrogeologic Units

Data Gap 7: *The fate and transport of contaminants beneath the unconfined aquifer has not been evaluated.*

Underlying the upper aquifer in 100-K is the RUM Unit. The RUM Unit is generally recognized as the base of the upper unconfined aquifer in 100-K, but is poorly characterized. The RUM Unit has been described as primarily clayey silt and silty clay, with lenses of silty sand and sandy silt. Only one Well (199-K-32B) in 100-K has been completed in the RUM Unit (or hydrogeologic units beneath the RUM Unit). Net groundwater movement in the RUM Unit is upward, based on upward hydraulic gradients, measured from 1993 to 2008, between well 199-K-32A (completed in the upper unconfined aquifer) and well 199-K-32B (completed in the RUM Unit). Since only one well in the 100-K Area has been completed beneath the unconfined aquifer, groundwater flow directions and velocities are relatively undefined.

Groundwater in the RUM Unit has been sampled for organics, inorganics, and radionuclides. However, samples have not been collected from the wells for all of the contaminants that were identified as COPCs in the 1996 interim action ROD. Well 199-K-32B is completed in an area where CrVI concentrations in the upper unconfined aquifer have been historically low (e.g., less than 50 μg/L), and the well is not downgradient of the highest concentrations of CrVI and other contaminants (e.g., tritium) detected in the upper aquifer. Therefore, impacts to the RUM Unit and the vertical extent of contamination from the highest concentration areas within the upper aquifer have not been defined.

Data Gap 8: *It is unknown if contamination within the RUM Unit will adversely affect aquatic receptors in the Columbia River.*

Based on current knowledge of the elevation of the RUM Unit from inland wells (the upper aquifer thickness) and river bathymetry, the top of the RUM Unit does not intersect the river channel. Therefore, it does not appear that contamination (if any) above aquatic cleanup standards within the RUM Unit or lower units will affect aquatic receptors. However, detailed bathymetric data are needed to confirm whether the RUM Unit intersects the river. As a result of the lack of wells completed beneath the upper aquifer in 100-K, current discharge points for groundwater beneath the upper aquifer are not known. The RUM Unit is not currently considered a future drinking water source. However, additional hydrogeologic data (e.g., hydraulic conductivity and hydraulic gradient information) are needed to confirm the current CSM hypothesis that the RUM Unit cannot support a drinking water resource.

4.3.2.2 Pump-and-Treat Operations

A pump-and-treat remediation system was installed in 100-K to reduce/eliminate the discharge of CrVI to the river. Pump-and-treat activities have removed CrVI mass from the groundwater. During operations of the systems, groundwater flow at 100-K has been locally altered.

Data Gap 9: *The hydraulic rate of exchange between the groundwater and the river is unknown.*

Operation of the pump-and-treat systems has influenced groundwater flow directions and velocities in 100-K. The pump-and-treat operations in the 100-K Area have not substantially reduced groundwater concentrations since 1996. At this time, it is uncertain whether the persistent CrVI concentrations in groundwater within 100-K are the result of continuing vadose zone sources, CrVI within the periodically rewetted zone that enters the plume via fluctuations of groundwater, or sources within the aquifer or underlying RUM Unit. In addition, as a result of the lack of monitoring wells near many of the

groundwater extraction and injection wells, the magnitude of mounding near injection wells and lowering of the water table near the extraction wells within the aquifer are not defined.

4.3.3 Groundwater/River Interactions

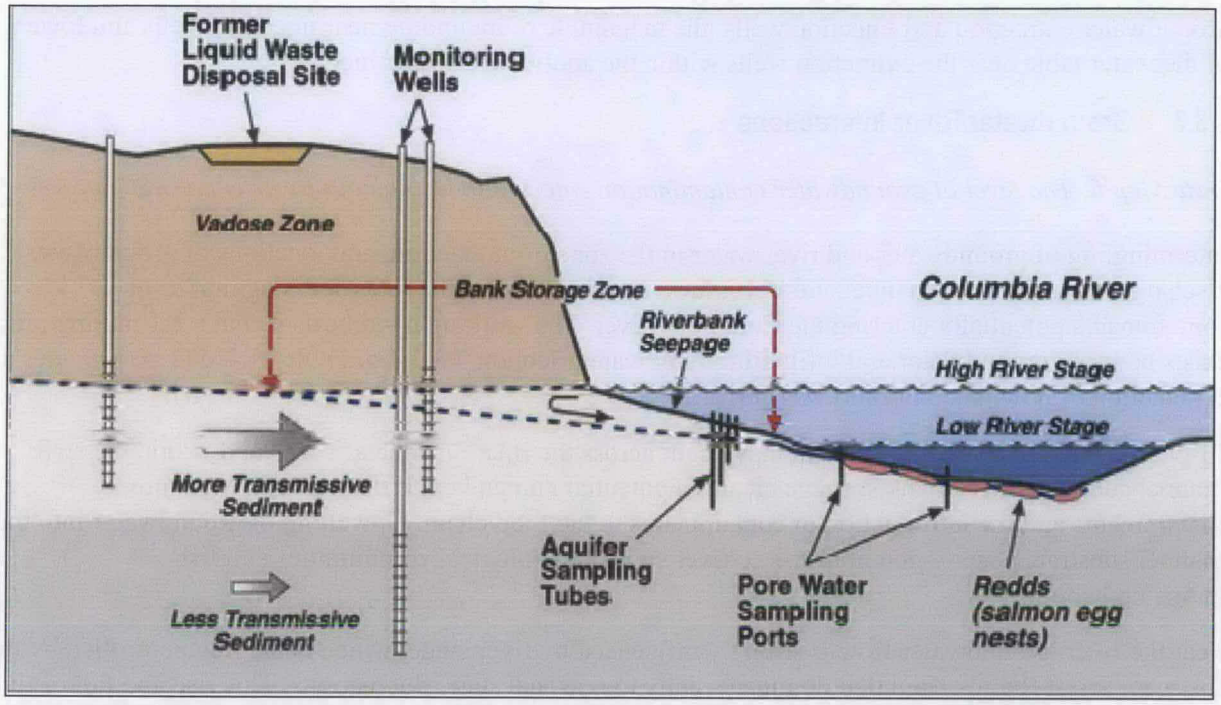
Data Gap 6: *The level of groundwater contamination entering the Columbia River is not well known.*

Intermingling of groundwater and river water in the zone of interaction, and locations of groundwater discharges into the river channel, are key issues to understanding the rates and magnitudes of contaminants potentially entering the Columbia River. The working hypothesis is that a 1:1 mixing ratio exists between groundwater and infiltrating river water. Section 2.3.3.4 of DOE/RL-2008-46 provides an explanation of how this unit ratio was derived.

Discharge into the river environment may occur across the riparian zone as seeps and within the river channel substrate. Riverbank seepage creates a potential human health risk through exposure to contaminants and the introduction of contaminants to the food chain. Upwelling of groundwater into the channel substrate poses a potential risk to river substrate biological communities and fish spawning habitat.

Near the river, groundwater flow is strongly influenced by river stage, which is directly controlled by the upstream Priest Rapids Dam that dominates daily to seasonal stage fluctuations. This rise and fall of river stage creates a dynamic zone of interaction between the groundwater and river water, and influences flow patterns, transport rates, contaminant concentrations, and attenuation rates within the system (PNNL-13674).

Riverbank seep discharges to the river are visible during low river stage. Conversely, during high river stage, the seeps are submerged as river water infiltrates into the riverbanks and forms either a layered system or a mixture during interaction with approaching groundwater. Data indicate riverbank storage water composition oscillates dramatically from nearly completely river water, during high river stage, to primarily groundwater, during low river stage (PNNL-13674). Figure 4-4 shows an illustrated model of the zone of interaction.



Source: PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River.*

Figure 4-4. Principal Features and Monitoring Sites for Zone of Interaction

In the channel substrate, sediment pore water may be influenced by the entrainment of river water and the gradual influx of groundwater that upwells from the underlying aquifer. Physical, chemical, and biological characteristics of this interface have been the focus of research in aquatic biology (Geist and Dauble, 1998, "Redd Site Selection and Spawning Habitat Use by Fall Chinook Salmon: The Importance of Geomorphic Features in Large Rivers" and Geist, 2000, "The Interaction of Ground Water and Surface water within Fall Chinook Salmon Spawning Areas in the Hanford Reach of the Columbia River"). Upwelling of groundwater from the 100-K Area is considered unlikely to directly affect salmon spawning areas (Figure 4-5) and other aquatic species.

Physical, chemical, and biological processes occur within the zone of interaction that potentially alters the characteristics of approaching groundwater. Data suggest physical processes dominate influences on contaminant concentrations and fluxes, where groundwater discharges into the free-flowing river. Chemical processes may render contaminants as less mobile as they adsorb to sediment or precipitates. Zone of interaction biological activity may also capture contaminants and immobilize them, or introduce them into the food chain (PNNL-13674).

Columbia River elevations have varied up by as much as 2.7 m (9 ft) in a single day (PNL-9437). Groundwater elevations have varied by up to 0.9 m/day (3 ft/day) in some wells nearest the river and up to approximately 1.8 m (6 ft) over the season in a few wells (PNL-9437).

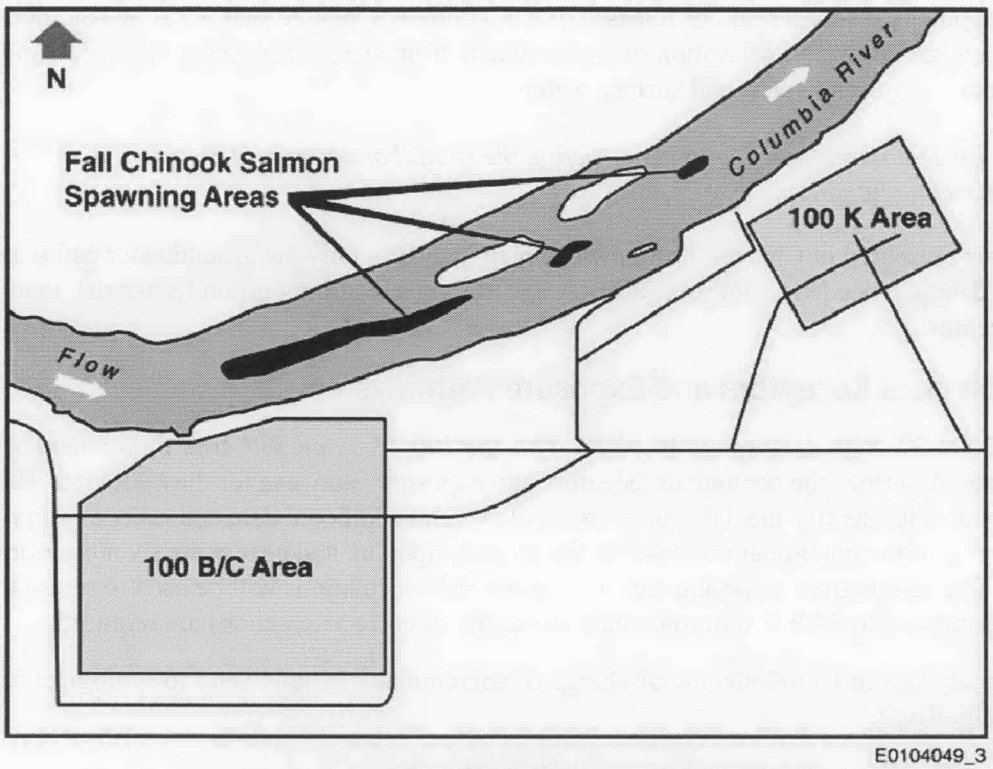


Figure 4-5. Salmon Redds Adjacent to 100-K

4.3.4 Potential Alternative Remedial Technologies

Data Gap 11: *Potential alternative remedial technologies have not been sufficiently investigated.*

Groundwater contamination above aquatic standards and drinking water maximum contaminant levels has been detected in 100-K. Interim remedial actions are currently in operation. Additional data and information are needed to evaluate potential final remedies as part of the future project FS.

4.4 Human Receptors and Exposure Pathways

EPA risk assessment guidance describes an exposure pathway as being the course that a contaminant takes from a source to a receptor (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual*). Exposure pathways integrate information relating to sources and/or releases of contamination, contaminant transport pathways in the environment, exposure media, and exposure routes for receptors. Exposure pathways must contain all of the following elements; otherwise, the pathway is not complete and does not present a risk or hazard (EPA/540/1-89/002; EPA/540/1-89/001, *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual*):

- Known and potential sources and/or releases of contamination
- Contaminant migration pathways
- Potential exposure scenarios
- Potential exposure media
- Potential exposure routes and receptors

Known and potential sources and/or releases of contamination include shallow zone soil, deep zone soil, sediment, and groundwater. Migration of contaminants from one source media may affect other media such as biota, air, groundwater, and surface water.

Data Gap 13: *Data areas needed to better define the spatial and temporal distribution of groundwater contamination.*

The analysis presented in Chapter 3 of the work plan identifies only the groundwater pathway as a remaining data gap needed to address RCBRA uncertainties regarding groundwater risk to a human receptor.

4.5 Ecological Receptors and Exposure Pathways

DOE/RL-2004-37, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA*, identifies and describes the ecological receptors and exposure pathways for the 100 Area. The scope of the work plan is to identify the data currently available and additional data and tasks required to assess the risks resulting from contaminant releases in the upland, riparian, and near shore river environments in the 100 Area. The results from sampling and subsequent risk calculations will be used to revise the data quality objectives and SAP if additional data collection or corrective actions are required.

Exposure pathways in 100-K include discharge of contaminated groundwater to ecological receptors in the Columbia River.

4.6 Identification and Resolution of Data Needs

A summary of the data needs necessary to fill the data gaps, as well as the specific work proposed for this work plan, are presented in Table 4-5. The proposed sampling for the RI for 100-K is presented in Table 4-6. Table 4-7 summarizes the approximate number of soil and water samples and analyses that would result from this field work. As described in earlier sections, other remediation activities and characterization efforts associated with interim RODs will also make a significant contribution to the quantity of data collected in 100-K.

Table 4-5. 100-K Data Needs

Data Gap	Data Need No.	Data Need	Description	Additional Data Collection Recommended?	Scope of Work	Justification
Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath unremediated waste sites.	1	Characterize below unremediated waste sites to assess the nature and extent of contamination in the vadose zone.	Continue interim remedial actions as they have demonstrated to be efficient in obtaining the necessary data during remediation using the observational approach. Obtain data documenting the remaining residual contamination following completion of the interim remedial action.	Yes	Continue contaminated soil removal and sampling at 110 waste sites in 100-K. The location of unremediated waste sites is shown in Appendix B. *Special Case: Petroleum hydrocarbons in the 100-KW area.* At this time, there is no additional work scope for the unplanned release related with the 166-KW Oil Storage and Oil Pump Equipment facility. The associated waste site, 100-KW-2, is currently an accepted site and will be remediated. The plume will be chased laterally until sufficient contamination is removed.	Continue remediation to protect human health and environment. Data collected during and at completion of remediation is needed to assess the nature and extent of vadose zone contamination.
Vadose zone contaminant nature and extent needed to assess protection of groundwater beneath remediated waste sites.	2	Characterize beneath remediated waste sites to assess the nature and extent of contamination in the vadose zone.	Drill two boreholes to groundwater and sample beneath the 116-K-2 Trench. Details of the sampling are found in the SAP (DOE/RL-2009-41).	Yes	Through this RI, drill two boreholes within the trench and sample according to the target analyte list provided in the SAP (Boreholes B1 and B2, Figure 4-6). Soil samples should generally be collected continuously from the bottom of the waste site (or the maximum depth of remedial action) to the water table. Groundwater samples and aquifer sediment samples will be collected and analyzed.	A lack of data at the 116-K-2 Trench exists to support an assessment of the vertical distribution of contamination beneath the waste site. This waste site is near the CrVI and other groundwater plumes. Contaminant inventory and effluent volume received at this waste site indicate there was impact to groundwater during operation. Characterization will be performed to validate interim remedial action, address uncertainty regarding the nature and extent of residual contamination in soils, refine the CSM (if necessary), and support decision making for the final ROD for 100-K.
Vadose zone contaminant nature and extent needed to assess protection of human health, ecological resources, and groundwater around reactor structures.	3	Characterize around the reactor structures to assess nature and extent of contamination in the vadose zone.	Data are needed to determine the nature and vertical extent of the contamination in the vadose zone around reactor structures (105-KE and 105-KW Reactors).	Yes	Continue contaminated soil removal and sampling at waste sites associated with the 105-KE and 105-KW Reactor sites. The location of these waste sites is shown in Appendix B.	Continue remediation to protect human health and environment. Data collected during and at completion of remediation is needed to assess nature and extent of vadose zone contamination.
Unidentified waste sites (orphan/discovery sites) may exist.	4	Identify new waste sites and potential sources of contamination.	Complete OSE process.	Yes	Complete OSE process inside the fence line. The discovery site process will continue until waste site and facility removal is complete.	The OSE and waste site discovery processes are performed to identify new waste sites and sources that are not in CERCLA decision documents.

Table 4-5. 100-K Data Needs

Data Gap	Data Need No.	Data Need	Description	Additional Data Collection Recommended?	Scope of Work	Justification
The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been defined in select areas.	5	Define the extent of groundwater contamination above cleanup standards in select areas of the unconfined aquifer.	Determine the extent of select contaminants (e.g., CrVI) at concentrations above water quality standards in select locations of the unconfined aquifer in 100-K.	Yes	Through this RI, install nine new monitoring wells (Figure 4-6) and three aquifer tubes (Figure 4-6). Wells 1, 3, 7, 8, and 9 are planned to define the extent of CrVI in groundwater. Well 4 is proposed to better define a CrVI hot spot. Well 2 and the aquifer tubes are planned to define the extent of CrVI, Sr-90, C-14, TCE, and tritium downgradient of the 105-KE Reactor area. Well 5 is planned as a replacement for Well 199-K-109A to further monitor and define the extent of the Sr-90 hot spot. Well 6 will be installed to define the extent of CrVI and tritium near the 116-K-2 Trench. Sampling details are found in the SAP (DOE/RL-2009-41).	The extent of the CrVI plumes above the aquatic cleanup standard have not been defined in several areas, including the eastern boundary of the 105-KW Reactor plume, upgradient of the 105-KE and 105-KW Reactors and the Mile-Long Trench plumes. C-14, tritium, and TCE have been detected on the downgradient edge of the 107-KW Waste Site above DWS. The extent of contamination for these contaminants in this area has not been defined. Tritium at more than 10 times the DWS has been detected upgradient of the southwest portion of the 116-K-2 Trench. The extent of tritium contamination has not been defined upgradient of the southwest portion of the 116-K-2 Trench.
The level of groundwater contamination entering the Columbia River is not well known.	6	Collect groundwater upwelling data and information during the RI for Hanford Site releases to the Columbia River.	Groundwater upwelling sampling and analysis in the Columbia River channel is planned for fall 2009, and it is expected that these data will provide further insight regarding contaminant levels entering the river and groundwater/ river mixing ratio within the biotic zone (upper 30.5 cm [~12 in.] of substrate). Evaluate additional methods (e.g., new rounds of pore water samples, horizontal aquifer tubes in the biotic zone) in appropriate 100-K locations to validate/update the porewater sampling conducted in 1995 which serves as the basis for the 1:1 minimum mixing ratio assumed for groundwater/river water in the River Corridor.	Yes	Collect groundwater upwelling samples in the Columbia River.	Currently, reevaluation of the groundwater remedial activities (i.e., Pump-and-Treat) is being conducted. The focus of the reevaluation is to recover contaminants adjacent to the river and therefore prevent contaminants from entering the river.
The fate and transport of contaminants beneath the unconfined aquifer has not been evaluated.	7	Collect physical and hydrogeologic parameters from soil samples to support the determination of contaminant fate and transport beneath the unconfined aquifer.	CrVI has been detected in one well completed beneath the unconfined aquifer above the aquatic standard and DWS in 100-K. The fate and transport of this contamination has not been quantified.	Yes	Through this RI, drill and sample soil and groundwater from four groundwater monitoring wells (R1, R2, R3, and R4) drilled through the unconfined aquifer to approximately 15 m (50 ft) within the RUM Unit. Complete the wells in a water-producing zone within the RUM Unit, if found. Locations are shown in Figure 4-6. Sampling details are found in the SAP (DOE/RL-2009-41).	The location of groundwater monitoring wells and sampling approaches were selected to provide data for multiple purposes, including the refinement of the extent of contamination; evaluation of contaminant persistence; and to collect physical, chemical, and hydrologic properties of the RUM Unit.

Table 4-5. 100-K Data Needs

Data Gap	Data Need No.	Data Need	Description	Additional Data Collection Recommended?	Scope of Work	Justification
It is unknown if contamination within the RUM will adversely affect aquatic receptors in the Columbia River.	8	Update bathymetric data for the river within 100-K to support calculations of contaminant transport to the river and ecological receptors.	Aquatic ecological receptors have been identified in the river. To evaluate flow paths of contaminants to receptors from the RUM Unit, updated and accurate bathymetric data for the river are needed.	No	NA	Bathymetric data for 100-K have been collected but not evaluated yet. Preliminary evaluation of the top of the RUM Unit surface using near-river wells indicates the top of the RUM Unit does not intersect the Columbia River; therefore, no new data collection is proposed for the area. However, the existing data should be evaluated to better define the river bathymetry.
The hydraulic rate of exchange between the groundwater and the river is unknown.	9	Collect geochemical and hydrogeologic data to evaluate near-shore area groundwater contaminant fate and transport.	The near-shore area is directly affected by river stage. Limited data have been available to adequately understand groundwater flow paths, contaminant migration, and mixing in the near-shore area.	No	NA	Reevaluation of the groundwater remedial activities (i.e., pump-and-treat) is being conducted. The focus of the reevaluation is to recover contaminants adjacent to the river and prevent them from entering the river.
The mechanism to explain the persistence of the CrVI plume is unknown.	10	Collect soil and water samples from the following units: • Vadose zone • Deep vadose zone • Rewetted zone • Unconfined aquifer • Above the RUM Unit • Within the RUM Unit	Soil and water analyses are needed to determine the potential for each unit to contain sufficient CrVI contamination continue to be a source of groundwater contamination.	Yes	Through this RI, drill and sample soil and groundwater from the following: • Four groundwater wells completed within the RUM Unit. • Eight groundwater wells completed within the unconfined aquifer. • Two boreholes drilled through the 116-K-2 Trench. Sampling details are found in the SAP (DOE/RL-2009-41). Locations are shown in Figure 4-6.	This data is needed to evaluate alternative CSM components regarding whether groundwater contamination is from vadose zone sources (in areas of past handling and storage of high-concentration sodium dichromate, and in the periodically wetted zone), within the unconfined aquifer, above the RUM Unit, or within the RUM Unit and diffusing to the unconfined aquifer.
Potential alternative remedial technologies have not been sufficiently investigated.	11	Evaluate alternative potential remedial technologies.	Groundwater contamination above aquatic standards and drinking water MCLs has been detected in 100-K. Interim remedial actions are currently in operation. Additional data and information are needed to evaluate potential final remedies as part of the future project FS.	No	This information will be collected through the groundwater remedial process optimization activity.	The remedial process optimization activity for 100-D/H has evaluated potentially applicable remediation technologies. This evaluation will be used during preparation of the 100-K Operable Units FS.
Insufficient data are available to support fate and transport modeling.	12	Collect additional data to support future fate and transport modeling. Assess the physical and hydraulic properties of soil and confirm contaminant distribution coefficients to support modeling.	Estimate soil and hydraulic properties, determine level of contamination, confirm contaminant distribution coefficients, and perform batch leach contacting test on selected soil samples.	Yes	Through this RI, drill and sample soil and groundwater from • Three groundwater wells completed within the RUM Unit. • Eight groundwater wells completed within the unconfined aquifer. • Two boreholes drilled through the 116-K-2 Trench. Sampling details are found in the SAP (DOE/RL-2009-41). Locations are shown in Figure 4-6.	These data will be used in future fate and transport modeling.

Table 4-5. 100-K Data Needs

Data Gap	Data Need No.	Data Need	Description	Additional Data Collection Recommended?	Scope of Work	Justification
Data are needed to better define the spatial and temporal distribution of groundwater contamination.	13	Collect and analyze groundwater samples from select groundwater monitoring wells.	Additional groundwater data are needed that are spatially representative of an area, reflect river stage influence, and include groundwater COPCs.	Yes	Collect and analyze groundwater samples from 18 groundwater monitoring wells to characterize the spatial, temporal, and chemical extent of groundwater contamination. Wells are shown in Figure 4-6. Sampling details are found in the SAP (DOE/RL-2009-41).	These spatial/temporal groundwater data are needed to address uncertainties associated with initial RCBRA groundwater risk results.

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

C-14 = carbon-14
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC = contaminant of potential concern
CrVI = hexavalent chromium
CSM = conceptual site model
DWS = drinking water standard
FS = feasibility study
MCL = maximum contaminant level
OSE = orphan site evaluation
RCBRA = River Corridor Baseline Risk Assessment
RI = remedial investigation
ROD = Record of Decision
RUM = Ringold Upper Mud
SAP = sampling and analysis plan
Sr-90 = strontium-90
TCE = trichloroethylene

Table 4-6. Proposed 100-K Characterization

Type	Number
Source waste sites to be characterized and/or remediated	110
New boreholes (vadose zone)	2
New wells (unconfined aquifer)	9
New wells (extending into the RUM Unit)	4
New aquifer tube locations	1
Current monitoring wells (sampling to support risk characterization)	18

RUM = Ringold Upper Mud

Table 4-7. Number of Field Samples and Analytes Proposed for 100-K

Source	Soil Samples	Groundwater	Analysis*
New boreholes (vadose zone)	15	2	178
New wells (unconfined aquifer)	117	117	2,042
New wells (extending into the RUM Unit)	64	60	1,152
New aquifer tube locations	0	9	36
Current monitoring wells (sampling to support risk characterization)	0	54	486

NOTE: Table does not include field, quality control, or archive samples.

* Includes both chemical and physical property analysis.

RUM = Ringold Upper Mud

4.6.1 100-K Data Needs – Source Areas

Data needs specific to sources (soils) are identified and described in this section.

4.6.1.1 Data Need 1: Characterize Below Unremediated Waste Sites to Assess Nature and Extent of Contamination in the Vadose Zone

Data Need Description: Continue interim remedial actions, as they have demonstrated to be efficient in obtaining the necessary data during remediation using the observational approach.

Remedial action in the 100-K Area began in 2002 under remedial authority of an interim action ROD and continues to the present. Cleanup will primarily consist of implementation of the remove, treat, and dispose (RTD) remedy, which will generate additional characterization data to address many of the current data needs and help refine overall site knowledge. Contaminated soil and debris will be removed and disposed to the ERDF or offsite facilities (as appropriate) until the cleanup levels are met. As part of the remedy, borehole drilling and/or additional test pitting in conjunction with sampling and analysis may be performed to better define the nature and extent of the contamination and identify sources within the

vadose zone. Activities are guided during excavation using data obtained through field measurements or in process sampling using quick turnaround laboratory analyses working concurrently with excavation and used to continually update the site characteristics databases. The observational approach-based cleanup also provides opportunities for discovery of new waste sites that will be plugged in to the existing remedies for cleanup. It is anticipated that an additional remedy will be authorized to allow use of chemical treatment for specific contaminants (e.g., CrVI) at waste sites that fit specific characteristics to supplement the RTD remedy. Sequencing of waste site cleanup is based on the Tri-Party Agreement (Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order)* milestone framework. Within this framework, knowledge of operational process (e.g., sodium dichromate use) and past releases may be used to target and prioritize specific waste sites or areas with contaminants that presently exist in or potentially impact groundwater. Effective implementation of waste site cleanup prevents further degradation of groundwater, thereby increasing the likelihood for success of cleanup actions (e.g., pump-and-treat) directed specifically at contaminated groundwater.

Thirty-nine waste sites in 100-K have been reclassified as closed, interim closed out, no action sites, and not accepted under regulatory authority to address and mitigate impacts from known and suspected releases to the environment. A total of 96 accepted (unremediated) waste sites, including the 105-KE and 105-KW Reactor sites, and 14 discovery waste sites remaining in the area will be addressed according to the interim action ROD. Appendix D summarizes the status of all operable unit waste sites.

4.6.1.2 Data Need 2: Characterize Beneath Remediated Waste Sites to Assess the Nature and Extent of Contamination in the Vadose Zone

Data Need Description: Drill two boreholes to groundwater and sample beneath the 116-K-2 Trench. Details of the sampling are found in the SAP (DOE/RL-2009-41).

Characterization of the 100-K Area has been extensive. Approximately 80 boreholes and test pits (exclusive of groundwater monitoring wells) have been sampled and the soil analyzed to assess subsurface conditions in the vadose zone. Contaminant data are also available from the interim remedial actions at 13 waste sites. Most of the contaminant data collected from the vadose zone were collected from depths no greater than 9.1 m (30 ft) bgs, with few exceptions. However, there is a lack of nitrate, tritium, and CrVI data to assess the vertical and lateral extent of vadose contamination.

The term "interim closed out" is a reclassification status indicating, due to actions taken, a waste management unit meets cleanup standards specified in an interim action ROD or action memorandum, but for which a Final ROD has not been issued. To establish which sites to consider for further soil characterization under 100-K, waste sites that had been previously remediated and interim closed out, but had the following characteristics, were identified:

- Sites that historically affected groundwater quality.
- Sites with soils concentrations above screening levels for groundwater protection.
- Sites with evidence of deep soil contamination.
- Sites that were not remediated to the bottom of the engineered structure.
- Sites identified in orphan site reports as potential waste management units.
- Sites in or near high concentration groundwater plumes.
- Sites where low volumes of high concentration liquids were disposed.
- Sites where possible data needs were identified in the systematic planning workshop.

Subject matter experts reviewed and evaluated the data and information available for the sites with the above characteristics in contaminant fate and transport, site remediation, risk assessment, cleanup

verification packages, and environmental modeling. Based on the evaluation, one waste site (116-K-2 Trench) was identified for further soil characterization to address CSM uncertainties regarding contaminant distribution in the vadose zone and groundwater protection. Interim remedial action was successfully completed at this site in 2005. However, this site is being characterized because it appears to have the potential to continue to affect groundwater quality and contribute to localized CrVI and tritium groundwater plumes.

The main data need associated with the vadose zone is to assess the nature and vertical extent of contamination. The information will be used for CSM development, to locate and understand the distribution of potential sources of CrVI, and to support an assessment of potential impacts to groundwater and the Columbia River.

Vadose zone analytical data (i.e., soil chemistry) are based on constituents identified in the master target analyte list for 100-K identified in the SAP (DOE/RL-2009-41).

The following will occur for borehole drilling:

- Drill two boreholes in the 116-K-2 Mile-Long Trench.
- Samples will be screened in the field for radiological contamination.
- Continuous sampling will be performed for chemical analysis starting from the bottom of the waste site (or the maximum depth of remedial action) to the water table. One additional soil sample will be collected from the aquifer. Additional samples may be collected at the discretion of the geologist or sampling personnel based on field screening results. Specific sample intervals are defined in the SAP (DOE/RL-2009-41).

This waste site was selected for characterization for the following reasons:

- Residual contamination remaining in the soil column below the remediated waste site (after the completion of interim remedial action) may be above soil concentrations protective of groundwater and the Columbia River cleanup.
- Lack of data to support an assessment of the vertical distribution of contamination beneath the waste site.
- The waste site location is near an existing CrVI groundwater plume.
- Contaminant inventory and effluent volume received indicate there was impact to groundwater when the waste site was operational.

4.6.1.3 Data Need 3: Characterize Around the Reactor Structures to Assess the Nature and Extent of Contamination in the Vadose Zone

Data Need Description: Data are needed to determine the nature and vertical extent of contamination in the vadose zone around reactor structures (105-KE and 105-KW Reactors).

This data need will be partially filled by obtaining verification data associated with the 105-KE and 105-KW Reactor sites. After cleanup verification data are available to characterize these reactor sites, evaluation will be performed to assess the need for additional characterization. The need to further determine the extent of contamination around the 105-KE and 105-KW Reactors will generally be guided by remedial action goals for protection of groundwater and protection of the Columbia River.

4.6.1.4 Data Need 4: Identify New Waste Sites and Potential Sources of Contamination

Data Need Description: Complete OSE process.

This process may identify new waste sites and potential sources of contamination in 100-K. The OSE and waste site discovery processes are performed to identity new waste sites and sources that are not in CERCLA decision documents.

The historical evaluation and walk-down of the orphan site process for outside the fence line is complete. The historical evaluation portion of the OSE has been completed for the exclusion area (i.e., inside the fence) of the 100-K Area. Information pertaining to the 19 new sites resulting from this evaluation will be accepted as waste management units and then characterized to determine if they should be added to the scope of the existing 100-K Area Interim ROD and remediated. The opportunity for additional discoveries will continue throughout cleanup of 100-K, including those activities that are conducted after final RODs are issued (e.g., CERCLA 5-year reviews).

4.6.2 100-K Data Needs – Groundwater

This section identifies and describes data needs specific to groundwater.

4.6.2.1 Data Need 5: Define the Extent of Groundwater Contamination above Clean Standards in Select Areas of the Unconfined Aquifer

Data Need Description: Determine the extent of select contaminants (e.g., CrVI) at concentrations above water quality standards in select locations of the unconfined aquifer in 100-K.

Install nine new groundwater monitoring wells (Figure 4-6) and three aquifer tubes to different depths at one location. During well drilling, soil samples will be collected above and below the unconfined aquifer and on the entrance of the RUM Unit. Water samples will be collected to define the distribution of contamination within the aquifer.

Additional groundwater wells need to be installed specifically to define the nature and extent of C-14, CrVI, tritium, TCE, and Sr-90 contamination in 100-K. The new groundwater wells will be sampled for the COPCs identified in the SAP (DOE/RL-2009-41). Eight new wells in the upper aquifer and one aquifer tube location (with three tubes completed to different depths) are proposed to define the extent of contamination in the upper aquifer.

During well installation, the following data will be collected:

- Soil data (split spoons) above the unconfined aquifer, within the aquifer, and before and after entering the RUM Unit.
- Water samples within the unconfined aquifer to determine vertical distribution of contamination within the aquifer.

In addition, groundwater elevation data will be used to evaluate groundwater and plume flow directions. The SAP includes details of the sampling and analysis program (DOE/RL-2009-41).

The purpose and justification of well and aquifer tube locations are as follows:

- Hexavalent Chromium: Wells 1, 3, 6, 7, 8, and 9 (Figure 4-6) are proposed to define the extent of CrVI in groundwater. Well 1 is proposed to define the western extent of the 105-KW Reactor groundwater plume. Well 3 is proposed to define the upgradient extent of the 105-KE Reactor plume. Wells 6, 7, and 8 are proposed to define the upgradient extent of the 116-K-2 Trench plume. Well 2 and Aquifer Tube Location 1 (Figure 4-6) are proposed to define the extent of CrVI downgradient of

the 105-KW Reactor area. One well (Well 4, Figure 4-6) is proposed to define the extent of an identified hot spot of CrVI in groundwater. Existing wells are available to define the extent of the hot spot to the east and north. No wells are currently available to define this anomalous CrVI concentration to the northwest and west (Figure 4-7).

- Strontium-90: One new well (Well 5, Figure 4-6) is proposed as a replacement for Well 199-K-109A to further monitor and define the extent of the Sr-90 hot spot (Figure 4-8). Proposed Well 4 and existing monitoring wells will be used as additional wells to define the Sr-90 hot spot. Proposed Well 2 and Aquifer Tube Location 1 will be used to define the extent of Sr-90 downgradient of the 105-KW Reactor area.

- Tritium: Two groundwater wells and three aquifer tubes (Wells 2 and 6 and Aquifer Tube Location 1, Figure 4-6) are proposed to further define the extent of groundwater impacts. Well 2 and Aquifer Tube Location 1 are proposed to define the extent of groundwater impacts downgradient of the 107-KW Condensate Tanks. Well 6 is proposed to define the extent near the 116-K-2 Trench, particularly in the vicinity of well 199-K-144, located downgradient of the 116-K-2 Trench, which in recent sampling events exhibited tritium concentrations of more than 10 times the DWS (Figure 4-9). This well is also proposed (as discussed previously) to further define the extent of CrVI in groundwater.

- Carbon-14 and Trichloroethene: Proposed Well 2 and aquifer tubes (AT1, Figure 4-6) will also be used to define the extent of C-14 and TCE in groundwater near the 116-KW-3 Waste Site, 107-KW Condensate Tanks, and downgradient of 105-KW Reactor area. Figures 4-10 and 4-11 show the current extent of C-14 and TCE contamination in groundwater, respectively.

4.6.2.2 Data Need 6: Collect Groundwater Upwelling Data and Information during the Remedial Investigation for Hanford Site Releases to the Columbia River

Data Need Description: Groundwater discharges to the river at concentrations above aquatic cleanup levels (e.g., CrVI) have been documented in 100-K. Aquifer tubes have been installed to analyze for groundwater contaminants discharging to the river. These aquifer tubes are typically analyzed for contaminants twice per year.

Groundwater upwelling sampling and analysis in the Columbia River channel is planned for the fall of 2009, and it is expected that this data will provide further insight regarding contaminant levels entering the river and groundwater/river mixing ratios within the biotic zone (upper approximately 30 cm [approximately 12 inches] of substrate).

Evaluate additional methods (e.g., new rounds of pore water samples, horizontal aquifer tubes in the biotic zone) in appropriate 100-K locations to validate/update the pore water sampling conducted in 1995 which serves as the basis for the 1:1 minimum mixing ratio assumed for groundwater/river water in the River Corridor.

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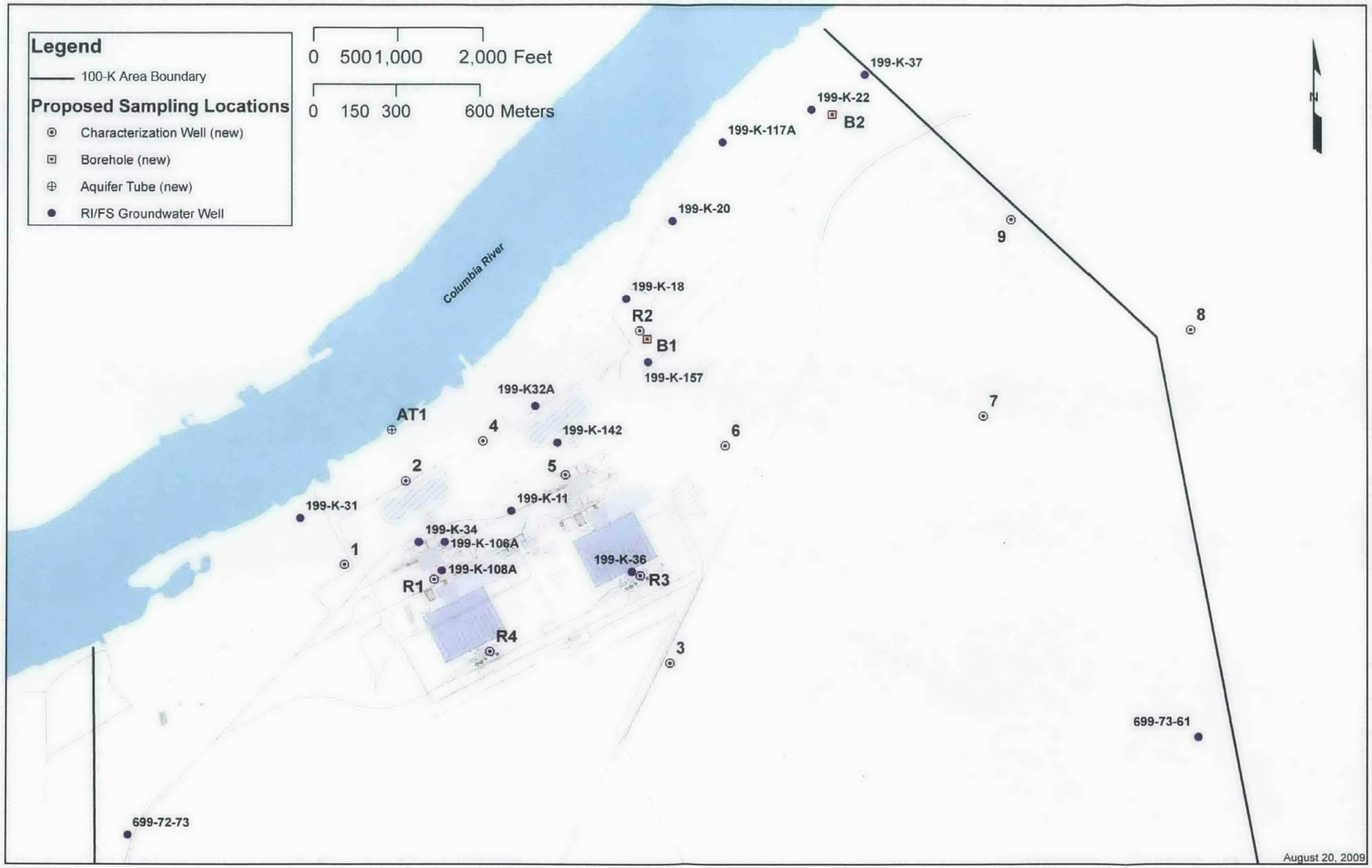

Figure 4-6. Location Map for Planned 100-K Characterization Activities

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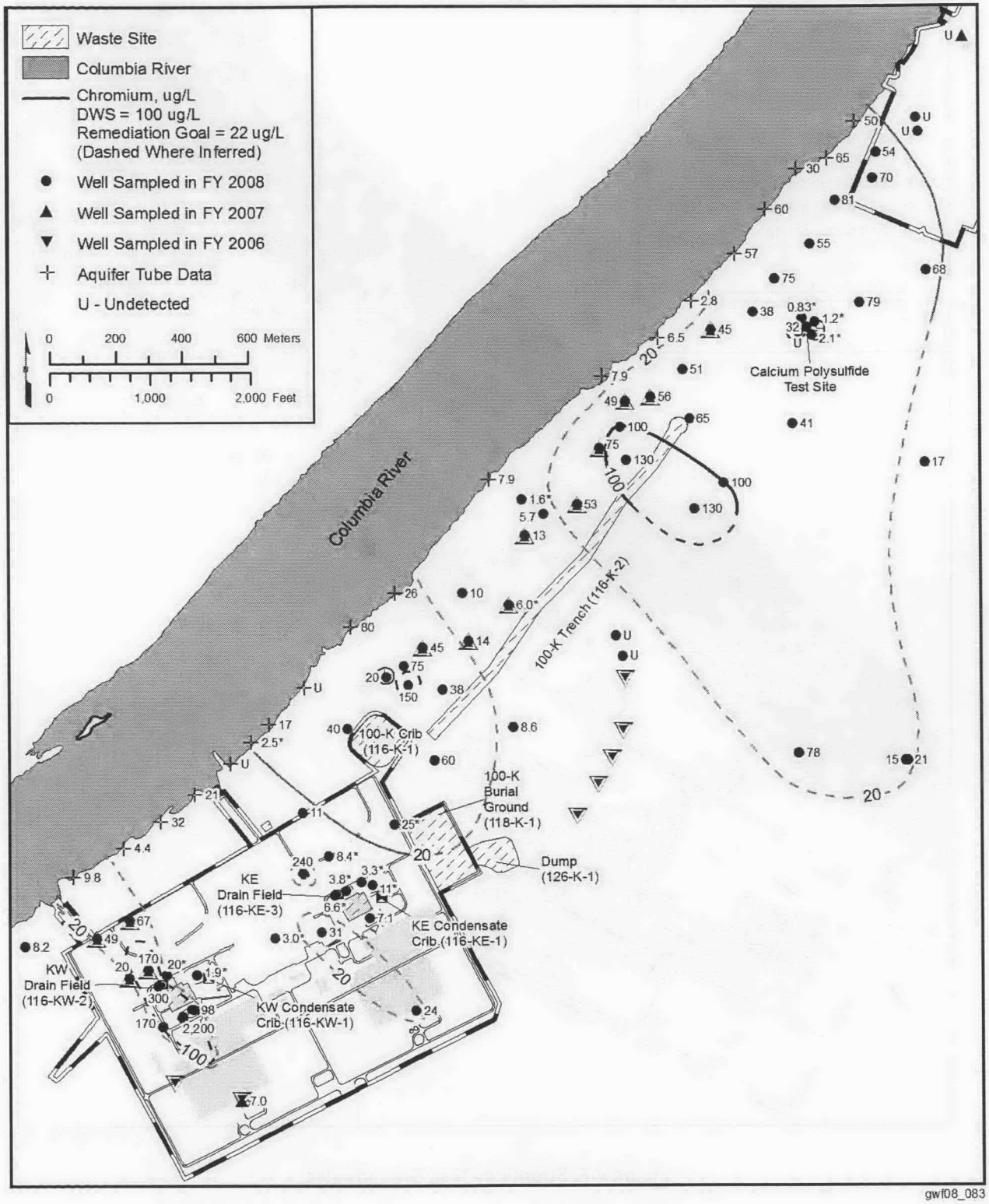

Figure 4-7. Hexavalent Chromium in Groundwater

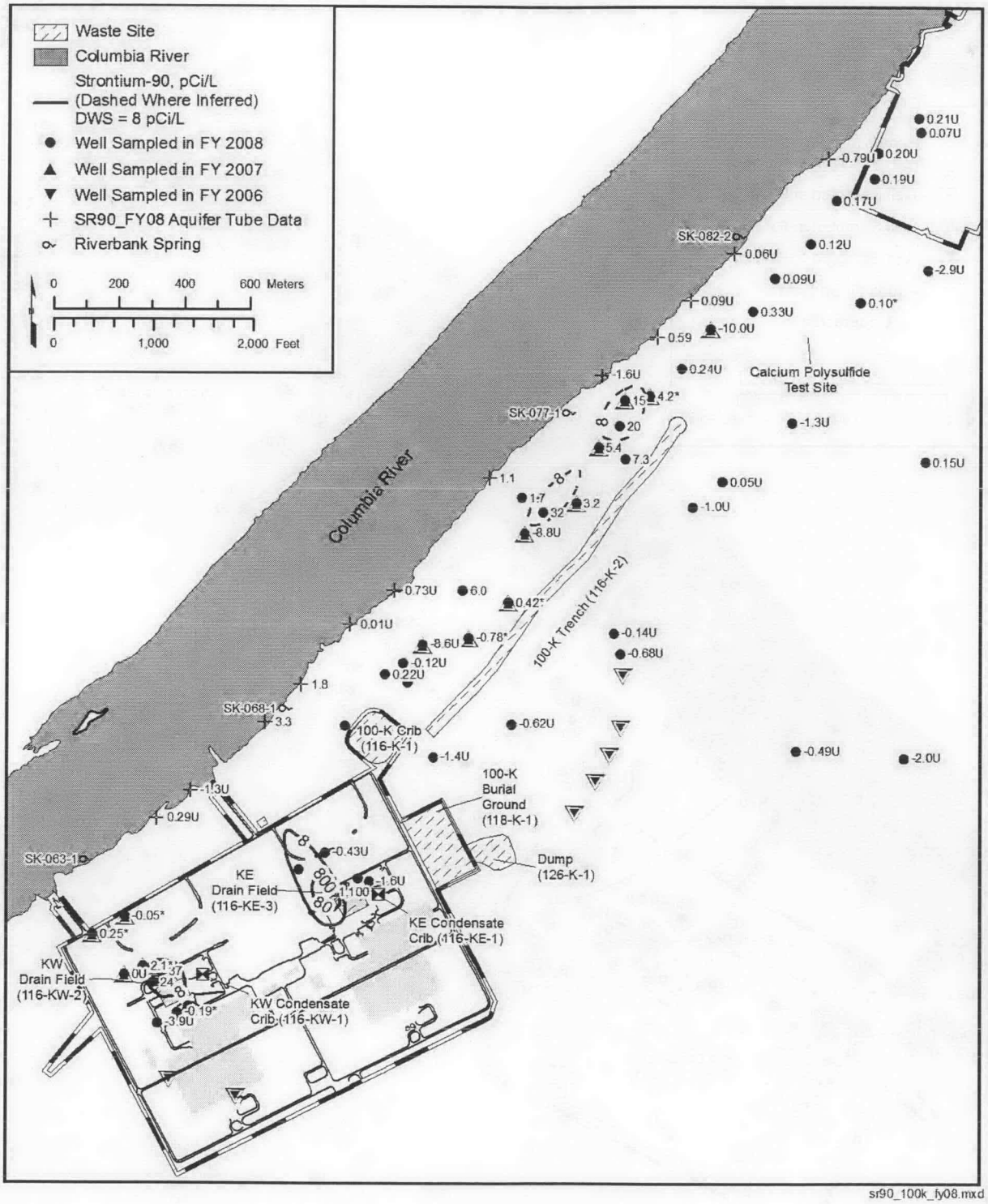

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Figure 4-8. Strontium-90 in Groundwater

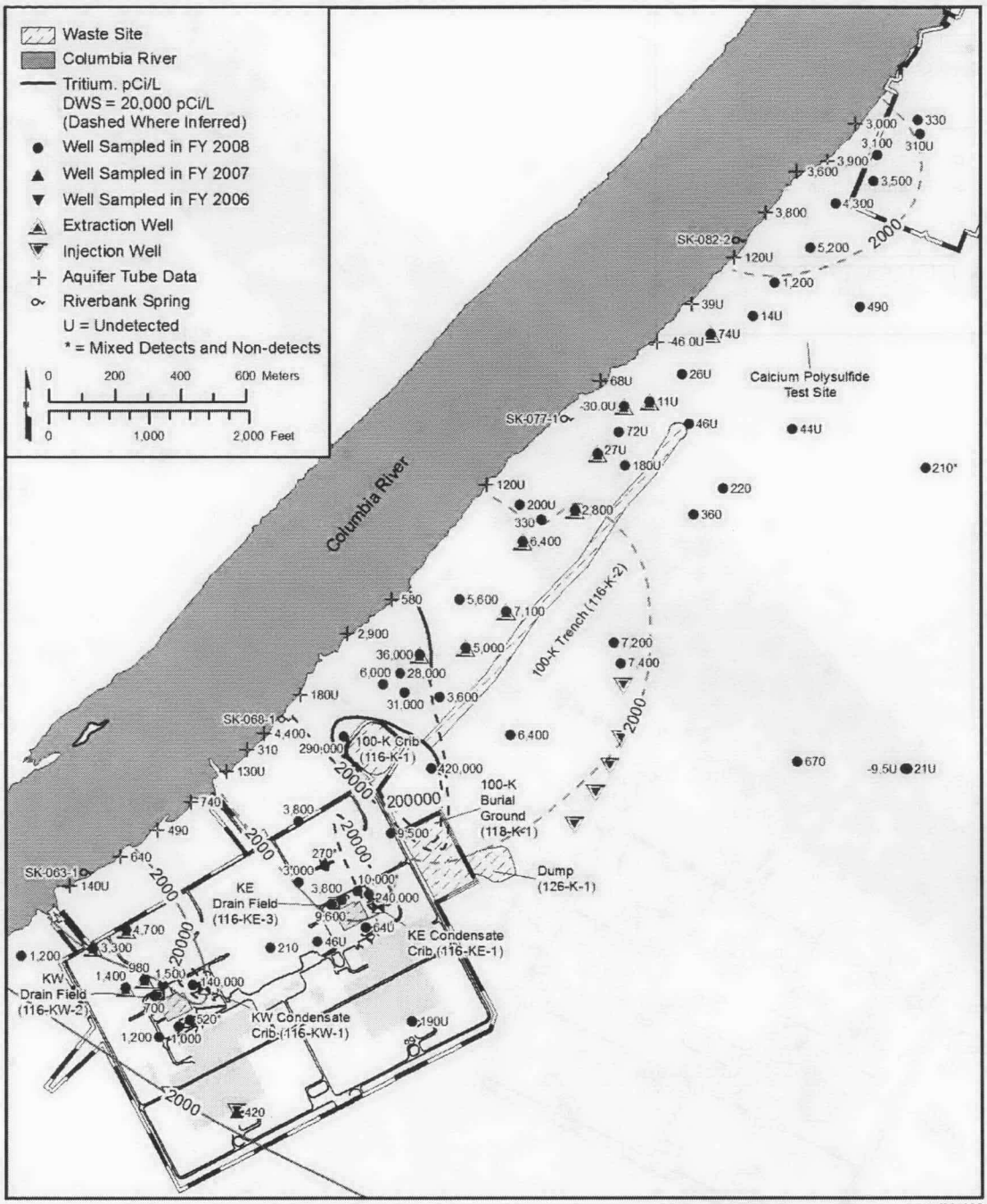

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Figure 4-9. Tritium in Groundwater

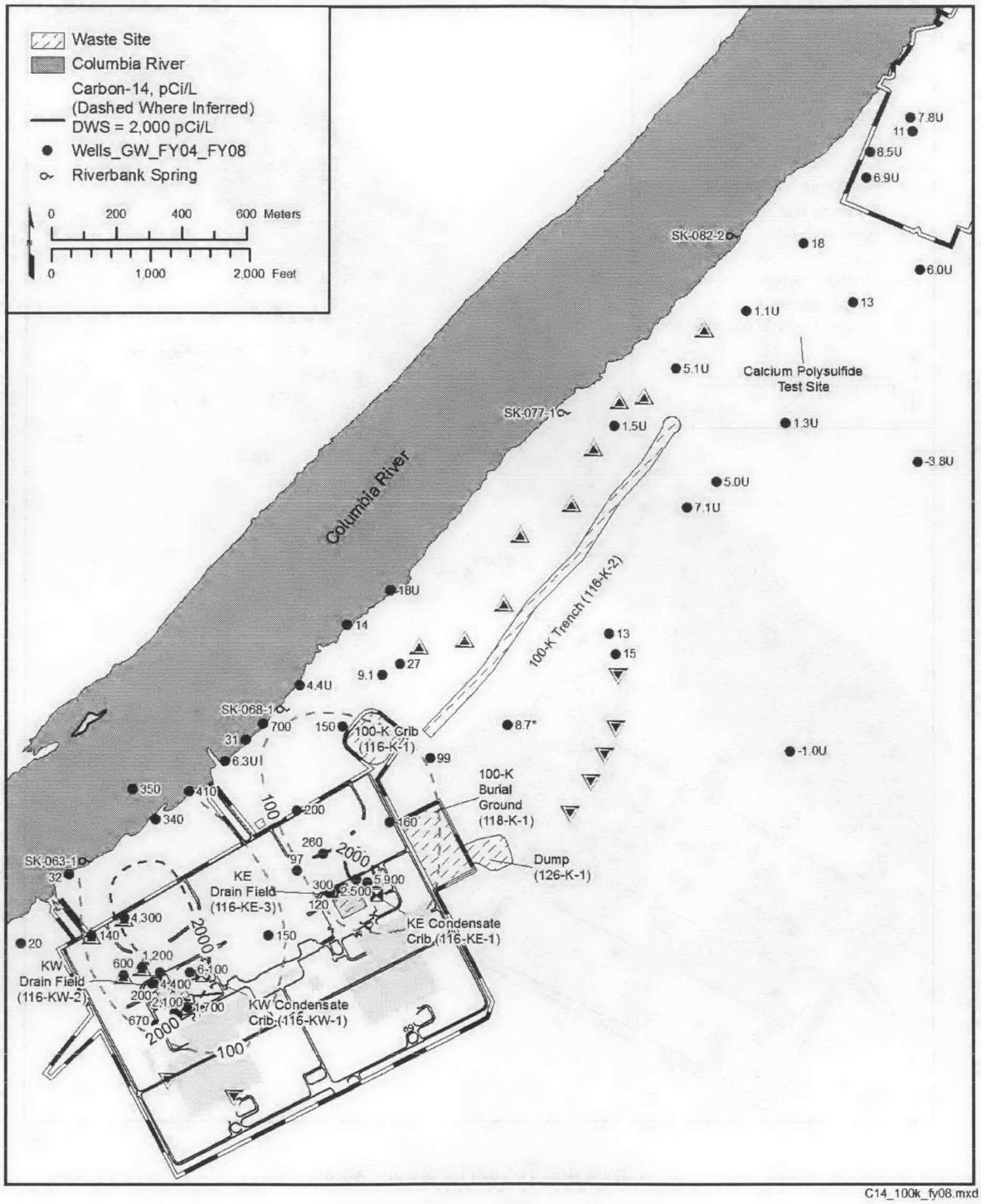


Figure 4-10. Carbon-14 in Groundwater

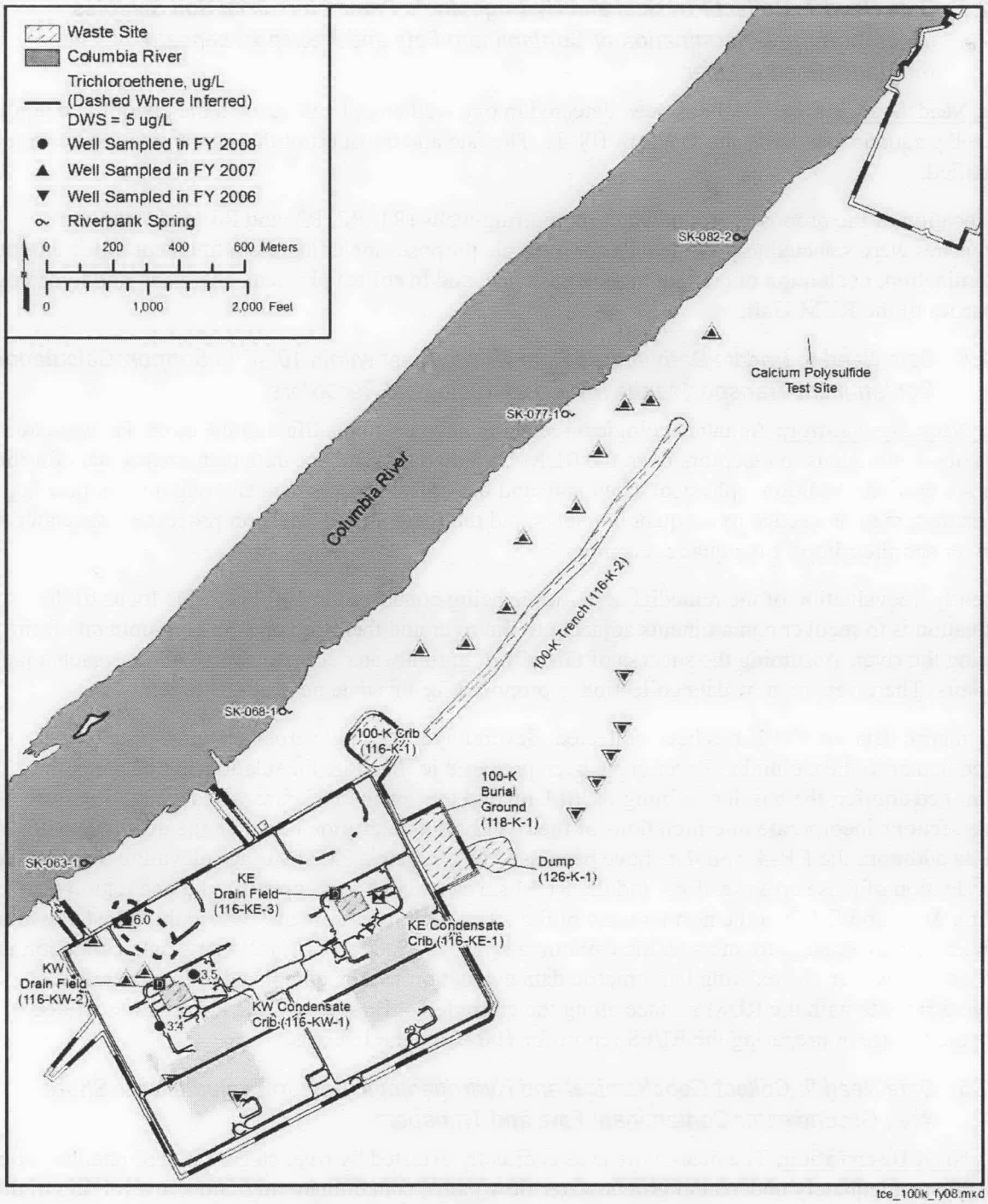


Figure 4-11. Trichloroethene in Groundwater

4.6.2.3 Data Need 7: Collect Physical and Hydrogeologic Parameters from Soil Samples to Support the Determination of Contaminant Fate and Transport beneath the Unconfined Aquifer

Data Need Description: CrVI has been detected in one well completed beneath the unconfined aquifer above the aquatic standards and DWS in 100-K. The fate and transport of this contamination has not been quantified.

The location of the proposed groundwater monitoring wells (R1, R2, R3, and R4) and sampling approaches were selected to provide data for multiple purposes including the refinement of the extent of contamination, evaluation of contaminant persistence, and to collect physical, chemical, and hydrologic properties of the RUM Unit.

4.6.2.4 Data Need 8: Update Bathymetric Data for the River within 100-K to Support Calculations of Contaminant Transport to the River and Ecological Receptors

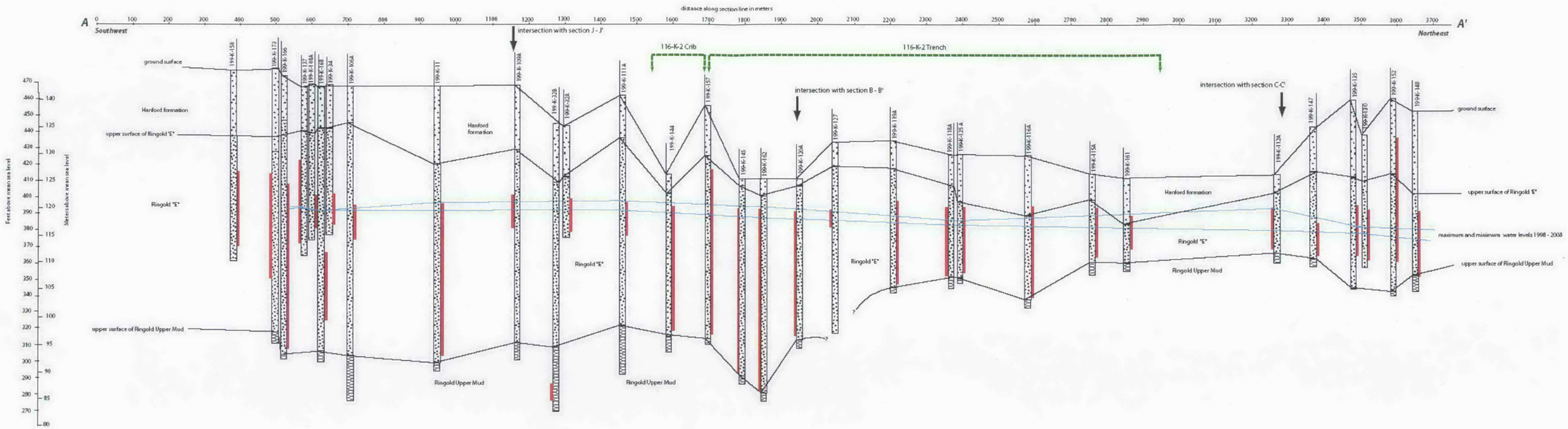
Data Need Description: Aquatic ecological receptors have been identified in the river. To evaluate flow paths of contaminants to receptors from the RUM Unit, updated and accurate bathymetric data for the river are needed. Additional physical, chemical, and biological process data and ongoing monitoring information may be needed to adequately understand the features and transport processes associated with the river and their impact to aquatic receptors.

Currently, reevaluation of the remedial activities is being conducted in 100-D/H. The focus of the revaluation is to recover contaminants adjacent to the river and therefore prevent contaminants from entering the river. Assuming the success of this effort, groundwater contaminants will not reach aquatic receptors. Therefore, no new data collection is proposed for this data need at this time.

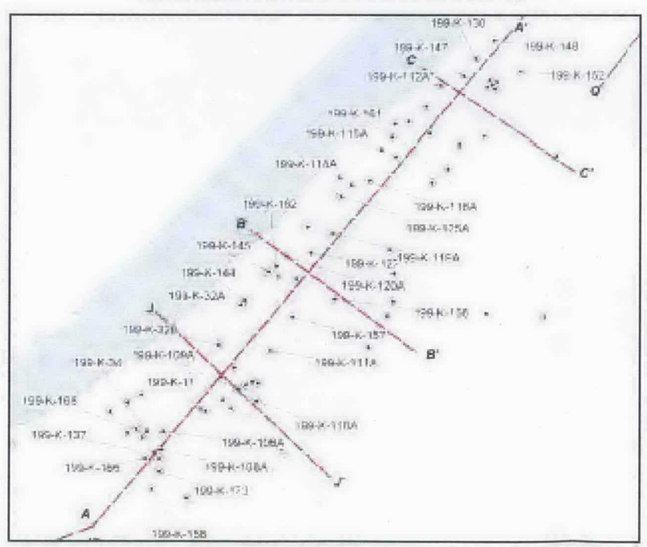
Bathymetric data for 100-K has been collected. Several hydrogeologic cross sections, oriented perpendicular to the Columbia River, have been prepared to illustrate the relationship between the unconfined aquifer, the basalt confining RUM Unit and the riverbed (Figure 4-12 through Figure 4-14). These sections incorporate interpretations of the river bottom elevation based on the available bathymetric data. In addition, the KR-4 well data have been used to generate a RUM surface elevation map. Based on an evaluation of these cross sections and the RUM surface map, there appears to be one region (see Section A-A' and C-C') at the northern end of the KR-4 well (downstream), where the RUM elevation is sufficiently high enough to intersect the Columbia riverbed (Section C-C'). No new data collection is proposed. However, the existing bathymetric data evaluation will be completed to incorporate the bathymetric data with the RUM surface along the entire KR-4 Boundary. This information will be available for use in preparing the RI/FS report for 100-K Operable Units.

4.6.2.5 Data Need 9: Collect Geochemical and Hydrogeologic Data to Evaluate Near-Shore Area Groundwater Contaminant Fate and Transport

Data Need Description: The near-shore area is directly affected by river stage. Limited data have been available to adequately understand groundwater flow paths, contaminant migration, and mixing in the near-shore area. Scenarios for plume discharge to the river vary widely based on the season and the dynamic conditions in the near-shore area. The greatest contaminant flux and highest concentrations at exposure locations are postulated to occur during periods of low river-stage conditions, when the hydraulic gradient toward the river is steepest and river water and groundwater mixing is minimal. Additional physical, chemical, and biological process data and ongoing monitoring information may be needed to adequately to understand the features and transport processes associated with the near-shore area.



Index Location Map Cross-Section A-A' (100-K Area)



Legend

- Hanford formation sandy gravel
- Ringold "E" sandy gravel
- Ringold Upper Mud
- max / min water levels (1998 - 2008)
- screened interval

note: some elevations of the Ringold E surface are interpolated mid-way between elevations shown on closely adjacent wells that are projected to the line of the section (e.g., Ringold E surface in wells 199-K-173 and 199-K-166)

Figure 4-12. Northeast-Southwest Hydrogeologic Cross Section of 100-K Area

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100-KR-4 Groundwater Operable Unit

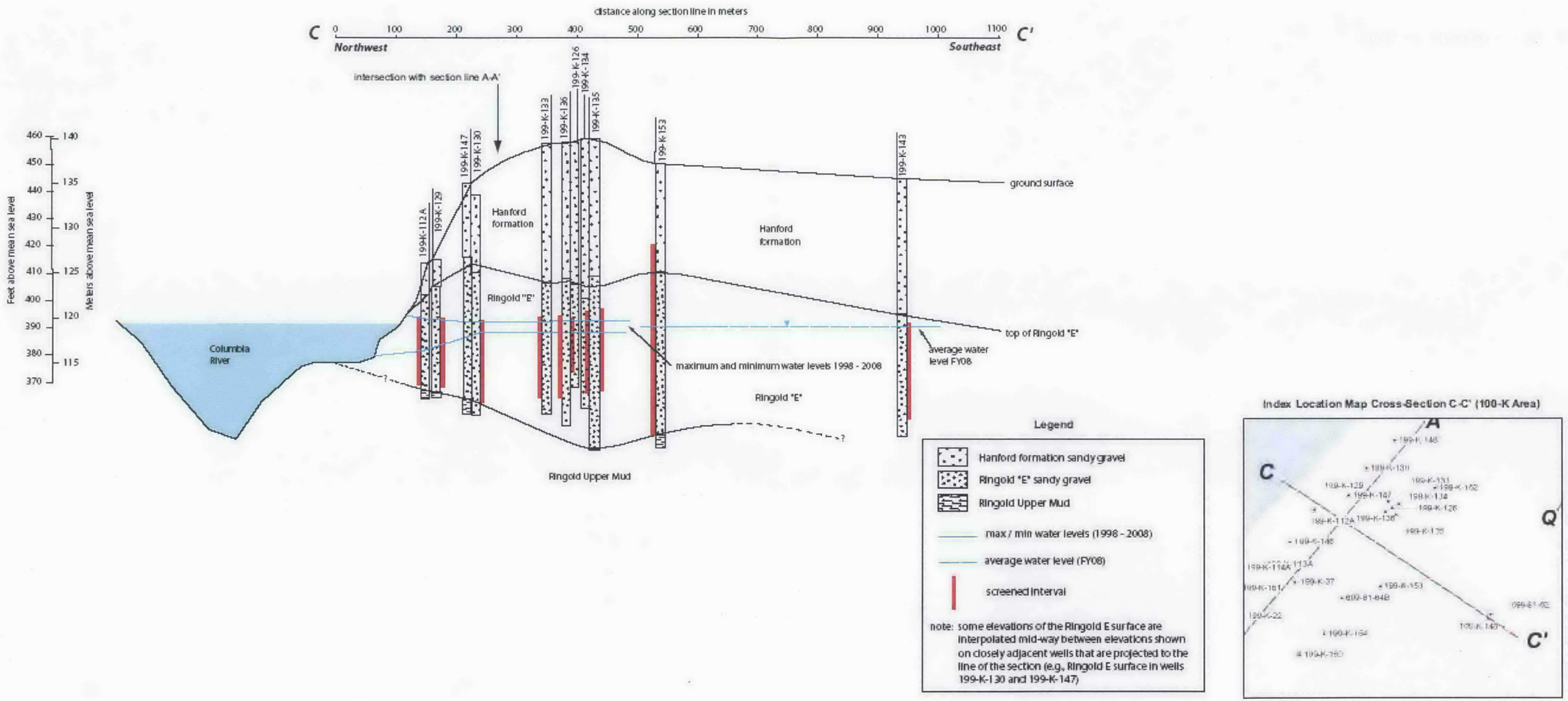

Figure 4-13. Northwest-Southeast Hydrogeologic Cross Section of 100-K Area

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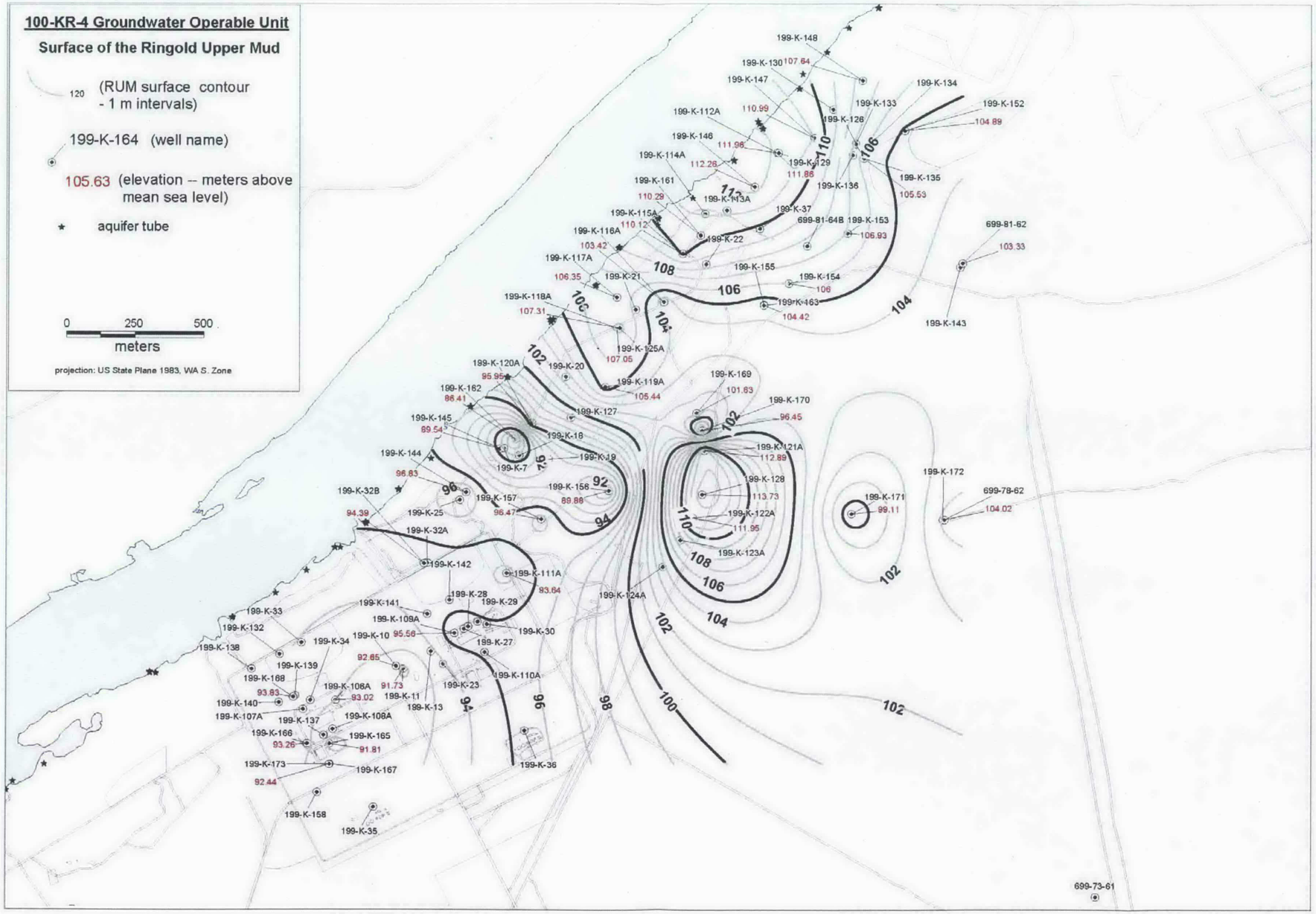

Figure 4-14. Structure Contour Map of the Ringold Upper Mud Surface

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4.6.2.6 Data Need 10: Collect Soil and Water Samples from the Following Units: (1) Vadose Zone, (2) Deep Vadose Zone, (3) Rewetted Zone, (4) Unconfined Aquifer, (5) Above the RUM, and (6) Within the RUM

Data Need Description: Soil and water analyses are needed to determine the potential for each unit to contain sufficient CrVI contamination to be a continuing source of groundwater contamination.

An uncertainty exists as to whether persistent inland CrVI in groundwater is the result of the following:

- Continuing vadose zone sources from beneath the waste sites, particularly those where high-concentration (70 percent solution) sodium dichromate was handled and stored.
- Vadose zone contamination (mass) within the periodically rewetted zone.
- Contamination within the unconfined aquifer.
- Contamination within or even below the RUM Unit.
- A combination of some or all of the above.

The periodically rewetted zone is the area in which the water level in a well fluctuates throughout the year. Adjacent to 100-K, river stage changes relatively rapidly on various time scales (e.g., hourly, daily, and seasonally). Groundwater levels in the upper aquifer and the RUM Unit respond to changes in river stage. The water table in the aquifer responds to changing river stage up to several hundred meters (several hundred feet) inland, including areas where the highest CrVI concentrations have been detected in 100-K. During high river stage (and, therefore, high groundwater table), contaminants such as CrVI suspended in the periodically rewetted zone can be remobilized to groundwater at unknown rates and concentrations, which may be a continuing source of the relatively high concentrations of CrVI observed in groundwater. Conversely, during low river stage, contaminants in groundwater are left suspended on the soil matrix and are dissolved within residual soil moisture.

Sampling from four boreholes (described in Data Need 7) is proposed to address this need. Boreholes R3 and R4 are proposed through drains associated with former sodium dichromate storage tanks (120-KW-5 and 120-KE-6) where high concentration 70 percent solution was stored. Soil data will be collected and analyzed for leachable chromium from the following locations:

- Above the unconfined aquifer
- Within the aquifer
- Above the RUM Unit
- Immediately on entering the RUM Unit
- Within the RUM Unit

Figure 4-6 shows well locations, and the details of the sampling plan are included in the SAP (DOE/RL-2009-41).

4.6.2.7 Data Need 11: Evaluate Alternative Potential Remedial Technologies

Data Need Description: Groundwater contamination above aquatic standards and drinking water MCLs has been detected in 100-K. Interim remedial actions are currently in operation. Additional data and information are needed to evaluate potential final remedies as part of the future project FS.

The remedial process optimization activity for 100-D/H has evaluated potentially applicable remediation technologies. This evaluation will be used during preparation of 100-K FS since the primary risk in both 100-D/H and 100-K is CrVI.

4.6.2.8 Data Need 12: Collect Additional Data to Support Future Fate and Transport Modeling. Assess the Physical and Hydraulic Properties of Soil and Confirm Contaminant Distribution Coefficients to Support Modeling.

Data Need Description: On selected soil samples, estimate soil and hydraulic properties, determine level of contamination, confirm contaminant distribution coefficients, and perform batch leach contacting test.

Data needed for modeling include the following:

- Unsaturated soils
  - Moisture content
  - Grain size distribution
  - Bulk density
  - Porosity
- Saturated soils
  - Grain size distribution
  - Bulk density
  - Porosity
- Saturated hydraulic conductivity

Soil data will also be analyzed for chemical and radiological contamination and leachability of contamination.

Batch leach contacting tests will be performed on soil and aquifer sediment samples. Standardized batch leach tests are done using a leach procedure based on ASTM D3987-85. The laboratory should be consulted regarding the amount of soil required. At a minimum, one batch from each soil sample should be leached at a soil-to-water weight ratio of 1-to-1. It is suggested that demineralized water, pH adjusted according to EPA's West Coast recommendation, be used as the leaching liquid.

Selected soil samples will be leached at soil to water weight ratios of 1 to 1, 1 to 2.5, and 1 to 5 with one test in each series duplicated. Soil/water mixtures are placed in clean, watertight sample containers (extraction vessels) and rotated end over end through the vessel centerline at a rate of about 30 rotations per minute for 18 hours. Following 18 hours of mixing, the soil/water slurry is pressure-filtered using a 0.45-µm filter. The leachate will be analyzed for pH, conductivity, and metals or other contaminants of interest.

The SAP includes a detailed description of the analyses planned (DOE/RL-2009-41).

4.6.2.9 Data Need 13: Collect and Analyze Groundwater Samples from Select Groundwater Monitoring Wells

Data Need Description: Additional groundwater data are needed that are spatially representative of an area, reflects river stage influence, and includes groundwater COPCs.

Collect and analyze groundwater samples from 18 groundwater monitoring wells to characterize the spatial, temporal, and chemical extent of groundwater contamination. Figure 4-6 shows wells. The SAP includes sampling details (DOE/RL-2009-41).

5 Project Schedule

Figure 5-1 shows the project schedule for activities discussed in DOE/RL-2008-46 and this work plan addendum. This schedule will serve as the baseline for the work planning process and will be used to measure the implementation progress of this project. Milestones associated with the activities described in this work plan addendum are provided in Appendix C of DOE/RL-2008-46. Any updates to the project schedule will be reflected in the annual work planning process and are not anticipated to require a revision to this work plan addendum.

RI/FS and Proposed Plan for 100-KR-1, 100-KR-2, and 100-KR-4 Operable Units (Calendar Year)[1]

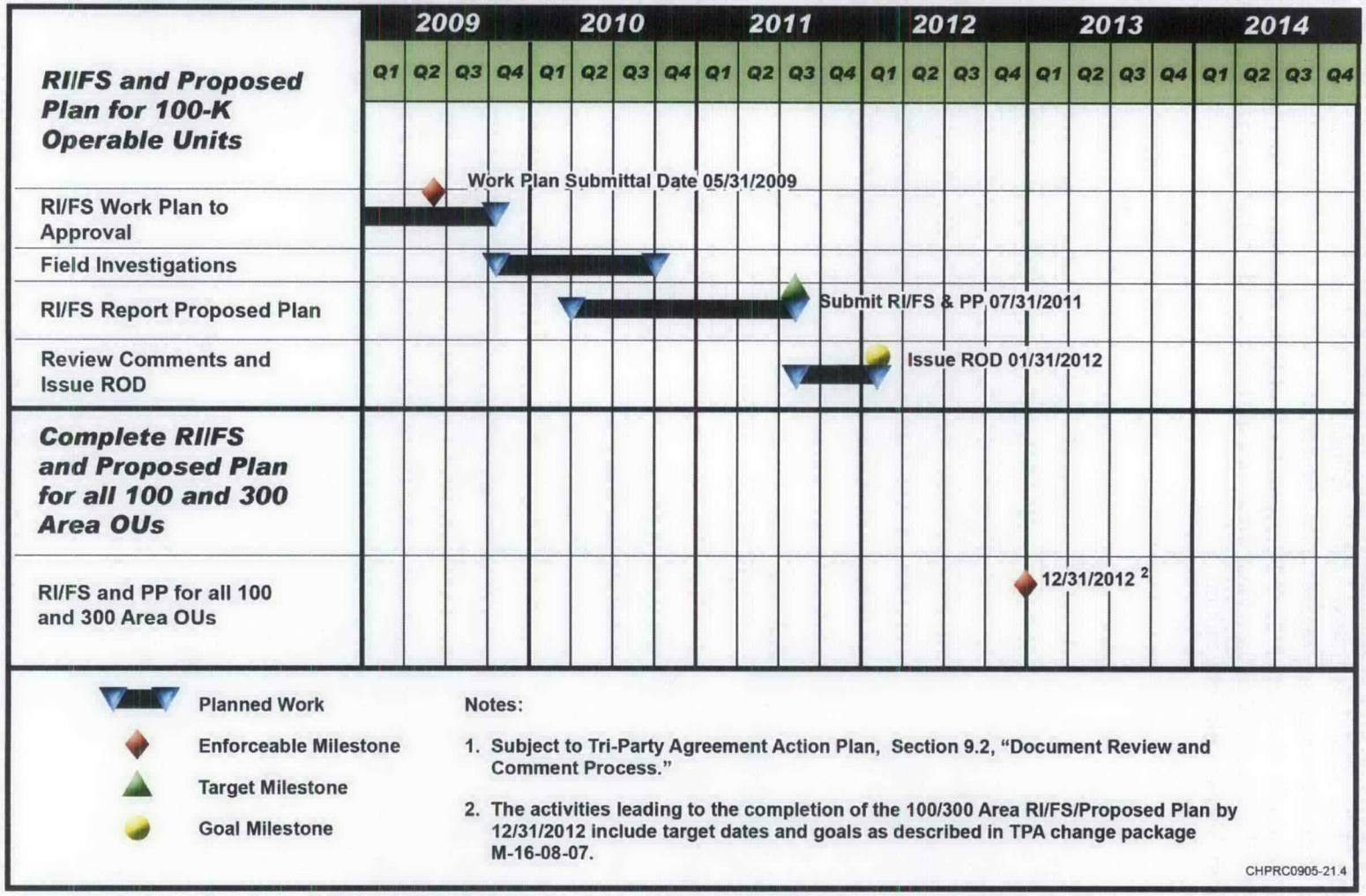

Figure 5-1. 100-K Project Schedule

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Appendix A

100-K Conceptual Site Model Component Plates

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A1 Introduction

During meetings, conceptual site model component summaries were provided to identify and foster discussion of issues of concern to the participants. Copies of the plates for 100-K, used to solicit input from regulators, agencies, and subject matter experts, are provided here.

A2 References

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PROBLEM STATEMENT

- Large quantities of radioactive and hazardous liquid waste and solid waste were disposed to the 100-K Area vadose zone close to the river. Subsequent contaminant (i.e., CrVI) releases from the disposal areas migrated to groundwater and eventually reached the river. The lifecycle of the 100-K Area can be categorized into four distinct eras, each contributing different features, events, and processes:
  - Production, including 105-KE and 105-KW Reactor construction and operations (1952-1971).
  - Deactivation and long-term maintenance, including N Reactor support and SNF storage (1971-1989).
  - Initial Tri-Party Agreement (Ecology et al., 1989) cleanup, including SNF isolation (1989-2005).
  - Restoration, including reactor/support facility decommissioning and demolition and SNF removal (2005-present).
- Contaminants from waste disposal sites remain in vadose zone soil and groundwater. Contaminants may pose a threat to human and ecological receptors.
- Groundwater and vadose zone contamination persists at the 100-K Area after:
  - Initial facility deactivation (1971-1989) to reduce source area contaminants.
  - The application of pump and treat as an interim remedial measure (1996 Interim ROD) to remediate CrVI in groundwater.

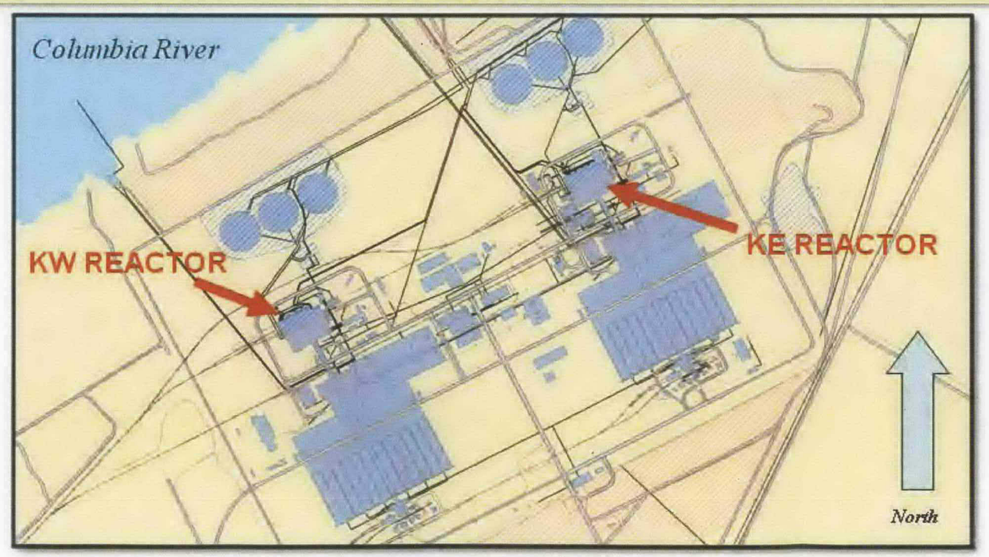
PROCESS AND HISTORY

- The 100-K Area operating design and waste management processes were considerably different from those of the other, earlier 100 Area reactors.
  - The 100-K Area Facilities were constructed to be substantially larger, with greater initial and final operating power.
  - The consolidated chemical handling facilities operated with automated process control.
  - The alum production and storage facilities for all the 100 Area water treatment plants were centralized at the 100-K Area.
  - The use of an inert gas blanket was switched from helium and carbon dioxide to nitrogen, which likely led to the C-14 contamination observed at the 100-K Area.
  - The 116-K-2 Trench provided consolidated management of contaminated waste (chemical, radiological, and mixed) generated during production.
  - The CrVI contaminant plume concentration at the 116-K-2 Trench is slowly diminishing from pump-and-treat remediation. Other source areas detected near reactor buildings are not well understood.
- Ancillary support of N Reactor and SNF storage at the K-Basins was ceased with other miscellaneous site uses long after production operations ended:
  - These activities resulted in much longer operating timeframes for various 100-K Area facilities, increasing the opportunity for contaminant transport from them.
  - Nearly all of the infrastructure present remains active (raw water, septic, electrical).
  - However, onsite storage of generated wastes ended in 1975; wastes generated after this time were transported to the Central Plateau.
  - The 183-KE and 183-KW Basins were used as a fish hatchery for several years in the mid-1990s. Operation of these facilities likely had an effect on groundwater flow and contaminant fate and transport.

FACILITY CONDITION AND REMEDIATION STATUS

- Remove, Treat, and Dispose Interim Action-Significant source remediation has not been conducted. Only 12 waste sites have been remediated at the 100-K Area.
- Although directed in 2005, ISS for the KE and KW Reactors has not been conducted. ISS is a robust but temporary measure that will protect the KE and KW Reactors from environmental degradation and limit the spread of surface contamination.
- The Groundwater Pump and Treat Interim Action has been in process since 1996. This action was expanded in 2007 with the addition of new injection wells.
- SNF Program – SNF and sludge have been removed from the KE Basin, and it was pumped dry. Removal activities continue for the SNF at the KW Basin. Contamination around and under the K Basins contributes to environmental risk. This condition will persist after the basins are emptied and closed, and the surroundings are excavated.

100-K AREA REACTOR



100-K AREA REACTOR DURING OPERATIONS

MILE-LONG TRENCH – BACKFILLED AND READY FOR REVEGETATION

Figure A-1. 100-K Process and Description History

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PROBLEM STATEMENT

- Past operations, disposal practices, spills, and unplanned releases have resulted in contamination of the facility structures, vadose zone soil, underlying groundwater, and the Columbia River.
- Active and inactive facilities may contribute to vadose zone and groundwater contamination.

FACILITY DESCRIPTION AND PROCESSING

- The 100-K Area of the Hanford Site contains the 105-KE and 105-KW Reactor Buildings and supporting facilities. The KE and KW Reactors are almost identical, and were used to produce plutonium for nuclear weapons. These reactors are the largest water-cooled, single-pass, graphite-moderated reactors in the 100 Area and are approximately 20 percent larger than other area reactors.
- Construction of the KE and KW Reactors was initiated in 1952. Initial startup of the reactors was achieved in 1955. The KW Reactor was shut down in January 1970, and the KE Reactor was shut down in January 1971.
- The 105-KE and 105-KW Fuel Storage Basins stored thousands of metric tons of SNF primarily from the N Reactor. Leaks of radioactively contaminated water from the 105-KE Basin were released to the soil column and have impacted the groundwater.
- 100-K Area also housed facilities to store alum and sulfuric acid for use in conditioning reactor cooling water. Contaminated inorganic residuals from these facilities were disposed to the soil column.
- The 183-KE and 183-KW Water Treatment Plant basins stored large volumes of treated river water for use as reactor cooling water. These basins were likely to have leaked clean water into the soil column.

FACILITY CERCLA REMOVAL PLAN

- Alternatives for conducting non-time-critical removal actions for various facilities in the 100-K Decision Unit were recommended by DOE to:
  - Deactivate, decontaminate, decommission, and demolish the ancillary facilities and portions of the 105-KE and 105-KW Reactor facilities.
  - Construct an ISS storage enclosure over the reactors followed by long-term surveillance and maintenance.
- The Action Memorandum documented approval of the recommendation in 2007.
- The Removal Action Work Plan supports implementation of the non-time-critical removal action and includes the following removal action activities:
  - Surveillance and maintenance activities
  - Waste characterization sampling and analysis
  - Site mobilization and preparation activities
  - Hazardous substances (chemical and radiological) removal
  - Deactivation activities
  - Facility equipment and miscellaneous piping removal
  - Decontamination and demolition of various facility structures
  - Construction of the ISS enclosure
  - Disposition of waste
  - Maintenance of access restrictions until the removal action is complete
  - Documentation of remaining conditions and stabilization of the site and/or performance of verification sampling and analysis demobilization
- The Tri-Party Agreement (Ecology et al., 1989a) Milestone for completion of 105-KE and 105-KW Reactor ISS is September 31, 2011, and December 31, 2012, for completion of IRAs for the 100-K Area.
- EPA ROD 1999 describes the selected IRA retrieval of SNF, sludge, debris, and water from the 105-KE and 105-KW Basins; basin deactivation; and treatment. Subsequent actions under CERCLA will remediate the basins and releases of hazardous substances to the underlying soil and groundwater and constitute the final remedy for the Site.

FACILITY REMOVAL STATUS

Active Facilities	55
Inactive Facilities	36
Demolished Facilities	6
Removed	10
Total Facilities:	**107**

DATA GAPS

- The orphan site evaluation process is a systematic approach involving historical review and field investigation to locate previously unidentified waste sites associated with facilities. This process identified 16 potential waste sites (discovery sites) associated with various 100-K Area facilities in 2008. Most of the discovery sites have a current status of accepted in WIDS. Data are not available to assess the nature and extent of contamination, impact to groundwater, and impact to the Columbia River at these waste sites.

100-K DECISION UNIT

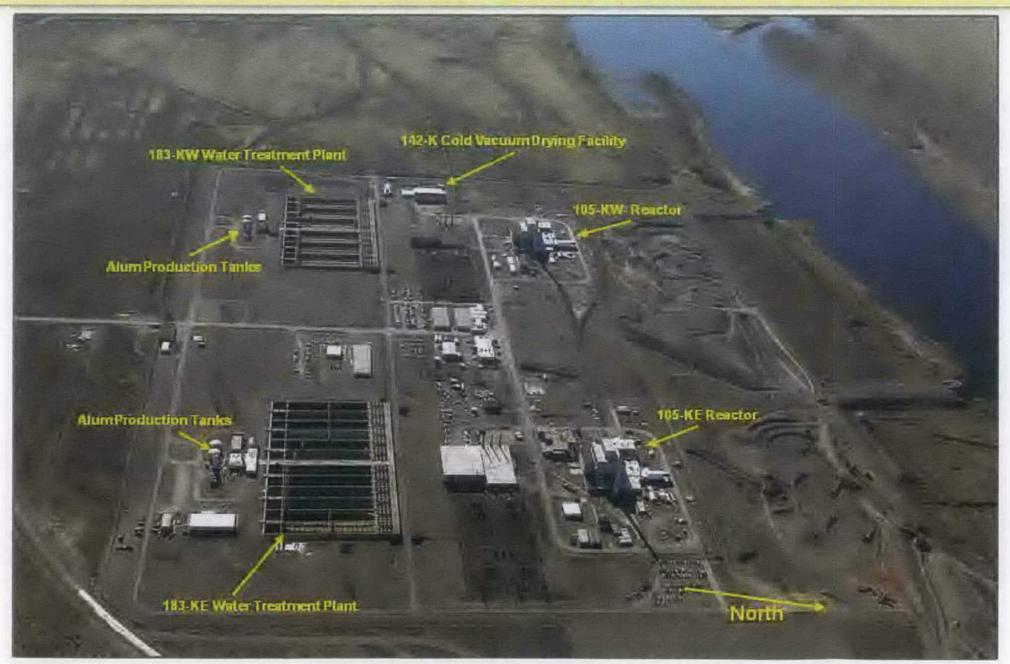

Figure A-2. 100-K Facilities

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PROBLEM STATEMENT

- The discharge of liquid effluent to the soil column and the management of solid waste generated from the reactor operations activities have impacted the vadose zone and underlying aquifer. There may be current and future impacts to groundwater from the contamination in the vadose zone.
- Waste sites may be a continuing source of groundwater contamination. Residual contamination in the 116-K-2 Trench may be impacting groundwater.
- K-Basins (100-K-42 and 100-K43) prerequisite preparation for remediation as CERCLA waste site: removal of SNF, sludge, debris, and water from the K East and K West Basins to mitigate the potential for release of contaminated water to the environment. Potential loss of structural integrity at the K Basins may release contaminants into the environment.

CONTAMINATION IN THE 100-K AREA IS FROM PRIMARY AND SECONDARY SOURCES

- Activities from reactor operations resulted in numerous liquid and solid waste streams. Primary contamination source wastes were discharged or disposed below ground surface, leaked into soil (i.e., liquid waste sites), or were discharged to the river.
- The 116-K-2 Trench received all contaminated effluent from the floor drains in the 105-KE and 105-KW Reactors and approximately 43mn (1,893 gal./min) of the 105-KE and 105-KW Reactors metal storage basin overflow.
- Secondary contamination sources are composed of waste sites generated by waste streams. A total of 135 waste sites and 14 discovery sites (149 total sites) have been identified in the 100-K Area.
- Groundwater assessments indicate that CrVI, tritium, C-14, Sr-90, nitrate, and trichloroethylene are present in the aquifer at concentrations greater than drinking water standards.

AERIAL PHOTOGRAPH OF THE 100-K AREA

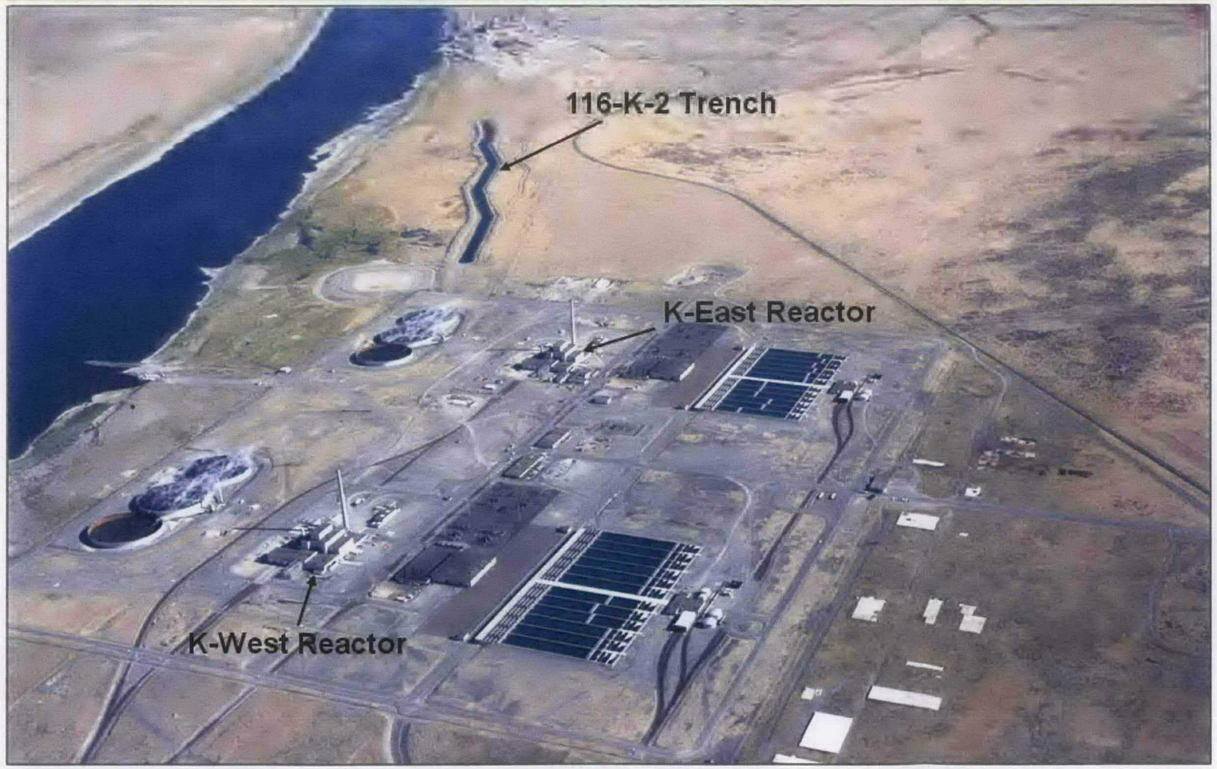

Figure A-3. 100-K Waste Sites

THE DISTRIBUTION OF CONTAMINATION IN THE 100-K AREA IS NOT COMPLETELY CHARACTERIZED

- The nature and extent of contamination is better characterized in the upper portion of the vadose zone. Few data are available deep within the vadose zone.
- Where IRAs have been completed, waste sites are well characterized 0 to 4.5 m (0 to 15 ft) below ground surface. In some cases, soil sample data indicate contamination is present at concentrations greater than screening levels for protection of groundwater and the Columbia River. RESRAD modeling suggest future groundwater impacts are not anticipated at these remediated waste sites and therefore were reclassified to interim closed. Data used to interim close waste sites are documented in cleanup verification packages and remaining site verification.
- Very little data have been collected where remedial actions are planned. A total of 96 waste sites remain on the remedial action evaluation path.
- CrVI, nitrate, and tritium are not well characterized in the vadose zone.
- The 116-K-2 Trench is suspected of being the source of a large CrVI, tritium, and Sr-90 groundwater plume in the KR-1 OU.

SUMMARY OF WASTE SITES AND WASTE SITE STATUS

- A total of 39 waste sites have been dispositioned under regulatory authority to mitigate impacts from releases to the environment. A total of 96 accepted waste sites and 14 discovery sites remain in the 100-K Area to be cleaned up and evaluated in accordance with the Interim Action ROD. The orphan site investigation was completed in 2006.

Accepted	96
Closed Out	1
Interim Closed Out	12
No Action	0
Discovery Sites	14
Not Accepted Sites	26
Total Waste Sites	**149**

DATA GAPS

- Insufficient data are available to assess the nature and extent of contamination throughout (i.e., from greater than 5m [15 ft] to groundwater) the vadose zone to support CSM development and quantify contamination at depth.
- Data are needed from "unremediated waste sites" (accepted waste sites) to assess risk for direct exposure and protection of groundwater.
- Insufficient data are available to assess the nature and extent of contamination beneath the 105-KE and 105-KW Reactors structures.

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PROBLEM STATEMENT

- The principal contaminant in the 100-K Area is chromium. Chromium has impacted groundwater from the 100-K Area vadose zone sources, and perhaps from the upgradient 100-BC5 Groundwater OU as well.
- 100-K Area radiological and non-radiological contaminants were released to the subsurface as a result of past Hanford Site operations, such as liquid disposal to the 116-K-2 Trench. Some of these contaminants have migrated down through the vadose zone to groundwater.
- Characterization of contaminant migration in the 100-K Area vadose zone is not complete but is continuing through waste site remediation. Further, some identified vadose zone sources await remediation.
- Waste site remediation activities have removed many source sites and near-surface soil contamination. However, the fate and transport are not sufficiently understood for residual contamination, particularly to groundwater, below the areal limits of source area excavations.

100-K DECISION UNIT GEOLOGY

- Most of the vadose zone lies within the gravel-dominated faces of the Hanford formation (where it exists) and dips downward into the upper part of the Ringold Formation Unit E (predominantly a fluvial gravel) (Exhibit 1).
- The Hanford formation is absent along the shoreline at the 100-K Area, and the Ringold Formation is exposed from the riverbank up to 366 m (1,200 ft) inland. Gravels dominate the uppermost Ringold Formation at the 100-K Area.
- The Hanford formation at the 100-K Area increases in thickness from 0 to 37 m (0 to 120 ft) away from the river, as the Ringold Formation Unit E thins from a maximum thickness of 180 m (590 ft). The Hanford formation is composed mainly of highly permeable gravels and generally is coarser at this location than in the other 100 Area reactor sites. At least the upper 5 m (16 ft) of the Hanford formation can consist of open framework boulder-cobble gravels.
- The vadose zone varies in thickness and reaches to more than 45 m (150 ft) in the inland, southeastern portion of the 100-K Decision Unit.
- The contact between the Ringold Formation Unit E and RUM do not intersect the river (Exhibit 2), based on geologic data from borings completed beneath the riverbed depth, and stratigraphic and structural interpretations of these data projected toward the river from inland wells.

GEOLOGIC UNIT CONTACTS

- Backfill material at most 100-K Decision Unit locations does not extend past 0.9 m (3 ft) of depth. At well site 100-K-32, this material extends to ~10 m (33 ft) of depth (Exhibit 1). The permeability of backfill material may be greater than that of the surrounding, native (fine-grained surface deposits or the Hanford formation) soil and could provide a preferential pathway for contaminant migration.
- The Hanford formation/Ringold Formation contact is encountered at an elevation of ~135 m (425 ft) and generally is noted by iron staining and increased cementation of the Ringold Formation Unit E, such as observed at the nearby Coyote Rapids.
- The behavior (fate and transport) of contamination as it descends across the Hanford formation/Ringold Formation Unit E contact is not well understood. The differences in stratigraphy (i.e., grain size and grain orientation) may affect lateral contaminant spreading more than initially estimated. These effects may be observed well above or below this contact.

VADOSE ZONE CONTAMINATION

- While chromium is the principal COC in the vadose zone, tritium from vadose zone sources has also migrated to groundwater.
- In 1992, inorganic contaminants for the 116-K-2 Trench site where concentrations exceeded the Hanford Site background levels included chromium, copper, mercury, and zinc, with maximum concentrations detected in samples from 5 to 6 m (18 to 20 ft) below ground surface.
- In 1992, several radionuclides were detected in the 116-K-2 Trench: Am-241, carbon-14, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, Pu-39/240; K-40, Ra-226, Sr-90, Th-232, U-233/234, and U-238.
- Carbon-14 from vadose zone sources has been detected in 100-K Decision Unit groundwater. The carbon-14 sources have not been studied as part of the cleanup process.
- Vadose zone CrVI and tritium likely are suspended in soil moisture, rather than bound to soil grains, based on their near-zero soil distribution coefficient (Kd). Therefore, historic assessment for CrVI in the soil column may be biased toward false, lower concentrations.
- Subsurface soil contamination typically is found within immediate proximity to waste sites. However, the expanse between exploration areas and waste sites can be relatively great. Further, some vadose zone contaminants may have the potential for considerable lateral spreading and generate residual vadose zone contamination.

DATA GAPS

- The fate and transport properties of Carbon-14 in the vadose zone are not well understood, and may represent a substantial uncertainty for predicting future groundwater contamination.
- Soil sample collection depths have been biased to shallower depths. Insufficient assessment of soil in the deep vadose zone has resulted in a deficiency for decision making that will lead to a final ROD.
- Limited information is available regarding the potential lateral movement of contaminants at the Hanford formation/Ringold Formation Unit E boundary and contaminant mobility characteristics at this boundary. Because of the much higher permeability of the overlying Hanford formation, it is reasonable to assume that lateral spreading of contamination will also be greater than estimated for the Ringold Formation Unit E.

STRATIGRAPHY AND HYDROSTRATIGRAPHY AT THE 100-K DECISION UNIT

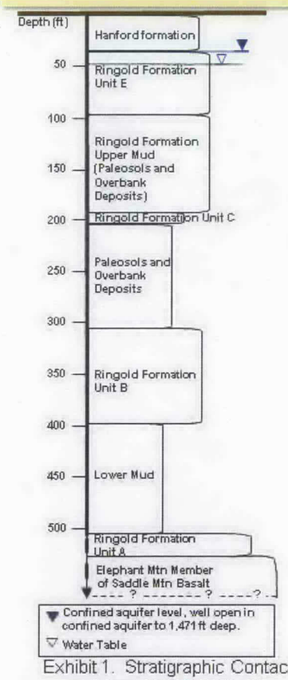
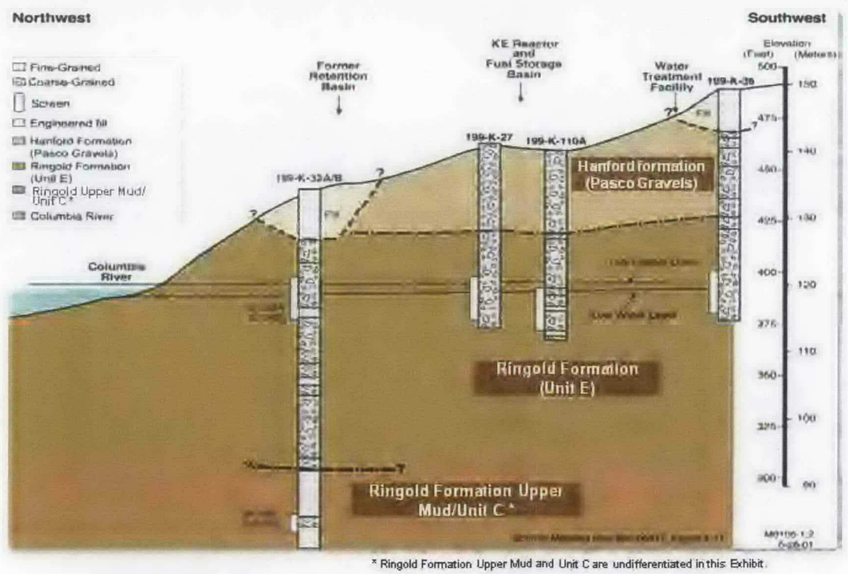


Exhibit 1. Stratigraphic Contacts at Inland Well 699-81-82



* Ringold Formation Upper Mud and Unit C are undifferentiated in this Exhibit.

Exhibit 2. Hydrostratigraphic Units Between the KE Basin and Columbia River.

Figure A-4. 100-K Geology

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PROBLEM STATEMENT

- The principal groundwater contaminant at the100-K Area is CrVI monitored in three plumes: (1) the 116-K-2 Trench plume is the largest, extending into the 100-N Area; (2) the KW Reactor plume is located downgradient of the KW Reactor; and (3) near the KE Water Treatment Plant.
- Chromium has been detected in groundwater monitoring wells along the river, but the potential exposure of chromium to ecological receptors is unquantified.
- Past shielding water leakage from the onsite fuel storage basins has impacted groundwater with radionuclides: Sr-90, tritium, and Tc-99 (an indicator of irradiated fuel releases).
- Inorganic chemicals and radionuclides from waste sites have reached groundwater.
- During low groundwater and river stage, chromium groundwater concentrations near the river generally are greater than the Freshwater Chronic Toxicity Criteria of 22 µg/L established as the compliance level in the Interim Action ROD.
- Nitrate concentrations exceed drinking water standards in some portions of the 100-K Area and are likely associated with septic system discharges.

RINGOLD FORMATION UPPER MUD

- The RUM is the base of the unconfined aquifer. In 2007 and 2008, several new well boreholes confirmed the depth of the RUM at ~15 m (49 ft) and near the river to greater than 52 m (170 ft) farther inland. This considerable relief difference may be explained as the magnitude of substantial erosional features of the RUM surface.
- The sizes and dimensions of erosional depressions in the RUM surface have not been described or sufficiently explained. The largest of such features potentially could significantly affect groundwater flow, and therefore, influence contaminant migration in groundwater.
- The bottom of the river is well above the RUM. Therefore, it is not likely that potential contaminants in the RUM could affect the river or pose a possible threat to ecological receptors.

GROUNDWATER CHARACTERISTICS

- During high river stage, the elevated water table may contact and mobilize contaminants potentially held in the periodically re-wetted zone. Also, river water flows inland as bank storage for ~61 lateral m (200 lateral ft). The effects of river stage on hydraulic head are observed much farther inland than the area where river water mixes with groundwater along the river.
- Water in the aquifer tubes is dominated by groundwater, based on the much higher specific conductance of groundwater.
- Data collection from many aquifer tubes is seasonally limited because they are submerged in the river during high stage.
- At the 100-K Area, the unconfined aquifer thickness is ~24 m (80 ft) (exclusively Ringold Formation fluvial sand and gravel). In contrast, the unconfined aquifer is considerably thinner up to 5 m (~15 ft) at the 100-H Area (Hanford formation).
- In 2007 and 2008, groundwater was encountered from ~7 to 33 m (22 to 107 ft) below ground surface.
- Long-term water level trends in most monitoring wells mimic river stage fluctuations but with amplitudes greatly attenuated by pump-and-treat operations.

GROUNDWATER FLOW

- Upward vertical hydraulic gradients have been observed within the Ringold Formation Unit E and from the RUM to the Ringold Formation Unit E. This upward gradient provides a natural control over potential downward mobilization of chromium deeper into the Ringold Formation.
- Natural groundwater gradients are toward the river during low river stage and away from the river during high river stage. Net annual groundwater movement is toward the river with a northward component toward the 100-N Area.
- Mounded, radial flow is observed around the injection area. A seasonal influence is observed for groundwater flow directions northeast of the 116-K-2 Trench (Exhibits 1 and 2).
- High river stage in spring causes inland flow in the zone of interaction, semi-aligned with river flow (Exhibit 1).
- Measured flow velocities show components perpendicular to the river bank, which vary in magnitude through the direct influence of river stage.
- Groundwater flows at a comparatively faster rate within the KW Reactor vicinity.

RELATIVE PLUME SIZE

COPC	Contaminant Thresholds	Plume areas Km^2
Carbon-14 (drinking water standard)	2,000 pCi/L	0.09
Cr(VI) (MCL, federal drinking water standard)	100 µg/L	0.07
Cr(VI) (1998 WA State AWQA)	11 µg/L[a]	
Cr(VI) (Interim Action ROD Groundwater Compliance Level)	22 µg/L	2.60[b]
Nitrate	45 µg/L	0.11
Strontium-90	8 pCi/L	0.08
Tritium	20,000 pCi/L	0.17

a: The current state AWQA is 10 µg/L.
b: Based on a 20 µg/L concentration.

Source DOE/RL-2008-01

2007 GROUNDWATER CONTAMINANT LEVELS

- Pump and treat operations, and dispersion and dilution have contributed to the general decrease in contaminant concentrations over time. However, near-river groundwater contaminant concentrations do not meet the RAOs during low river stage.
- Elevated chromium concentrations have revealed a "new hot spot" near the KE Reactor.
- Contaminant concentrations between the 100-KR-4 Injection Wells and the river have met compliance with the RAO and likely are attributable to injection operations.
- Aquifer tube data suggest that the 116-K-2 Trench plume continues to move northward toward the 100-N Area. Further, the highest 100-K Decision Unit CrVI concentration (3,600 µg/L) has been reported just inside the 100-N Area boundary.
- Persistently high tritium concentrations downgradient of the former KE and KW Condensate Facilities suggest a vadose zone source beneath each crib.
- The highest Sr-90 concentrations occur near the northwestern corner of the KE Reactor. The suspected source is the fuel storage basin.
- Carbon-14 concentrations exceed the drinking water standard at several wells downgradient of the former cribs near the KE and KW Reactors.

DATA GAPS

- The extent and dimensions of the contaminant plumes are not well-defined in all areas (e.g., southeast and west portions of the 100-K Decision Unit).
- The chromium source to the "hot spot" (well 199-K-137 Area) has not been identified.
- Potential deep vadose zone sources in communication with the periodically re-wetted zone have not been identified.
- Potential impacts of groundwater contamination on the Columbia River are not well known.
- The role of the unconfined aquifer thickness and the RUM surface on contaminant migration and distribution are not defined for the 100-K Decision Unit.
- The groundwater conditions and characteristics have not been adequately quantified.
- A final list of COPCs and target analytes should be developed before additional remedial investigation activities are proposed.
- The cause of greater groundwater flow beneath the KW Reactor has not been determined. The source of comparatively high Sr-90 concentrations near the northwestern corner of the KE Reactor has not been identified.

2007 SEASONAL CONTAMINATION CONCENTRATION CONTOURS

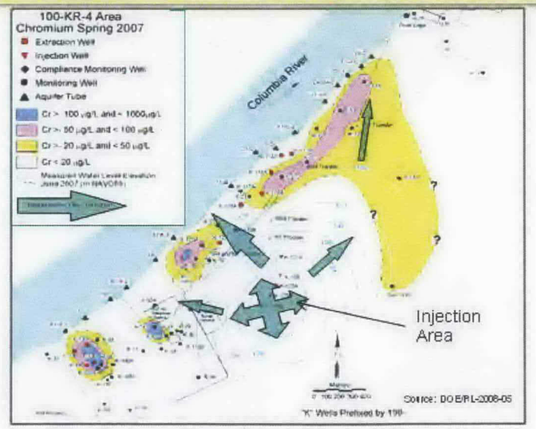

Exhibit 1. June 2007 Groundwater Elevation and Plume Concentration Contours

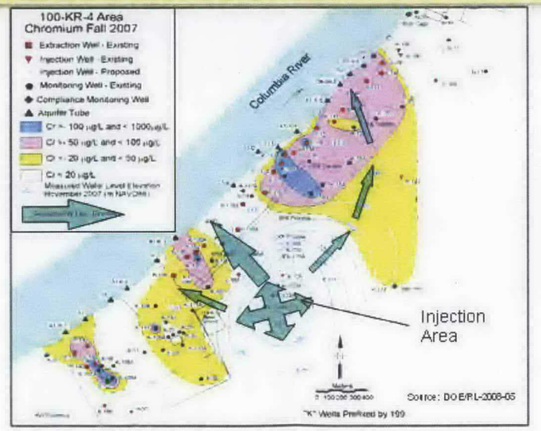

Exhibit 2. November 2007 Groundwater Elevation and Plume Concentration Contours

Figure A-5. 100-K Hydrogeology and Contaminant Mobility

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PROBLEM STATEMENT

- Chromium may pose a potential threat to ecological receptors in the river at concentrations in excess of the RAO of 22 µg/L for near-river groundwater. Compliance well coverage is inadequate to sufficiently quantify near-river chromium concentrations.
- The inland extent of contamination and the capture zone of the 100-KR-4 pump-and-treat system are not quantified.
- The 100-KR-4 pump-and-treat system has not adequately controlled the 116-K-2 Trench Plume, which has reached the nearby shoreline and has migrated northward to the 100-N Area. Near the KE and KW Reactors, localized chromium plumes of uncertain origin have not been adequately captured by extraction wells.
- The available installation locations and optimal efficiency of the injection wells are limited by existing infrastructure and culturally sensitive locations.
- Contaminant dispersion and/or dilution in the zone of interaction greatly affect the efficiency and performance of the pump-and-treat systems to treat chromium in groundwater.
- Mass contaminant estimates in groundwater and the periodically re-wetted zone have not been prepared as criteria to use during system performance and coverage evaluations.
- Part of the 100-K Area chromium plume has entered the 100-N Area.

KW REACTOR PUMP-AND-TREAT SYSTEM CHRONOLOGY

- In 2006, four extraction wells and two injection wells were installed to focus on the KW Reactor plume, with a design process capacity initially set at 283 L/min (75 gpm).
- System startup occurred in January 2007. The reinjection chromium concentration goal was set at 10 µg/L to meet the 22 µg/L compliance standard for river protection by 2012.

100-KR-4 PUMP-AND-TREAT SYSTEM CHRONOLOGY

- Pump-and-treat with ion exchange was identified as the preferred IRM for the 100-KR-4 Groundwater OU in the 1995 Proposed Plan. The 1996 Interim Action ROD selected this IRM technology for implementation under regulatory oversight with the objective to reduce chromium concentrations in groundwater to meet the 22 µg/L compliance level of the Interim Action ROD.
- On October 1, 1997, the pump-and-treat system became fully operational. The initial pumping rate goal was designed with a capacity of 757 L/min (200 gpm).
- In 2005, calcium polysulfide treatability testing was conducted to evaluate immobilization of chromium in groundwater. This method proved to be a potential alternative to pump-and-treat technology for the cleanup of CrVI.
- A 2007-2008 system expansion resulted in installing 19 new wells and converting three existing monitoring wells for use as extraction or injection wells.

5-YEAR REVIEWS: 2001 AND 2006

- In 2001, the first 5-Year Review recommended optimizing the 100-KR-4 pump-and-treat system. At that time, the Washington Ambient Water Quality Standard for chronic exposure to chromium was changed from a concentration of 11 to 10 µg/L. However, this legislation protective standard set at a concentration of 22 µg/L did not affect the Interim Action RODs.
- The 2006 5-Year Review recommended improving system performance and coverage, and installation of a new pump-and-treat system to prevent chromium from reaching the river from the KW Reactor Area.

TWO SYSTEM CONFIGURATIONS

- Both the pump-and-treat systems' components include groundwater extraction and injection wells plus above ground ion exchange equipment and piping.
- Several modifications have been made to the original 100-KR-4 pump-and-treat system. Chromium entering the 100-N Area is being addressed as part of this system's operation.
- The KW Reactor system has not required modification since startup in January 2007
- The selected 100-K Area Compliance Wells are 199-18, 199-K-20, and 199-K-117A.

100-K Area Pump-and-Treat Systems

100-KR-4 OU System					KW Reactor System	
Extraction Wells			Injection Wells		Extraction Wells	Injection Wells
199-K-113A	199-K-127	199-K-147	119-K-121A	119-K-160	199-K-132	199-K-35
199-K-114A	199-K-129A	199-K-148	119-K-122A	119-K-164	199-K-138	199-K-158
199-K-115A	199-K-130	199-K-149	119-K-123A	119-K-169	199-K-139	
199-K-116A	199-K-131	199-K-150	119-K-124A	119-K-170	199-K-140	
199-K-119A	199-K-144	199-K-161	119-K-143	119-K-171		
199-K-120A	199-K-145	199-K-162	119-K-156	119-K-172		
199-K-125A	199-K-146		119-K-159			

PUMP-AND-TREAT SYSTEM PERFORMANCE

- Although more recent decisions (e.g., the ISRM at the 100-D Area) use a revised CrVI cleanup standard of 20 µg/L, the purpose of the 100-KR-4 and KW Reactor pump-and-treat IRAs is to reduce the chromium concentrations in groundwater in near-river monitoring compliance wells to less than 22 µg/L.
- Annually collected data from multiple monitoring wells are used to evaluate system performance. System maintenance and performance adjustments (i.e., flow rates) are made as necessary.
- The KW Reactor pump-and-treat system yields an average annual pumping rate of 327.8 L/min (86.6 gpm), which more than meets its initial design criteria.
- Since 1997, groundwater CrVI concentrations have decreased up to 98 percent to less than 20 µg/L between the injection wells and the river, and up to 97 percent to less than 10 µg/L in aquifer tubes downgradient of the 116-K-2 Trench center.
- Downgradient of the north end of the 116-K-2 Trench, groundwater injection and/or flow rates may be the cause for a more than 25 percent increase in groundwater CrVI concentrations.
- At well 199-K-18, an increasing CrVI concentration trend since 1997 has been attributed to startup of the 100-KR-4 pump-and-treat System. This suggests a relationship to changes in groundwater flow patterns because of groundwater extraction and injection influences.
- The removal efficiency by mass is less for the 100-KR-4 pump-and-treat System than for the much-smaller KW Reactor system.

System Performance:	100-KR-4 OU System	KW Reactor System
CY07 Volume Extracted	~529.2 million liters	NA
Total Volume Extracted	~4.41 billion liters	172.49 million liters
CY07 Chromium Mass Removed	~20.5 kg	NA
Total Chromium Mass Removed	~324.7 kg	21.08 kg
Removal Efficiency by Mass	91.90%	100%
Maximum Effluent Cr(VI) Concentration	10 µg/L	~0.0 µg/L
Time-Weight Average Cr(VI)	73.6 µg/L	122.2 µg/L

DATA GAPS

- The CrVI mass within the periodically rewetted zone has not been estimated to evaluate its relationship to plume contaminant concentrations and distribution.
- Further evaluation is needed to quantify the fate, transport, and continuing contribution of vadose zone contamination sources to groundwater.
- The 116-K-2 Trench plume's inland extent to the northeast of the 100-KR-4 System's injection wells has not been sufficiently delineated. The relationship between the 116-K-2 Trench plume's inland extent and chromium at well 699-78-62 has not been identified.
- Chromium concentrations at wells 199-K-18 and 199-K-120A appear to be increasing over time and the chromium source for these wells has not been identified.
- Potentially mobile chromium in the lower vadose zone has not been quantified, particularly beneath waste sites and in the aquifer upgradient (southwest) of the 116-K-2 Trench.

PLUME PROGRESSION AND CONTAMINANT TRENDS FROM 1997 TO 2007

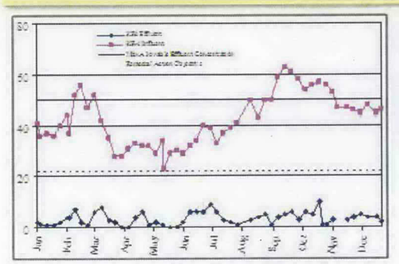
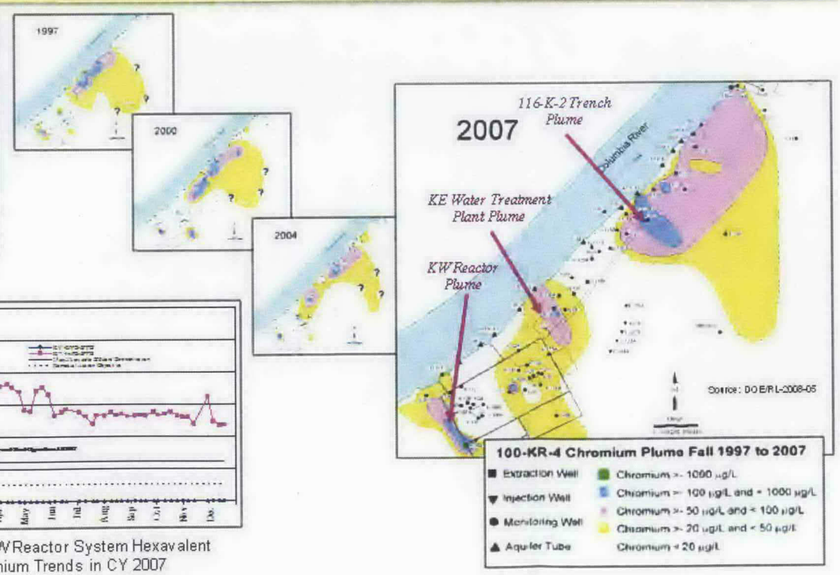


Exhibit 1. 100-KR-4 System Hexavalent Chromium Trends in CY 2007.



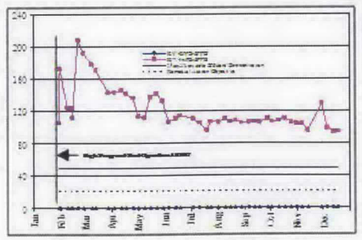


Exhibit 2. KW Reactor System Hexavalent Chromium Trends in CY 2007

Figure A-6. 100-K Groundwater Remediation

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Appendix B

100-K Area Maps

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Introduction

Maps showing the facilities and waste sites located in the 100-K Area.

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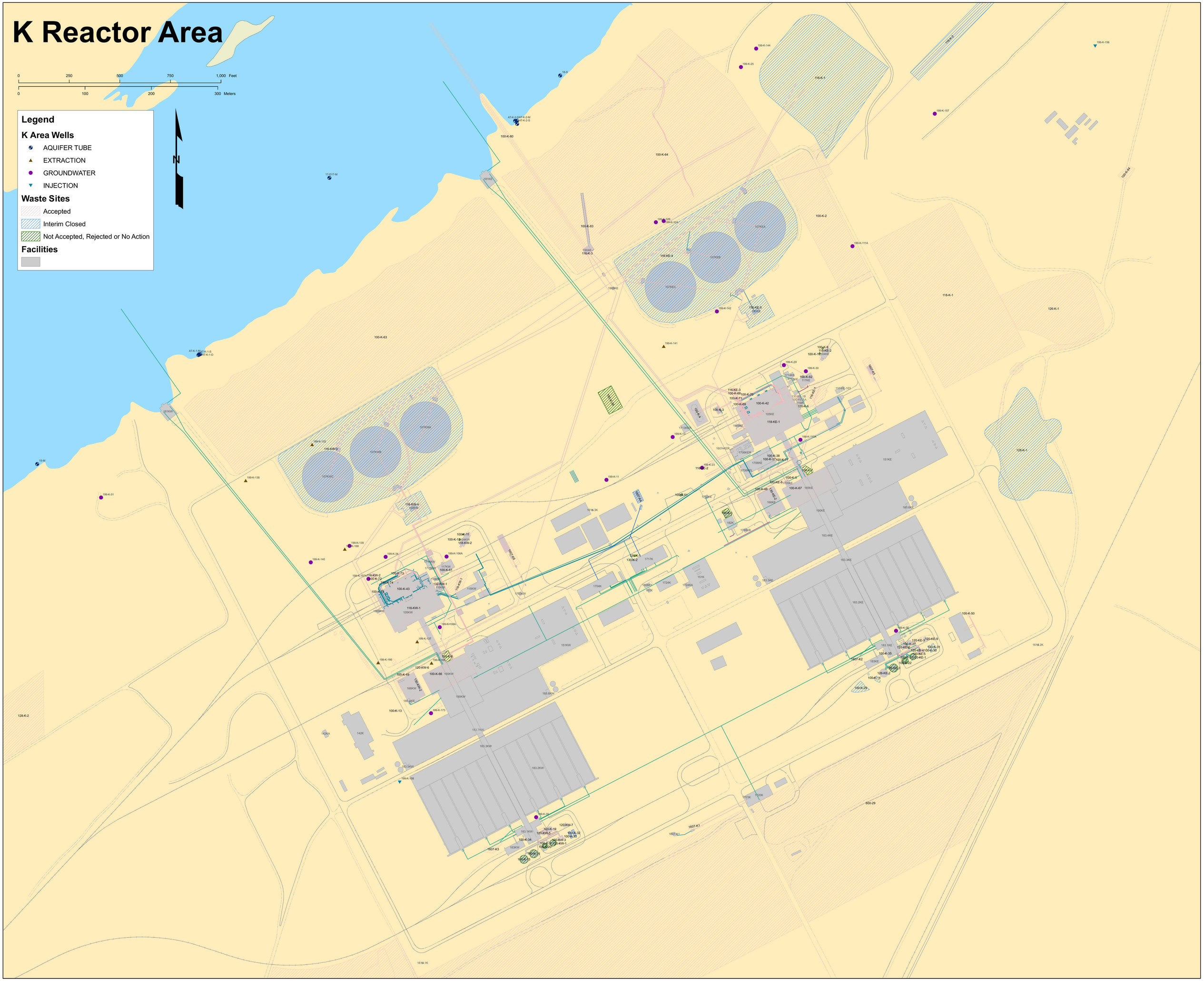
K Reactor Area



100-K Area Base Map

0 500 1,000 1,500 2,000 Feet

0 200 400 600 Meters

Legend

K Area Wells

- AQUIFER TUBE
- EXTRACTION
- GROUNDWATER
- INJECTION

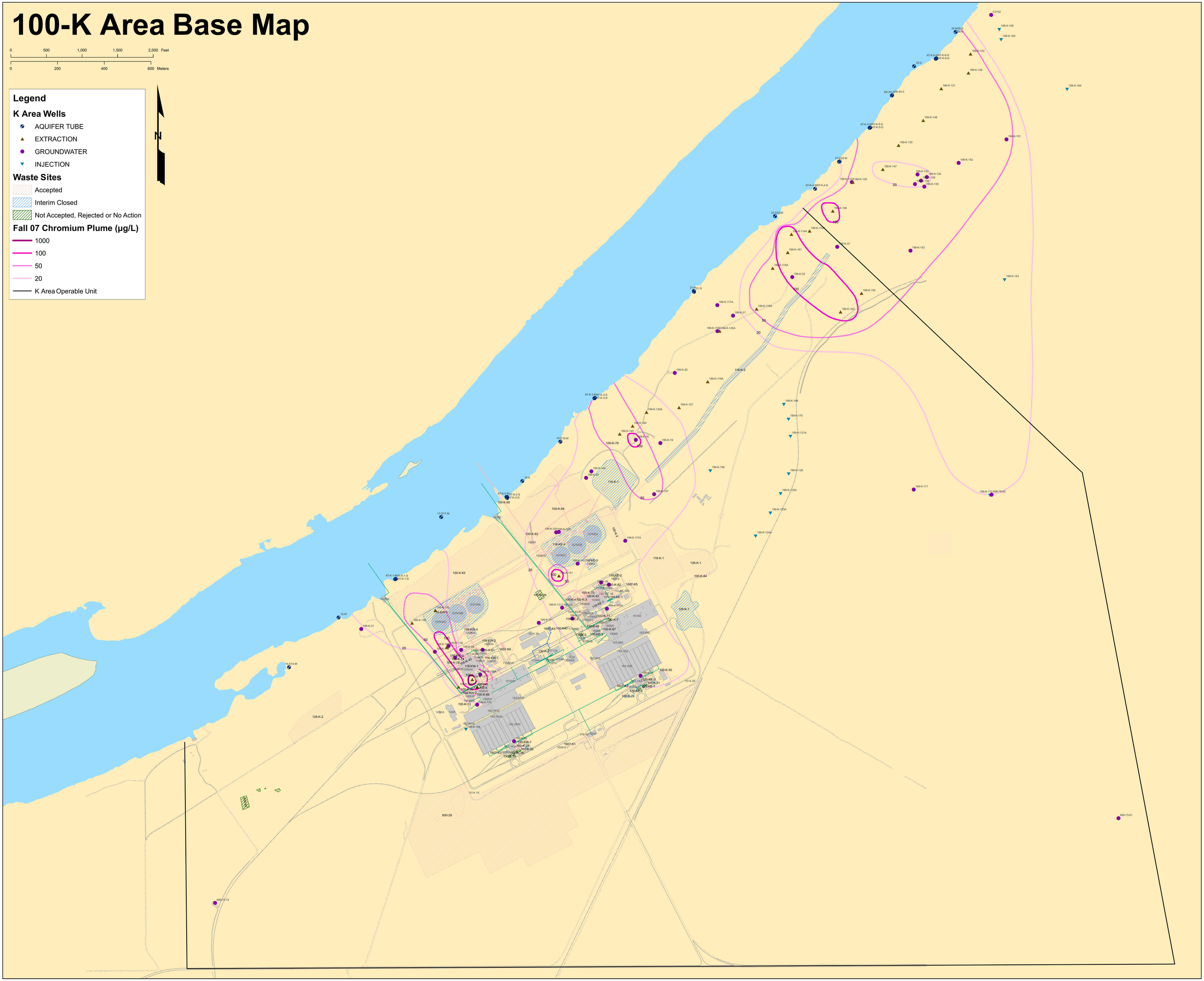
Waste Sites

- Accepted
- Interim Closed
- Not Accepted, Rejected or No Action

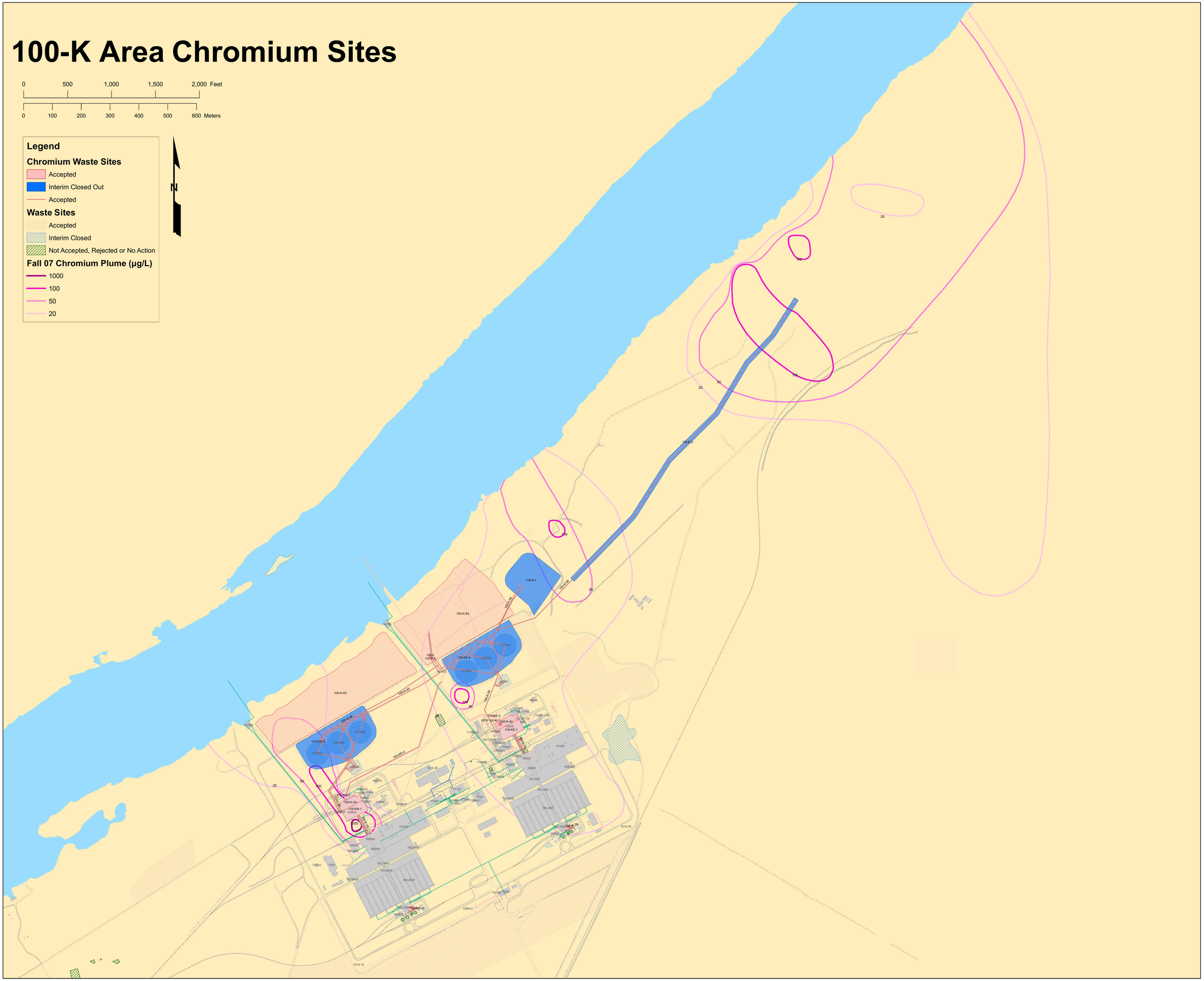
Fall 07 Chromium Plume (µg/L)

- 1000
- 100
- 50
- 20
- K Area Operable Unit

N



100-K Area Chromium Sites



Appendix C

100-K Waste Sites Description and History

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C1 Introduction

Table C-1 provides a summary of the codes, types, and status of waste sites in 100-K of the Hanford Site. Table C-1 also provides physical dimensions, dates of operation, a brief history for each site, and relevant decision/remedial action information, if available. Table C-2 (Facility Waste Cross-Walk) lists 100-K facilities and associated waste sites.

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Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-1	French Drain	100-KR-2	Diameter: 1.52	1961-1970	This site is a concrete French drain that received heat exchanger cooling water from sample equipment in the 119-KW Building, wastewater from a swamp-type cooler, and effluent from a floor drain also located in the 119-KW-Building.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								
100-K-10	French Drain	100-KR-2	4 m^2	1953-1971	This site is the southernmost of two French drains at the 118-KE-2. The French drain is a 0.6 m (2 ft) diameter steel pipe with a steel cover. It is gravel filled to grade and surrounded by a yellow wooden barricade. The steel cover is posted with a confined space sign. The adjacent area is covered with gravel and cobbles.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-11	French Drain	100-KR-2	4 m^2	Not Documented	This site is the northernmost of two French drains at the 118-KW-2. The French drain is a 0.6 m (2 ft) diameter steel pipe with a steel cover. It is gravel filled to grade and surrounded by a yellow wooden barricade. The steel cover is posted with a confined space sign. The adjacent area is covered with gravel and cobbles.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-12	French Drain	100-KR-2	4 m^2	Not Documented	This site is the southernmost of two French drains at 118-KW-2. The French drain is a 0.6 m (2 ft) diameter steel pipe with a steel cover. It is gravel filled to grade and surrounded by a yellow wooden barricade. The steel cover is posted with a confined space sign. The adjacent area is covered with gravel and cobbles.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-13	French Drain	100-KR-2	Diameter: 1.52	1953-1955	This site is a French drain that is a 1.5 m (5 ft) diameter vertical concrete pipe filled with gravel. It is believed that the drain was installed and used as a disposal site for sanitary-type waste from several temporary 100-KW construction facilities located near the site.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-14	French Drain	100-KR-2	Diameter: 1.52	Unknown	The pit is 4.6 m (15 ft) deep with aggregate placed to a depth of 2.1 m (7 ft). A 0.76 m (2.5 ft) diameter, vitrified clay pipe was placed vertically in the center of the pit and limestone chips were added to the pipe interior. A 5.1 cm (2 in.) polyvinyl chloride pipe enters through the side 1 m (3.3 ft) below grade. The pipe is an overflow and drain line for the 183-KE day-use acid tank.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-15	Storage Tank	100-KR-2	120 m^2	Not Documented	This site is an above ground, vertical, stainless steel storage tank mounted on a concrete base. The tank was part of a system called the liquid alum system, which supplied liquid alum for water treatment. The liquid was supplied by either rail car or tank truck, as both connections are shown on the Liquid Alum System diagram in HW-24800-103. H-1-16552 shows the pipelines, valves, and instrumentation related to the tank. During the winter, the liquid alum was pumped through heat exchangers for heating and agitating the chemicals.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-16	Storage Tank	100-KR-2	117 m^2	Not Documented	This site is an above ground, vertical, stainless steel storage tank mounted on a concrete base. The tank was part of the liquid alum system, which supplied liquid alum for water treatment. The liquid was supplied by either rail car or tank truck, as both connections are shown on the Liquid Alum System diagram in HW-24800-103. H-1-16552 shows the pipelines, valves, and instrumentation related to the tank. During the winter, the liquid alum was pumped through heat exchangers for heating and agitating the chemicals.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-18	Sump	100-KR-2	2.54 x 1.93 x 0.9	Unknown	The pit is a 2.54 m (8.3 ft) long, 1.93 m (6.3 ft) wide, 0.9 m (3 ft) deep, brick-lined concrete box with a wooden cover. The pit received, neutralized, and disposed of caustic (sodium hydroxide) waste from overflow and transfers associated with the 183-KW Water Treatment System.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-19	Foundation	100-KR-2	Diameter: 7.8	1954-1970	This site was originally an above ground, cylindrical, vertical steel caustic soda (sodium hydroxide) storage tank on a concrete base. The above ground tank was 7.8 m (25.5 ft) in diameter with a capacity of 287,660 L (76,000 gal). Sometime in the past (date unknown), the tank was removed. Today, the site is the 9.1 m (30 ft) diameter grade-level concrete tank base and the soil surrounding the base.	Accepted	Not Documented	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-2	Burial Ground	100-KR-2	53.34 x 18.29 x 4.57	Unknown	This site has appeared in different locations on several sketch-type drawings as a sludge burial ground. Today, the surface of the site is vegetation-free and covered with soil and rocks. The surface shows no signs of the waste site.	Accepted	EPA/ROD/R10-00/121	2010 (tentative)								
100-K-20	Foundation	100-KR-2	Diameter: 9.14, Capacity: 395,197 L	1955-1964	This site was the westernmost of the above ground vertical tanks that were used to store liquid sodium silicate. Initially, tank trucks supplied the chemical for the tanks. Estimating from procurement and construction drawings for the bauxite tank (Project CAI 105), the sodium silicate tanks were removed in 1964 or 1965. Following removal, the bagged dry powder form of the chemical was used.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-21	Foundation	100-KR-2	Diameter: 9.14 Capacity: 395,197 L		This site was the easternmost of the above ground vertical tanks that were used to store liquid sodium silicate. Initially, tank trucks supplied the chemical for the tanks. Estimating from procurement and construction drawings for the bauxite tank (Project CAI 105), the sodium silicate tanks were removed in 1964 or 1965. Following removal, the bagged dry powder form of the chemical was used.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-22	Foundation	100-KR-2	Diameter: 9.14 Capacity: 395,197 L	1955-1964	This site was the westernmost of the above ground vertical tanks that were used to store liquid sodium silicate. Initially, tank trucks supplied the chemical for the tanks. Estimating from procurement and construction drawings for the bauxite tank (Project CAI 105), the sodium silicate tanks were removed in 1964 or 1965. Following removal, the bagged dry powder form of the chemical was used.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-23	Foundation	100-KR-2	Diameter: 9.14, Capacity: 395,197 L	1955-1964	This site was the easternmost of the above ground vertical tanks that were used to store liquid sodium silicate. Initially, tank trucks supplied the chemical for the tanks. Estimating from procurement and construction drawings for the bauxite tank (Project CAI 105), the sodium silicate tanks were removed in 1964 or 1965. Following removal, the bagged dry powder form of the chemical was used.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-24	Storage Tank	100-KR-2	Length: 17.07 Diameter: 5.49	1966-1972	This site is a single bauxite (aluminum oxide) above ground storage tank (silo). The addition of the tank was part of a proposal to reduce water treatment costs by approximately $278,000 per year in the 183-KE and 183-KW Buildings.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-25	Sump	100-KR-2	2.54 x 1.93 x 1.45	Unknown	The pit received and neutralized sodium hydroxide waste from overflows and transfers associated with water treatments at the 183-KE Building.	Accepted	Not Documented	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-27	Foundation	100-KR-2	Diameter: 7.8	1954-1971	This site was originally an above ground, cylindrical, vertical steel caustic soda (sodium hydroxide) storage tank on a concrete base. The above ground tank was 7.8 m (25.5 ft) in diameter with a 287,660 L (76,000 gal) capacity. Sometime in the past (date unknown), the tank was removed. Today, the site is composed of 9.1 m (30 ft) diameter, grade-level concrete tank base and the soil surrounding the base.	Accepted	Not Documented	Per RAWP[c]								
100-K-28	Storage Tank	100-KR-2	Diameter: 5.49	1966-1972	This site is a single bauxite (aluminum oxide) above ground storage tank (silo). The addition of the tank was part of a proposal to reduce water treatment costs by approximately $278,000 per year in the 183-KE and 183-KW Buildings.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-29	Dumping Area	100-KR-2	46 x 120	early 1980s	This site was used for sand blasting. In the early 1980s, steel components from the 183-KE Settling Basins were sandblasted before being sold as scrap. Sampling in 1989 indicated the material present were non-regulated for EP toxicity.	Interim Closed	WSRF-2004-040	Dec-03	Dec-03	187	0.051	Lead	63.2	/	/	/
												Hexavalent chromium	0.24	/	/	/
												Chromium	24.7	/	/	/
												Aroclor-1254	0.047	/	/	/
												Arsenic	2.3	/	/	/
												Barium	66.4	/	/	/
												Cadmium	0.33	/	/	/
												Mercury	0.05	/	/	/
												Selenium	ND	/	/	/
												Silver	ND	/	/	/

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-3	Valve Pit	100-KR-2	Length: 8.23	1956-1965	This site includes two concrete pits, two concrete manholes, concrete encased pipelines, and non-encased pipelines. This site includes those pipelines that were specific to the 1706-KE water studies semi-works, and does not include the large 0.9 m (36 in.) or 1.8 m (72 in.) KE Reactor effluent pipelines.	Accepted	Not Documented	Per RAWP[c]								
100-K-30	Storage Tank	100-KR-2	1.22 x 3.66 x 1.83 (height-above ground)	1955-1971	This site consisted of two above ground U-shaped concrete bases and above ground piping. A cylindrical tank lay horizontally on the two concrete U-shaped bases. It is unknown when the tank was removed.	Interim Closed	WSRF-2003-036	Jan-04	Jan-04	Not documented	1	Arsenic	2.6	/	/	/
												Barium	69.7	/	/	/
												Cadmium	0.64	/	/	/
												Chromium (total)	15.2	/	/	/
												Hexavalent chromium	0.7	/	/	/
												Lead	36	/	/	/
												Mercury	17.5	/	/	/
												Sulfate	2,630	/	/	/
												Selenium	ND	/	/	/
												Silver	ND	/	/	/
												PCBs	ND	/	/	/
												Asbestos	3-8%	/	/	/
100-K-31	Storage Tank	100-KR-2	1.22 x 3.66 x 1.83 (height-above ground)	1955-1971	This site consisted of two above ground U-shaped concrete bases and above ground piping.	Interim Closed	WSRF-2004-038	Dec-03	Jan-04	Not documented	0.61	Arsenic	2.7	/	/	/
												Barium	169	/	/	/
												Cadmium	0.75	/	/	/
												Chromium (total)	17.5	/	/	/
												Hexavalent chromium	2.6	/	/	/
												Lead	23.3	/	/	/
												Mercury	35.4	/	/	/
												Selenium	0.55	/	/	/
												Sulfate	8,430	/	/	/

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
												Silver	ND	/	/	/
100-K-32	Storage Tank	100-KR-2	1.22 x 3.66 x 1.83 (height-above ground)	1955-1970	Two concrete tank pedestals and associated sulfuric acid piping were at the site.	Interim Closed	WSRF-2004-039	Dec-03	Jan-04	Not documented	0.61	Arsenic	3	/	/	/
												Barium	97.4	/	/	/
												Cadmium	0.38	/	/	/
												Chromium (total)	16.9	/	/	/
												Hexavalent chromium	2	/	/	/
												Lead	42.8	/	/	/
												Mercury	39.7	/	/	/
												Selenium	0.38	/	/	/
												Sulfate	8,290	/	/	/
												Silver	ND	/	/	/
100-K-33	Storage Tank	100-KR-2	1.22 x 3.66 x 1.83 (height-above ground)	1955-1970	The unit consisted of two above ground U-shaped concrete bases and above ground piping. A cylindrical tank lying horizontally on the two concrete U-shaped bases was observed in a March 1962 photograph.	Interim Closed	WSRF-2004-041	Dec-03	Jan-04	30 m^3	4	Arsenic	6.7	/	/	/
												Barium	105	/	/	/
												Cadmium	0.08	/	/	/
												Chromium (total)	20	/	/	/
												Hexavalent chromium	1.4	/	/	/
												Lead	6.9	/	/	/
												Mercury	26	/	/	/
												Selenium	0.4	/	/	/
												Silver	0.09	/	/	/
												Sulfate	3,490	/	/	/
100-K-34	Sump	100-KR-2	2.53 x 1.92 Area: 4.9 m^2	Unknown	This site is a below grade brick-lined concrete box backfilled with crushed limestone that was used to neutralize and dispose of overflow and transfer waste from nearby sulfuric acid tanks (near 183-KW).	Accepted	EPA/ROD/R10-00/121	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-35	Sump	100-KR-2	2.53 x 1.92, Area: 4.9 m^2	Unknown	This site is a below grade brick-lined concrete box backfilled with crushed limestone that was used to neutralize and dispose of overflow and transfer waste from nearby sulfuric acid tanks (near 183-KE).	Accepted	EPA/ROD/R10-00/121	Per RAWP[d]								
100-K-36	French Drain	100-KR-2	Length: 1.22, Diameter: 0.46 Area: 0.2 m^2	1962-Unknown	This site is a dry well (French drain) that was added to the 1706-KE Building as part of the chemical storage facility.	Accepted	EPA/ROD/R10-00/121	Per RAWP[c]								
100-K-37	Storage Tank	100-KR-2	Length: 4.88 Diameter: 2.13	1963-1986	This site is an above ground, vertical, stainless steel storage tank used to store sulfuric acid at 1706-KE.	Accepted	Not Documented	Per RAWP[c]								
100-K-38	Unplanned Release	100-KR-2	Length: 4.88 Diameter: 2.13	1963-1986	This site is contaminated soil from spills related to a caustic soda storage tank. The tank is above ground, vertical, and constructed of stainless steel.	Accepted	Not Documented	Per RAWP[c]								
100-K-39	Crib	100-KR-2	Not Documented	Not Documented	This site was reported to be a crib.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-4	Pond	100-KR-2	Diameter: 9.1 (two circular ponds)	1956-1965	This site is currently identified by two 9.1 m (30 ft) diameter circular ponds separated by a 2.7 m by 9.1 m (9 ft by 30 ft) rectangular pond and valve pit.	Accepted	Not Documented	Per RAWP[c]								
100-K-42	Storage	100-KR-2	41.45 x 21.34 x 6.71 Est. volume: 5,931 m^3	1955-1970	This site is the concrete fuel storage basin that served as a collection, storage, and transfer facility for the irradiated fuel elements discharged from the KE Reactor.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-43	Storage	100-KR-2	41.45 x 21.34 x 6.71 Est. volume: 5,931 m^3	1955-1971	This site is the concrete fuel storage basin that served as a collection, storage, and transfer facility for the irradiated fuel elements discharged from the KW Reactor.	Accepted	EPA/ROD/R10-99/039	Per RAWP[d]								
100-K-44	Unplanned Release	100-KR-2	Not Documented	Not Documented	The grounds within the 100-K Exclusion Area that are not part of other waste sites.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-46	French Drain	100-KR-2	Diameter: 0.91	1959-1971	This site is a drywell and small-diameter pipeline that received effluent from the 119-KE Building evaporative cooler, and likely sample waste and janitorial waste, as drainage from a floor drain in the building. The site has been covered with crushed rock and there is no visible evidence of the drywell on the ground surface.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-47	Process Sewer	100-KR-2	4,215	1955-present	This site includes those underground process sewer pipelines that begin at the KE Reactor, KW Reactor, 165-KE, 190-KE, 1706-KE, and terminate at either the 116-K-3 Outfall or join the 100-K-56 Pipeline south of the outfall.	Accepted	Not Documented	Per RAWP[d]								
100-K-48	Unplanned Release	100-KR-2	213.57 m^2	Unknown	This site shows evidence of past fuel oil spills especially around the railroad tracks. The spills have been absorbed into the soil and have formed an asphalt-like substance. Some areas may have been covered with clean soil.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-49	Unplanned Release	100-KR-2	746.32 m^2	Unknown	This site is likely to have been the result of several spills, which would have occurred during unloading of fuel oil from rail cars.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-5	French Drain	100-KR-2	Diameter: 0.9	Unknown	This site is a French drain consisting of a 0.9 m (3 ft) diameter vitrified clay pipe that received effluent from floor drains, overflows, and drainage from the 1705-KE Experimental Water Treatment Basin and facilities. It protrudes approximately 0.3 m (1 ft) above grade and has a heavy wooden cover.	Accepted	Not Documented	Per RAWP[c]								
100-K-50	Storage Tank	100-KR-2	7.47 x 3.81 x 2.74 Capacity: 17,034 L	1996-present	This site is a sanitary sewage holding tank that services 1725-K and 1726-K.	Accepted	Not Documented	Per RAWP[c]								
100-K-51	Storage Pad (<90 day)	100-KR-2	7.01 x 2.59	Not Documented	This site is a white, portable steel building, with no windows, and three doors that are all on one side. The Spent Fuel Division is using the site for the 90-day storage of hazardous waste.	Not Accepted	WSRF-2000-017	N/A								
100-K-52	Storage	100-KR-2	4.57 x 3.05	1956-1965	This site is currently in use by the SNF Program as a storage room. This site was split from 100-K-3 and 100-K-4, so that the programmatic responsibility for this area could be assigned to the correct program.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-53	Product Piping	100-KR-2	Not documented	1955-1971	This site includes those underground pipelines that transported glycol solutions from the 116-KE-5 (150-KE Heat Recovery Station) to their entrance to the 165-KE Power Control Building facilities.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-54	Product Piping	100-KR-2	852	1955-1971	This site includes those underground pipelines that transported glycol solutions from the 116-KE-5 (150-KE Heat Recovery Station) to their entrance to the 165-KE Power Control Building facilities.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-55	Radioactive Process Sewer	100-KR-2	Length: 3,906.93 Depth: 5.18	1955-1970	The effluent system transported the reactor process effluent water by means of gravity flow to the river. There, the effluent water was discharged underwater to be diluted both thermally and radioactively by the flow of the river. The effluent system piping was located underground to provide shielding from the radioactive water.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								
100-K-55:1	Radioactive Process Sewer	100-KR-2	0.08-1.83	1955-1970	The 100-K-55 Pipelines consisted of the gravity-flow process effluent pipelines that formerly serviced the KW Reactor, terminating at the 116-K-1 Crib, the 116-K-2 Trench, and the 116-KW-3 Retention Basins.	Interim Closed	CVP-2005-00006	9-Dec-02	15-Apr-05	86,551	8.8	Cesium-137	0.884	3.85	0.27	0.82
												Europium-152	3.87	1.85	0.73	0.74
												Europium-154	0.521	0.288	0.12	0.12
100-K-55:2	Radioactive Process Sewer	100-KR-2	Length: not documented Depth: 5.18	1955-1970	This sub-site consists of the remaining portion of the underground effluent pipeline inside the reactor security fence and near the active utility features of the 116-K-1 Crib, the 116-KW-3 Retention Basin, and the 116-K-2 Trench. Also included in this sub-site is a 0.61 m (24 in) process water pipeline connecting the two reactor buildings. This pipeline is located on the south side of the reactors.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-56	Radioactive Process Sewer	100-KR-2	Length: 1,902.87 Depth: 4.57	1955-1971	The effluent system transported the hot reactor effluent water by means of gravity flow to the river, where the effluent water was discharged underwater to be diluted both thermally and radioactively by the flow of the river. The effluent system piping was located underground to provide shielding from the radioactive water.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								
100-K-56:1	Radioactive Process Sewer	100-KR-2	0.08-1.83	1955-1971	The 100-K-56 Underground Pipelines consisted of the gravity-flow process effluent pipelines that formerly serviced the KE Reactor, terminating at the 116-K-1 Crib, the 116-K-2 Trench, and the 116-KE-4 Retention Basins.	Interim Closed	CVP-2005-00006	9-Dec-02	15-Apr-05	86,551	8.8	Cesium-137	2.38	5.4	0.61	1.32
												Europium-152	10.4	31.4	1.7	13.7
												Europium-154	ND	4.08	0.14	1.87
100-K-56:2	Radioactive Process Sewer	100-KR-2	Length: Not documented Depth: 4.57	1955-1971	This sub-site consists of the remaining portion of the underground effluent pipeline inside the reactor security fence and near the active utility features of the 116-K-1 Crib, the 116-KE-4 Retention Basin, and the 116-K-2 Trench. A 0.61 m (24 in) process water pipeline connecting the two reactor buildings is also administratively part of this sub-site.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								
100-K-57	Ditch	100-KR-1	570.0 x 1.52 x 1.22	1967-1971	This site is a ditch that was constructed to collect leakage from the 107-K Retention Basins and divert the flow directly to the Columbia River. Soil in and around the ditch is contaminated with radionuclides as a result of conveying reactor process effluent to the river.	Accepted	Not Documented	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-58	Product Piping	100-KR-2	3,569	1957-present	The pipelines included carried raw, sanitary, and fire water throughout the 100-KE Area.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-59	Product Piping	100-KR-2	3,394	1957-present	The pipelines included carried raw, sanitary, and fire water throughout the 100-KE Area.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-6	Process Unit/Plant	100-KR-2	Diameter: 3.05	1955-1970	The vacuum pit contains a cyclone separator in a vertically oriented 3 m (10 ft) diameter culvert that extends from grade level to 9.2 m (30 ft) below grade.	Accepted	Not Documented	Per RAWP[c]								
100-K-60	Process Sewer	100-KR-2	484	1955-1971	This site includes the underground process sewer pipeline that begins at 165-KW and runs up to the point of intersection with the 30.5 cm and 40.6 cm (12 and 16 in.) pipelines coming from the KW Reactor.	Accepted	Not Documented	Per RAWP[d]								
100-K-61	Process Unit/Plant	100-KR-2	317 m^2	1960-1970	The 117-KW Filter Building housed blowers and particulate filters used to treat the ventilation exhausted from the KW Reactor.	Accepted	Not Documented	Per RAWP[c]								
100-K-62	Process Unit/Plant	100-KR-2	312 m^2	1960-1971	The 117-KE Filter Building housed blowers and particulate filters used to treat the ventilation exhausted from the KE Reactor.	Accepted	Not Documented	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-63	Unplanned Release	100-KR-1	80,527.61 m^2	Unknown	This site is a large portion of the floodplain, along the shore of the Columbia River, north of the KW Reactor area that is posted as a radiological contamination area. Most of it is posted as an underground radioactive material area, but two sections remain posted as soil contamination areas.	Accepted	Not Documented	Per RAWP[c]								
100-K-64	Unplanned Release	100-KR-1	Length: 355.40 Diameter: 2.11.30 Area: 74,325.6 m^2	Unknown	The waste is contaminated soil related to the leakage of cooling water from the 107-KE Retention Basins (waste site 116-KE-4).	Accepted	Not Documented	Per RAWP[c]								
100-K-66	Control Structure	100-KR-2	73.15 x 33.53 x 4.57	Unknown	The 165-KW Power Control Building provided housing for the powerhouse, control room, valve pit, and electrical switchgear of the water supply system. This site is a bomb-resistant shelter without windows, contains asbestos, and has been cleaned twice (in 1993) for PCBs.	Accepted	Not Documented	Per RAWP[c]								
100-K-67	Control Structure	100-KR-2	73.15 x 33.53	Unknown	The purpose of the 165-KE Power Control Building was to provide housing for the powerhouse, control room, valve pit, and electrical switchgear of the water supply system. It was constructed as a bomb-resistant shelter without windows, and fans supply all ventilation.	Accepted	Not Documented	Per RAWP[d]								
100-K-68	Catch Tank	100-KR-2	Depth: 10.85 Diameter: 2.44	Unknown	The tank received wastewater from 105-KE Fuel Storage Basin sub-basin drainage header.	Accepted	Not Documented	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-69	Sump	100-KR-2	2.29 x 1.37 x 3.96	Unknown	The structure is a concrete sump that receives water from the 105-KE Fuel Storage Basin floor drains in the transfer area. Two electric-powered sump pumps return the drain water to the basin.	Accepted	Not Documented	Per RAWP[c]								
100-K-7	Storage Tank	100-KR-2	Length: 8.23 Overburden depth: 0.91 Diameter: 2.44	1955-1971	The tanks at this site contained ethylene glycol. The tanks were removed from the site in 1994. There was no evidence of contamination and the tanks were intact.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-70	Storage Tank	100-KR-2	Length: 12.19 Diameter: 2.74	1974-present	This site is a steel storage tank for the 105-KE Fuel Storage Basin radioactive drains. The tank is buried under a 1.8 m (6 ft) deep earth berm.	Accepted	Not Documented	Per RAWP[c]								
100-K-71	Diversion Box	100-KR-2	4.57 x 2.44 x 3.96 Overburden Depth: 8.84	1953-present	The collection box receives wastewater from nine underground process sewers that originate within the KE Reactor.	Accepted	Not Documented	Per RAWP[c]								
100-K-72	Catch Tank	100-KR-2	Depth: 10.85 Diameter: 2.44	Unknown	Wastewater from the 105-KW Fuel Storage Basin sub-basin drainage header.	Accepted	Not Documented	Per RAWP[c]								
100-K-73	Diversion Box	100-KR-2	4.57 x 2.44 x 3.96 Overburden Depth: 8.84	1954-present	The collection box receives wastewater from nine underground process sewers that originate within the KW Reactor.	Accepted	Not Documented	Per RAWP[c]								
100-K-74	Storage Tank	100-KR-2	Length: 12.19 Diameter: 2.74	1974-present	This site is a steel storage tank for the 105-KW Fuel Storage Basin radioactive drains. The tank is buried under a 1.8 m (6 ft) deep earth berm.	Accepted	Not Documented	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-75	Sump	100-KR-2	2.29 x 1.37 x 3.96	1974-present	The structure is a concrete sump that receives water from the 105-KW Fuel Storage Basin floor drains in the transfer area. Two electric-powered sump pumps return the drain water to the basin and/or the underground holding tank.	Accepted	Not Documented	Per RAWP[d]								
100-K-76	Unplanned Release	100-KR-2	Not Documented	1992	This site is a duplicate of 130-KW-1. The site is the location of two removed underground diesel storage tanks. The "unplanned release" is the radiation contamination detected when the tanks were excavated.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-77	Dumping Area	100-KR-2	2.90 x 3.10 x 2.10	Unknown	This site contains railroad ties that are covered with soil.	Accepted	Not Documented	Per RAWP[c]								
100-K-78	Unplanned Release	100-KR-1	19.40 x 16.40	Unknown	In April 2000, the site was enclosed within a post-and-chain area and posted with contamination area signs.	Accepted	Not Documented	TBD (2010 confirmatory sampling)								
100-K-79	Product Piping	100-KR-2	Not Documented	Unknown	The pipes carried sodium dichromate and sulfuric acid at both 100-KE and 100-KW.	Accepted	Not Documented	Per RAWP[c]								
100-K-8	Storage Tank	100-KR-2	Length: 8.23 Overburden depth: 0.91 Diameter: 2.44	1955-1970	This site was two carbon steel underground (positioned horizontally) ethylene glycol storage tanks. One tank contained pure ethylene glycol and the other tank contained a mixture of water and ethylene glycol.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators. (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
100-K-80	Radioactive Process Sewer	100-KR-1	3,292	1955-present	This site includes two, 2.1 m (7 ft) diameter, river effluent pipelines that extend 400.2 m (1,313 ft) from the face of 116-K-3 (the 1904-K Outfall Structure) into the main channel of the Columbia River.	Accepted	Not Documented	Per RAWP[d]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-81	Unplanned Release	100-KR-1	6.10 x 6.10	Unknown	This site consists of a soil contamination area surrounded by a rope and posted as a soil contamination area. Inside the roped area is a large cylindrical piece of equipment.	Accepted	Not Documented	Per RAWP[c]								
100-K-82	Unplanned Release	100-KR-2	Not documented	1974-1978	From 1973 through 1979, leak rates ranging between 9.8 and 35.9 liters/min (2.6 and 9.5 gal/min) were documented at the 105-K East Basin. In 1978, leakage was discovered in the 105-KW Pickup Chute area. The basin leaks were repaired with epoxy fiberglass. It is possible the leakage rates were similar to those noted at the 105-KE Basin.	Accepted	Not Documented	Per RAWP[d]								
100-K-83	Outfall	100-KR-1	68.58 x 3.05	Not Documented	This site is a spillway that leads to the Columbia River. There is no corroborated physical or historical evidence that the spillway was ever used.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
100-K-84	Unplanned Release	100-KR-2	1,167 m^2	Not Documented	This site consists of red-stained soil found southeast of the 118-K-1 Burial Ground. Four small areas were identified. Some of the material appeared crushed while other pieces looked like "slag." Similar piles of material have been found south of the 200 West Area, 100-BC Area, and the Riverland (McGee Ranch) Area.	Discovery	Not Documented	N/A								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-85	Trench	100-KR-2	707.8 m^2	1952-1954	This site is a large open pit that appears in a historical photograph estimated to be 30 m (98 ft) in diameter and appears to have supported construction operations. Currently all that exists at the site location is a flat grassy area. The waste may be temporary construction debris.	Discovery	OSR-2008-0003	N/A								
100-K-86	Unplanned Release	100-KR-2	Area 1: 20 m diameter Area 2: 5 x 12 Area 3: 2 m diameter Area 4: 0.5 x 3	Not Documented	This site is four areas with stained soil, surface debris, and the underlying soil. The COPCs are unknown. There was no information describing the release of these materials.	Discovery	OSR-2008-0003	N/A								
100-K-87	Unplanned Release	100-KR-2	0.6 x 0.3	Not Documented	This site consists of a segment of suspected friable asbestos pipe lagging and any contaminated soil related to the asbestos.	Discovery	OSR-2008-0003	N/A								
100-K-88	Unplanned Release	100-KR-2	4.0 x 5.0	Not Documented	This site consists of stained soil, scattered yellow granular material, and the underlying soil. There is no vegetation within the release area. The waste is potentially contaminated soil.	Discovery	OSR-2008-0003	N/A								
100-K-89	Burn Pit	100-KR-2	20.0 x 5.0	Not Documented	This site consists of burned debris (wood, metal, and roofing material) and the underlying soil. COPCs may include asbestos and petroleum products.	Discovery	OSR-2008-0003	N/A								
100-K-9	French Drain	100-KR-2	Diameter: 0.61	Not Documented	This site is the northernmost of two French drains at the 118-KE-2.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								

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Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-90	Unplanned Release	100-KR-2	3.0 x 1.0	Not Documented	This site consists of white granular material and the underlying soil. The vegetation at the site appears to be unaffected by the presence of the substance.	Discovery	OSR-2008-0003	N/A								
100-K-91	Unplanned Release	100-KR-2	1.0 x 1.0	Not Documented	This site consists of one intact vehicle battery, partially buried, and the underlying soil. The surrounding vegetation appears to be unaffected by its presence. The COPCs may contain lead and possibly sulfuric acid in the soil.	Discovery	OSR-2008-0003	N/A								
100-K-92	Unplanned Release	100-KR-2	Area 1: 3.0 x 1.0 Area 2: 3 m diameter	Not Documented	This site is two areas of reddish-crusted soil and the underlying soil. Area 1 – The site is reddish-crusted soil indicating that a liquid may have been dumped to the ground. There is little or no vegetation growing in the stained area. Area 2 – The site is reddish-stained soil, metal debris, and the remnants of a crushed drum. There is little or no vegetation growing in the affected area. The COPCs are unknown.	Discovery	OSR-2008-0003	N/A								
100-K-93	Unplanned Release	100-KR-1	0.8 m^2	Not Documented	The waste is the abandoned drum, tar-like substance, and any contaminated soil. The site consists of a 208 L (55 gal) drum remnant with solidified gray/black tar-like substance and the underlying soil.	Discovery	OSR-2008-0003	N/A								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
100-K-94	French Drain	100-KR-2	Diameter: 0.76	Not Documented	There are two identical sites, one each for the 1702-KE and 1702-KW Guard Houses. The waste was unconsumed water coming from the drinking fountains at both guardhouses. Waste drinking water flowed from the drinking fountain in each guardhouse through underground piping to a dry well.	Discovery	OSR-2008-0003	N/A								
100-K-95	Unplanned Release	100-KR-2	Diameter: 150	Not Documented	This location is a large area with tar dumps scattered throughout and underlying soil. The waste is construction debris. The COPCs may be PAHs and PCBs.	Discovery	OSR-2008-0003	N/A								
116-K-1	Crib	100-KR-1	121.92 x 121.92 x 6.10	1955-1956	This site received reactor coolant water from the 107-KE and 107-KW Retention Basins during reactor outages due to fuel ruptures. This site received 107-E and 107-KW Basin cleanout slurry from February 1955 to May 1956. Effluent volume received was 40 million L (22 million/gal) and inventory includes 40 µg of sodium dichromate. Radiological inventory was 46 Ci.	Interim Closed	CVP-2003-00024	Sep-03	Dec-03	101,396	~2.8[d]	Cesium-137	1.24	7.33	0.51	6.65
												Cobalt-60	0.038	4.02	0.0237	1.3
												Europium-152	0.405	13.2	0.211	5.17
												Europium-154	ND	2.45	0.0574	0.83
												Strontium-90	2.74	11.6	1.63	8.37
												Hexavalent chromium	0.26	0.56	0.26	0.56
												Chromium (total)	16	18	13.1	14.2

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116-K-2	Trench	100-KR-1	121.92 x 121.92 x 6.10 Area: 21,521.0 m^2	1955-1971	This site received all contaminated effluent from floor drains in the 105-KE and 105-KW Reactors (low volume) and approximately 1,893 L (500 gal) per minute of KE and KW Reactors metal storage basin overflow. Effluent volume received was $3x10^{11}$ L. Inventory included 299,825 µg of sodium dichromate, 499 µg of copper sulfate, 9,979 µg of sulfamic acid, and 9,979 µg (22,000 lb) of sulfuric acid. Radiological inventory was 2,100 Ci.	Interim Closed	CVP-2006-00001	17-Feb-04	27-Oct-05	410,000	7.6	**Samples Collected from East Side of Trench**				
												Carbon-14	2.98	2	0.7	1.26
												Cesium-137	1.45	227	0.56	130
												Cobalt-60	ND	6.16	0.018 (ND)	2.48
												Europium-152	0.346	132	0.153	62.7
												Europium-154	ND	11.5	0.056 (ND)	5.4
												Nickel-63	7.83	2,180	3.56	880
												Plutonium-239/240	ND	13.1	0.023 (ND)	6.9
												Strontium-90	0.194	13	0.143	7.12
												Hexavalent chromium	0.85	13.3	0.39	5.3
												Samples Collected from West Side of Trench				
												Carbon-14	1.45	4.62	0.29	1.44
												Cesium-137	4.69	261	1.1	117
												Cobalt-60	6.16	9.62	0.023 (ND)	4.23
												Europium-152	2.62	194	0.626	76
												Europium-154	0.299	18	0.129	7.2
												Nickel-63	5.03	1,570	1.77	650
												Plutonium-239/240	ND	13.4	0.024 (ND)	4.7
												Strontium-90	0.374	20.1	0.201	6.3
												Hexavalent chromium	0.31	4.6	0.23	2.4
116-K-3	Outfall	100-KR-1	10.67 x 10.06 x 7.01 Area: 107.3 m^2	1955-?	The unit received reactor coolant water from the 107-K Retention Basins. The radionuclide content is unknown.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
116-KE-1	Crib	100-KR-2	Depth: 7.77 Overburden Depth: 5.33 Diameter: 12.19 Area: 27.8 m^2	1955-1971	The crib and pipeline have been removed and the site backfilled with clean soil to the average adjacent grade elevation. Effluent volume received was 800,000 L (845,598 gal) and radiological inventory was <240 Ci (H-3, C-14).	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
116-KE-2	Crib	100-KR-2	4.88 x 4.88 Area: 24.2 m^2	1955-1971	This site received wastes from cleanup columns in the 1706-KER Waste Crib. Effluent volume received was 3 million L (79 million gal) Inventory included 100,000 kg (1,100 lb) of sodium hydroxide and 100,000 kg (1,100 lb) of sulfuric acid. Radiological inventory was 38 Ci.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]									
116-KE-3	Injection/ Reverse Well	100-KR-2	Depth: 9.83 Overburden Depth: 8.84 Diameter: 6.10 Area: 32.0 m^2	1955-1971	This site is part of the sub-basin drainage disposal system for the 105-KE Fuel Storage Basin (100-K-42). The site includes the following components: a feed pipe, crib structure, dry well, and test hole.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								
116-KE-4	Retention Basin	100-KR-1	Depth: 3.93 Diameter: 76.20 Area: 27,870.9 m^2	1955-1971	This site received cooling water effluent from the KE Reactor for radioactive decay and thermal cooling before release to the Columbia River. Eighty percent of the total radionuclide inventory was contained within the soil adjacent to the basin.	Interim Closed	CVP-2005-00002	2-Oct-03	15-Mar-05	167,634	4.3	Cs-137	0.869	/	0.23	/
												Co-60	0.086	/	0.034	/
												Eu-152	2.08	/	0.67	/
												Eu-154	0.135	/	0.11	/
												Pu-239/240	ND	/	0.028	/
												Sr-90	0.549	/	0.24	/
												U-233/234	0.84	/	0.61	/
												Hexavalent chromium	1.3	/	0.7	/
116-KE-5	Process Unit/Plant	100-KR-2	12 x 6 x 4	1955-1971	The facility was constructed on a concrete pad and consisted of heat exchangers and associated piping. It was used to transfer heat from the KE Reactor cooling water effluent. The heat recovery stations used an ethylene glycol solution as the heat exchanger medium. The system is no longer intact. The heat exchangers have been removed and are being used elsewhere.	Interim Closed	CVP-2005-00006	9-Dec-02	15-Apr-05	86,551	8.8	Refer to 100-K-56:1				

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
116-KE-6A	Storage Tank	100-KR-2	Not documented	1984-1986	The unit consists of a 363 L (96 gal) condensate collection tank, which is part of a system installed in 1984 to treat radioactive mixed wastes generated in the 1706-KE Water Treatment Test Facility.	Accepted	Not Documented	Per RAWP[c]								
116-KE-6B	Storage Tank	100-KR-2	Not documented	1984-1986	The unit consists of a 10 L (30 gal) evaporation unit, which was part of a system installed to treat radioactive mixed wastes generated in the 1706-KE Water Treatment Test Facility.	Accepted	Not Documented	Per RAWP[c]								
116-KE-6C	Storage Tank	100-KR-2	Not documented	1984-1986	The unit consists of a 2,081 L (550 gal) waste accumulating tank, which was part of a system installed to treat radioactive mixed wastes generated in the 1706-KE Laboratories.	Accepted	Not Documented	Per RAWP[c]								
116-KE-6D	Process Unit/Plant	100-KR-2	Not documented	1984-1986	The unit consists of a 1.5 m^3 (5 ft^3) mixed-bed resin ion-exchange column, which was part of a system that was installed to treat radioactive mixed wastes generated in the 1706-KE Water Treatment Test Facility	Accepted	Not Documented	Per RAWP[c]								
116-KW-1	Crib	100-KR-2	Depth: 7.77 Overburden Depth: 5.33 Diameter: 12.19 Area: 27.8 m^2	1955-1971	The 115-KW Condensate Crib and pipeline received condensate and other wastewater from reactor gas purification systems. Remediation of the site could not be fully implemented because of the proximity of adjacent buildings; however, the crib and pipeline have been removed and the site backfilled with clean soil to the average adjacent grade elevation. Effluent volume received was 800,000 L (21,104 gal). Radiological inventory was 240 Ci (H-3, C-14).	Accepted	EPA/ROD/R10-95/126	Per RAWP[c]								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
116-KW-2	Injection/ Reverse Well	100-KR-2	Depth: 9.83 Overburden Depth: 8.84 Diameter: 6.10 Area: 32.0 m^2	1955-1970	This site is part of the sub-basin drainage disposal system for the 105-KW fuel storage basin (100-K-43). The site includes the following components: a feed pipe, crib structure, dry well, and test hole.	Accepted	EPA/AMD/R10-97/044	Per RAWP[c]								
116-KW-3	Retention Basin	100-KR-1	Depth: 3.93 Diameter: 76.20 Area: 13,759.3 m^2	1954-1970	This site received cooling water effluent from the KW Reactor for radioactive decay and thermal cooling before release to the Columbia River. Eighty percent of the total radionuclide inventory is contained within the soil adjacent to the basin.	Interim Closed	CVP-2004-00001	11-Dec-02	20-Sep-03	169,893	6.1	Cs-137	0.445	/	0.156	/
												Co-60	0.252	/	0.0975	/
												Eu-152	3.8	/	1.41	/
												Eu-154	0.785	/	0.258	/
												Pu-239/240	0.0419	/	0.113	/
												Sr-90	0.279	/	0.109	/
												U-233/234	1.59	/	0.644	/
												U-235	0.0938	/	0.0414	/
												Hexavalent chromium	0.85	/	0.85	/
116-KW-4	Process Unit/Plant	100-KR-2	12 x 6 x 4	1955-1970	The unit consisted of heat exchangers, pumps, and associated piping on a concrete pad. Disconnected piping remains at the site and the pipe ends are covered with plywood.	Interim Closed	CVP-2005-00006	9-Dec-02	15-Apr-05	86,551	8.8	Refer to 100-K-55:1				
118-K-1	Burial Ground	100-KR-2	365.76 x 182.88 x 6.10 Area: 66,890.2 m^2	1953-1975	This site runs northwest and southwest and contains approximately 50 trenches and pits and 11 silos. The trench and pit dimensions vary greatly.	Accepted	EPA/ROD/R10-00/121	2008								

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													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
118-KE-1	Reactor	100-KR-2	3,268 m^2	1955-1971	The unit consists of: (1) a reactor block, which includes the graphite moderator stack, biological and thermal shields, pressure tubes, and the safety and control systems; (2) the irradiated fuel storage basin; and (3) contaminated portions of the KE Reactor Building and remnant contaminated pipelines connected to the buildings and not removed through other remedial actions.	Accepted	Not Documented	Per RAWP[c]								
118-KE-2	Storage	100-KR-2	12.19 x 7.62 Area: 92.9 m^2	1955-1971	The unit was used for temporary storage of radioactive rod tips for radioactive decay pending subsequent disposal.	Accepted	Not Documented	Per RAWP[c]								
118-KW-1	Reactor	100-KR-2	3,273 m^2	1955-1970	The unit consists of: (1) a reactor block, that includes the graphite moderator stack, biological and thermal shields, pressure tubes, and the safety and control systems; (2) the irradiated fuel storage basin; and (3) contaminated portions of the KW Reactor Building and remnant contaminated pipelines connected to the buildings and not removed through other remedial actions.	Accepted	Not Documented	Per RAWP[d]								
118-KW-2	Storage	100-KR-2	12.19 x 7.62 Area: 92.9 m^3	1955-1971	The 105-KW Horizontal Control Rod Storage cave was used for temporary storage of irradiated and radioactively contaminated horizontal control rods containing unknown quantities of radionuclides.	Accepted	Not Documented	Per RAWP[c]								
120-KE-1	Sump	100-KR-2	2.54 x 1.93 x 1.45	1955-1971	This site received sulfuric acid for neutralization and acid sludge waste that was removed from the sulfuric acid storage tanks in the late 1960s and early 1970s.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
120-KE-2	French Drain	100-KR-2	Diameter: 0.91	1955-1971	This site received sulfuric acid sludge that was removed from sulfuric acid storage tanks.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
120-KE-3	Trench	100-KR-2	12.19 x 0.91	1955-1971	The unit was a trench lined with sand. The trench received a sludge-water slurry.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
120-KE-4	Storage Tank	100-KR-2	15.3 m^2	1955-1971	The unit is located above ground and has a storage capacity of 38,267 L (10,109 gal).	Accepted	Not Documented	Per RAWP[c]								
120-KE-5	Storage Tank	100-KR-2	Length: 6.10 Diameter: 2.74	1955-1971	This site is the westernmost of the two original sulfuric acid tanks at the 183-KE Head House.	Accepted	Not Documented	Per RAWP[c]								
120-KE-6	Foundation	100-KR-2	30.44 m^2	1955-1971	This site is a foundation where a sodium dichromate storage tank was placed.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
120-KE-8	Sump	100-KR-2	4.88 x 3.05 Area: 14.9 m^2	1955-1971	The unit contains salt brine and residue. Based on sampling performed at the 120-KE-9 and 120-KW-7 Brine Pits, the brine and residue may be regulated as dangerous in accordance with WAC 173-303.	Accepted	Not Documented	Per RAWP[c]								
120-KE-9	Sump	100-KR-2	7.01 x 5.28	1955-1971	The salt dissolving pits and brine pump pit are part of a single below grade concrete structure that provided brine for the 183-KE Filter Water Facility.	Accepted	Not Documented	Per RAWP[c]								
120-KW-1	Sump	100-KR-2	2.54 x 1.93 x 1.45	1955-1970	This site was an underground concrete structure used to neutralize acid waste before disposal.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
120-KW-2	French Drain	100-KR-2	Diameter: 0.91	1955-1970	This unit was an open-bottomed French drain. The site received sulfuric acid sludge that was removed from sulfuric acid storage tanks.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
120-KW-3	Storage Tank	100-KR-2	Length: 6.10 Diameter: 2.74	1955-1970	This site is the westernmost of the two original sulfuric acid tanks at the 183-KW Head House.	Accepted	Not Documented	Per RAWP[c]								
120-KW-4	Storage Tank	100-KR-2	17.24 m^2	1955-1970	The unit is an above ground sulfuric acid storage tank. The unit was used for storage of sulfuric acid product.	Accepted	Not Documented	Per RAWP[c]								
120-KW-5	Foundation	100-KR-2	28.6 m^2	1955-1971	This site is a foundation where a sodium dichromate storage tank was placed.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
120-KW-6	Sump	100-KR-2	4.88 x 3.05 Area: 14.9 m^2	1955-1970	The unit is a below grade concrete structure that provided brine for the 165-KW Powerhouse. The unit contains salt brine and residue.	Accepted	Not Documented	Per RAWP[c]								
120-KW-7	Sump	100-KR-2	7.01 x 5.28	1955-1970	The salt dissolving pits and brine pump pit were part of a single below grade concrete structure that provided brine for the 183-KW Filter Water Facility.	Accepted	Not Documented	Per RAWP[c]								
126-K-1	Inert/ Demolition Landfill	100-KR-2	11,743 m^2	1975-present	This unit is a gravel borrow pit that resulted from 100-K Area construction.	Interim Closed	Not Documented	N/A								
126-KE-2	Storage Tank	100-KR-2	Depth: 6.10 Diameter: 12.19 Capacity: 711,657 L	1955-1970	This site is an above ground vertical stainless steel storage tank mounted on a concrete base. The tank was part of a system called the liquid alum system, which supplied liquid alum for water treatment.	Accepted	Not Documented	Per RAWP[c]								
126-KE-3	Storage Tank	100-KR-2	Depth: 6.10 Diameter: 12.19 Capacity: 711,657 L	1955-1997	This site is an above ground vertical stainless steel storage tank mounted on a concrete base. The tank was part of a system called the liquid alum system, which supplied liquid alum for water treatment.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
128-K-1	Burn Pit	100-KR-2	30.48 x 30.48 x 0.91	1955-1971	This site was used for the disposal of nonradioactive combustible materials such	Interim Closed	WSRF-2004-042	Dec-03	Dec-03	161	0.5	Arsenic	3.7	/	/	/
												Barium	71.5	/	/	/

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
					as paint waste, office waste, and chemical solvents.							Cadmium	0.35	/	/	/
												Chromium (total)	13.5	/	/	/
												Lead	10.8	/	/	/
												Mercury	0.03	/	/	/
												Selenium	0.8	/	/	/
												TPH	14.4	/	/	/
												Hexavalent chromium	0.48	/	/	/
												Phenathrene	0.046	/	/	/
												Benzo(a) anthracene	0.1	/	/	/
												Benzo(a) pyrene	0.051	/	/	/
												Chrysene	0.15	/	/	/
												Benzo(k) fluoranthene	0.078	/	/	/
												Benzo(b) fluoranthene	0.075	/	/	/
												Indeno (1,2,3-cd) pyrene	0.029	/	/	/
												Bis (2-ethylhexyl) phthalate	0.069	/	/	/
												Fluoranthene	0.22	/	/	/
												Benzo(ghi) perylene	0.033	/	/	/
												Pyrene	0.153	/	/	/
128-K-2	Burn Pit	100-KR-2	243.84 x 85.34 Area: 6,967.7 m^2	Unknown	A broad range of trash is exposed on the ground surface. There is evidence of burning in many locations. Most of the material on the surface is scrap metal and glass. Office waste, paint, solvents, and laboratory waste also have been found. The area is covered with non-friable and friable asbestos.	Accepted	EPA/ROD/R10-99/039	Per RAWP[d]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
130-K-1	Storage Tank	100-KR-2	Capacity: 7,571 L	1955-1972	This site was an underground gasoline storage tank oriented with the long axis of the tank in an east-west direction.	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
130-K-2	Storage Tank	100-KR-2	Capacity: 2,082 L	1955-1972	This site was an underground waste oil storage tank oriented with the long axis of the tank in a north-south direction. The tank was used for storing used motor oil.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
130-K-3	Storage Tank	100-KR-2	Length: 10.06 Diameter: 2.90 Capacity: 66,230 L	1961-1970	The unit consisted of two steel underground diesel oil storage tanks. The tanks were used to supply diesel fuel to three engines located within the 182-K (Emergency Water Pump House).	Not Accepted	"Discovery Site Evaluation Checklist" approved by the regulators (RL-TPA-90-0001, TPA-MP-14, Figure 3)	N/A								
130-KE-1	Storage Tank	100-KR-2	Diameter: 1.83 Est. Volume: 9 m^3 Capacity: 7,571 L	1955-1971	This site was two underground storage tanks, a valve pit, and associated piping.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
130-KE-2	Storage Tank	100-KR-2	1,140 m^2	1955-1971	The unit was used for storage of oil (product) for the 165-KE Power Control Building boilers.	Accepted	Not Documented	Per RAWP[c]								
130-KW-1	Storage Tank	100-KR-2	Length: 3.35 Diameter: 1.83 Capacity: 7,571 L	1960-1971	This site is the location of two underground diesel storage tanks that were removed in 1992.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								
130-KW-2	Storage Tank	100-KR-2	1,140 m^2	1955-1970	The tank was used for storage of oil (product) for the 165-KW Power Control Building boilers.	Accepted	Not Documented	Per RAWP[c]								
132-KE-1	Stack	100-KR-2	Diameter: 6.71 Area: 35.3 m^2	1955-1971	Discharged ventilated air from the KE Reactor Building flowed through concrete ducts directly out of the stack.	Accepted	Not Documented	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
132-KW-1	Stack	100-KR-2	Diameter: 6.71 Area: 35.3 m^2	1955-1970	Discharged ventilation air from the KW Reactor Building flowed through concrete ducts directly out the exhaust stack.	Accepted	Not Documented	Per RAWP[c]								
1607-K1	Septic Tank	100-KR-2	Capacity: 3,785 L	1955-present	The sanitary sewer system received sewage from the 1701-K Badge House, 1720-K Patrol office and change room, and 1721-K Trailer. The flow rate to this unit is estimated to have been 1,982 L (525 gal) per day.	Accepted	Not Documented	Per RAWP[c]								
1607-K2	Septic Tank	100-KR-2	Capacity: 1,893 L	1955-present	The sanitary sewer system receives sewage from the 183-KE Filter Water Facility. The flow rate to this unit is estimated to have been up to 1,230 L (325 gal) per day.	Accepted	Not Documented	Per RAWP[c]								
1607-K3	Septic Tank	100-KR-2	Capacity: 1,893 L	1955-1970	The sanitary sewer system received sewage from 183-KW Water Treatment Plant. The flow rate to this unit is estimated to have been up to 1,230 L (325 gal) per day.	Accepted	Not Documented	Per RAWP[c]								
1607-K4	Septic Tank	100-KR-2	Capacity: 2,8391 L	1955-1999	The sanitary sewer system received sewage from 1704-K Office Building and the 1717-K Maintenance Shop. The flow rate to this unit is estimated to have been 1,982 L (525 gal) per day.	Closed Out (Left in Place)	99-EAP-392	N/A								
1607-K5	Septic Tank	100-KR-2	146.35	1955-present	This unit receives sanitary sewage from 1706-KER Flow Laboratory, 1706-K Water Treatment Laboratory, 165-KE Powerhouse, K Reactor Building, and 115-KE Gas Recirculation System.	Accepted	Not Documented	Per RAWP[c]								
1607-K6	Septic Tank	100-KR-2	723.37	1955-present	This unit receives sanitary sewage from the KW Reactor Building, 115-KW Gas Recirculation Building, and 165-KW Powerhouse	Accepted	Not Documented	Per RAWP[c]								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
600-29	Dumping Area	100-KR-2	609.60 x 304.80	1952-1954	The unit is an abandoned dumping area containing several rectangular depressions and waste burning sites. There are many areas of discolored soil that include coal, rust-colored soil, and white residue patches. Unit wastes consist of miscellaneous metals, wood, cans, bottles, construction hardware and materials; what appears to be tar dumped on the ground; buckets and mops covered with what appears to be tar; a 18.7 L (5 gal) bucket of oily rags; broken pieces of a toilet bowl; what appears to be asbestos and transite; and wire rope.	Accepted	EPA/ROD/R10-99/039	TBD (2010 confirmatory sampling)								
600-4	Dumping Area	100-KR-2	80,825.6 m^2	1950s	This site is a dumping area left from its use as a military encampment. It includes a garbage dump, the remains of an old military tent city, gun emplacements, two small water towers, and scattered debris. Available historical records for military encampments on the Hanford Site do not identify this area as a former military site. Based on historical documents and field walk downs, there is no evidence of hazardous constituents at this site.	Not Accepted	Not Documented	N/A								
600-55	Dumping Area	100-KR-2	45.70 x 21.60 (paved area) 7.0 x 7.0 (wooden structure) 4.3 x 2.3 (cellar) 15.0 x 15.0 (debris pile)	Not Documented	This site is a dumping area that consists of an asphalt-paved area that may have been a parking lot, miscellaneous farm debris, and a collapsed wooden building. The pre-Hanford Site farm debris is scattered approximately 135 m (443 ft) to the east of the paved area. There also is a cellar and an old stove near the collapsed wooden structure.	Not Accepted	Not Documented	N/A								

Table C-1. Summary of Waste Site Information at 100-K

Site Code	Site Type	Operable Unit	Site Dimensions (m)	Dates of Operation	Site History	Class Status (defined at end of table)	Decision Document	Remedial Action Start Date	Remedial Action End Date	Contaminated Waste Volume to ERDF (metric tons)	Maximum Depth of Remedial Action (m)	COC	Max Concentration (pCi/g, mg/kg)		95% UCL (pCi/g, mg/kg)	
													Shallow[a]	Deep[b]	Shallow[a]	Deep[b]
UPR-100-K-1	Unplanned Release	100-KR-2	Not documented	1974-1979	This site is a large, unplanned release to the ground. The site is not marked or posted on the surface. The release was completely contained below ground and caused no surface contamination.	Accepted	EPA/ROD/R10-99/039	Per RAWP[c]								

a. Shallow zone = soil above 4.6 m above ground surface.

b. Deep zone = soil below 4.6 m above ground surface.

c. Schedule for waste site remediation to be established according to the August 4, 2009 Federal Facility Agreement and Consent Order Change Control Form (Change Number M-16-08-09) and Milestones/Targets M-016-53 (Phase 1 actions), M-016-143 (Phase 2 actions), M-016-140 (Phase 3 actions) and M-016-145 (facilities and waste sites not included in Phases 1, 2, or 3).

d. The schedule for waste site remediation is documented in DOE/RL-96-17.

e. The cleanup verification package states that the excavation had a depth of approximately 11 m (36 ft) as measured from the uphill or southern surface grade.

Class Status Definitions:

Closed Out: A reclassification status indicating, due to actions taken, a waste management unit meets applicable cleanup standards or closure requirements.

Interim Closed Out: A reclassification status indicating, due to actions taken, a waste management unit meets cleanup standards specified in an Interim Action ROD or Action Memorandum, but for which a Final ROD has not been issued.

No Action: A reclassification status indicating a waste site does not require any further remedial action under RCRA Corrective Action, CERCLA, or other cleanup standards based on an assessment of quantitative data collected for the waste site.

Not Accepted: A classification status indicating an assessment has been made that a WIDS site is not a waste management unit and is not within the scope of Tri-Party Agreement Action Plan. This classification requires lead regulatory agency approval.

Accepted: A classification status indicating an assessment has been made that a WIDS site is a waste management unit as defined in the Tri-Party Agreement Action Plan.

Discovery: An initial classification status indicating evidence of a potential waste site; assessment not yet complete. This is the classification of a newly discovered WIDS site.

Sources are in the References section at the beginning of this appendix.

/ = no data collected
COC = contaminant of concern
COPC = contaminant of potential concern
EP = extraction procedure
ERDF = Environmental Restoration Disposal Facility
N/A = not applicable
ND = not detected
PAH = polyaromatic hydrocarbon
PCB = polychlorinated biphenyl
PVC = polyvinyl chloride
RAWP = Remedial Action Work Plan
RSVP = remaining site verification package
SCA = soil contamination area
SNF = spent nuclear fuel
TBD = to be determined
UCL = upper confidence limit
VCP = vitrified clay pipe
WIDS = Waste Information Data System

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Table C-2. Crosswalk of Facilities and Related Waste Sites within the Facility Footprint

100-K Facilities	100-K Waste Sites
105-KE Fuel Storage Basin	100-K-42 Storage
105-KE Reactor Building	118-KE-1 Reactor
105-KW Fuel Storage Basin	100-K-43 Storage
105-KW Reactor Building	118-KW-1 Reactor
107-KE Retention Basin	116-KE-4 Retention Basin
107-KW Retention Basin	116-KW-3 Retention Basin
115-KE Condensate Crib	116-KE-1 Crib
115-KW Condensate Crib	116-KW-1 Crib
116-KE Reactor Exhaust Stack	132-KE-1 Stack
116-KW Reactor Exhaust Stack	132-KW-1 Stack
117-KE Filter Building	100-K-62 Process Unit/Plant
117-KW Filter Building	100-K-61 Process Unit/Plant
150-KE Heat Recovery Station	116-KE-5 Process Unit/Plant
150-KW Heat Recovery Station	116-KW-4 Process Unit/Plant
165-KE Power Control Building	100-K-67 Control Structure
165-KW Power Control Building	100-K-66 Control Structure
1706-KE Waste Treatment System	116-KE-6D Process Unit/Plant
1706-KER Waste Crib	116-KE-2 Crib
1904-K Outfall Structure	100-K-83 Outfall
1908-K Outfall Structure	116-K-3 Outfall

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Appendix D

Summary of 100-K Facilities

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D1 Introduction

Table D-1 provides a summary of the buildings and facilities that have existed in 100-K of the Hanford Site. Many of these buildings and facilities have been demolished or are no longer used. Table D-1 also provides physical dimensions and a brief history for each building and facility.

D2 References

HW-24800-103, 1957, *Completion Report, Project CA-512, Volume 1, 100-K Reactor Plants*, Hanford Atomic Productions Operation, General Electric, Richland, Washington. Available at: http://apdrmweb.rl.gov/rimvu/default.aspx?id=D198187916.

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Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
104-KE	Storage	100-KR-2	18.3 x 2.4	Inactive	1955	N/A	This Horizontal Control Rod Storage Cave (118-KE-2, Thimble Cave) was used for the storage of horizontal control rods and their associated thimbles, which became radioactive during use. The cave was constructed by pouring a concrete slab, laying, anchoring, and grouting two half sections of 0.61 m (24 inch) pipe open side down on the slab, installing concrete wing-type vertical walls and steel doors at each end, and covering the pipe with 1.8 m (6 ft) of dirt. Each side of the cave floor was sloped toward a drain. Each drain was designed to receive rainwater that percolated through the earth covering the pipe, and route it to a French drain.
104-KW	Storage	100-KR-2	18.3 x 2.4	Inactive	1955	N/A	This Horizontal Control Rod Storage Cave (118-KW-2, Thimble Cave) was used for the storage of horizontal control rods and their associated thimbles, which became radioactive during use. The cave was constructed by pouring a concrete slab, laying, anchoring, and grouting two half sections of 0.61 m (24 in.) pipe open side down on the slab, installing concrete wing-type vertical walls and steel doors at each end, and covering the pipe with 1.8 m (6 ft) of dirt. Each side of the cave floor was sloped toward a drain. Each drain was designed to receive rainwater that percolated through the earth covering the pipe, and route it to a French drain. In 2005, the facility contained four rod tips and other rod removal components. Radiation readings inside the door were 50 mR/hr.
105-KE	Reactor	100-KR-2	149 x 66 x 32.6	Inactive	1955	N/A	The Reactor Building contains a reactor block, reactor control room, spent fuel discharge area, fuel storage basin and associated fuel handling equipment, fans and ducts for the ventilation and recirculating gas systems, water cooling systems, and supporting offices, shops, and laboratories. In addition to irradiated fuel, the basin contained more than 150 tons of irradiated and nonirradiated lead and cadmium. The reactor itself is located in the center of the building with the charging or front face of the reactor facing the 190 Building. The reactor was shut down at 4:00 p.m. on January 28, 1971, the last of the eight single-pass reactors to shut down. The basin originally was cleaned of debris and deactivated as part of the initial reactor shutdown conditions. As part of the operation of the N Reactor, the 105-KE Basin was reactivated to provide additional storage space for irradiated fuel removed from the N Reactor core. Under Project H-501, the original feed and bleed basin cooling system was replaced with a closed-loop recirculation system. N Reactor fuel began arriving at the KE Basin in mid-1975. During 1977 through 1978, the fuel storage basin was reported to be leaking up to 37 L (10 gal) per minute. The irradiated N Reactor fuel remained in storage at the KE Basin until 2004. Residual sludge was removed from the basin by May 2007. Demolition of the KE Basin began in July 2008.
105-KW	Reactor	100-KR-2	149 x 66 x 32.6	Inactive	1955	N/A	The primary nuclear process of the 105 Reactor was the transmutation of U-238 to Pu-239 and the fissioning of U-235. Reactor operations included fuel and target loading and removal, control and cooling of its operations, and maintenance and modification. The reactor received canned uranium slugs (fuel elements) by truck from the 300 Area. The slugs were made of metallic natural uranium and were charged into the reactor process tubes at the front face of the reactor. The reactor was shut down at 11:58 p.m. on January 30, 1970. During 1977 through 1978, the fuel storage basin was reported to be leaking up to 37 L (10 gal) per minute. The 100-K-82 summary report states that from 1973 through 1979, leak rates ranged between 9.8 to 36 L (2.6 and 9.5 gal) per minute. The KW Fuel Storage Basin was reactivated and modified in 1978 to provide additional storage of N Reactor fuel. The N Reactor fuel began arriving at the KW Basin in early 1981. The N Reactor operated until 1987, and its spent fuel was processed through the PUREx Plant until this plant was also shut down in 1989. The unprocessed N Reactor fuel remained in storage at the K Basins until 2004. As of 2008, residual sludge from both the KE and KW Basins remain in the KW Basin awaiting treatment for disposal. In addition to irradiated fuel, the basin contained more than 150 tons of irradiated and nonirradiated lead and cadmium.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
107-KE	Retention Basin	100-KR-1	7.6 (depth) 76 (diameter)	Demolished	1955	1993	Process water effluent from the reactor was routed through an underground pipeline to a diversion box, and motor-driven valves, controlled from the reactor building, diverted effluent to one of the three tanks. If the effluent was not contaminated, it would empty through a pipeline to the river through the outfall structure. If the effluent were contaminated, it would be discharged through a line to the crib. In 1993, the tanks were dismantled. Decontamination of the tanks was accomplished by wet sandblasting the interior and portions of the exterior. After cleaning, sections were removed, surveyed, and the steel was either buried in the 200 Area, or recycled. The bottoms of the tanks were left in place and 46 to 61 cm (18 to 24 in.) of uncontaminated backfill was placed over them. In 1999, large pieces of contaminated effluent piping and scrap metal were removed and taken to ERDF for disposal. Site excavation and waste disposal were completed, and exposed surfaces were sampled and analyzed to verify attainment of remedial action goals. The site has been interim closed out.
107-KW	Retention Basin	100-KR-1	7.6 (depth) 76 (diameter)	Demolished	1955	1993	Process water effluent from the reactor was routed to the retention basins through an underground pipeline to a diversion box, and motor-driven valves, controlled from the reactor building, diverted effluent to one of the three tanks. If the effluent was not contaminated, it would empty through a pipeline to the river through the outfall structure. If the effluent were contaminated, it would be discharged through a line to the crib. In 1993, the tanks were dismantled. Decontamination of the tanks was accomplished by wet sandblasting the interior and portions of the exterior. After cleaning, sections were removed, surveyed, and the steel was either buried in the 200 Area, or recycled. The bottoms of the tanks were left in place and 46 to 61 cm (18 to 24 in.) of uncontaminated backfill was placed over them. In 1999, large pieces of contaminated effluent piping and scrap metal were removed and taken to ERDF for disposal. Site excavation and waste disposal were completed, and exposed surfaces were sampled and analyzed to verify attainment of remedial action goals. The site has been interim closed out.
110-KE	Storage Tank	100-KR-2	2.1 x 9.1	Inactive	1955	N/A	This facility was an outdoor unloading gas storage area that supported the 115 Building. The facility contained high-pressure helium tanks and four large-diameter carbon-dioxide tanks located outside the facility.
110-KW	Storage Tank	100-KR-2	2.1 x 9.1	Inactive	1955	N/A	This facility was an outdoor unloading gas storage area that supported the 115 Building. The facility contained high-pressure helium tanks and four large-diameter carbon-dioxide tanks located outside the facility.
115-KE	Process Unit/Plant	100-KR-2	34.4 x 10.4 x 12.2	Inactive	1955	N/A	This facility was a one-story building designed to house gas recirculation pumps, gas dryers, filters, heat exchangers, and related instruments and piping for the reactor core gas cover system. The facility also contained heaters/coolers, gas dryer towers, condensers, filters, pumps, silica-gel drying beds, piping and ductwork, heating and ventilation systems, spindle-type helium storage tanks, and a gas unloading room. Gas was supplied to and returned from the 105 Building through two 46 cm (18 in.) steel gas mains, known as the "G" ducts. In 1976, radiological readings on piping, condensate drains, valves, and turbine blowers were about 10,000 cpm. The highest radiation readings were on the condensers in the dryer room at about 50,000 cpm. Direct dose rate readings on the condensers were about 30 mR/hr. Dose rates in the filter room, gas piping tunnels, and the piping itself were less than 20 mR/hr. Standard smears collected throughout the facility tested positive for various fission products. In 1994, the equipment was still in place due to its contaminated condition.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
115-KW	Process Unit/Plant	100-KR-2	34.4 x 10.4 x 12.2	Inactive	1955	N/A	This facility was a one-story building designed to house gas recirculation pumps, gas dryers, filters, heat exchangers, and related instruments and piping for the reactor core gas cover system. The facility also contained heaters/coolers, gas dryer towers, condensers, filters, pumps, silica-gel drying beds, piping and ductwork, heating and ventilation systems, spindle-type helium storage tanks, and a gas unloading room. Gas was supplied to and returned from the 105 Building through two 46 cm (18 in.) steel gas mains, known as the "G" ducts. In 1976, radiological readings on piping, condensate drains, valves, and turbine blowers were about 10,000 cpm. The highest radiation readings were on the condensers in the drier room at about 50,000 cpm. Direct dose rate readings on the condensers were about 30 mR/hr. Dose rates in the filter room, gas piping tunnels, and the piping itself were less than 20 mR/hr. Standard smears collected throughout the facility tested positive for various fission products. In 1994, the equipment was still in place due to its contaminated condition.
116-KE	Stack	100-KR-2	91.4 (depth) 6.3 (diameter)	Inactive	1955	N/A	The stack was designed to discharge KW Reactor Building ventilation gases to the atmosphere. After the reactor confinement upgrade in about 1960, the reactor effluents were routed through a massive filtration system in the newly constructed 117 Building, prior to discharge through the stack. In 1976, dose rates at the base of the stack were less than 1 mR/hr. Inside the base of the stack, smearable alpha was present at about 130 dpm/100 cm^2, and smearable beta was present up to 5,000 dpm/cm^2. In 1980 and 1981, the stack was shortened to 53 m (173 ft), and the rubble was placed in the remaining portion of the stack.
116-KW	Stack	100-KR-2	91.4 (depth) 6.3 (diameter)	Inactive	1955	N/A	The stack was originally 91 m (298 ft) high and designed to discharge KW Reactor Building ventilation gases to the atmosphere. After the reactor confinement upgrade in about 1960, the reactor effluents were routed through a massive filtration system in the newly constructed 117 Building, prior to discharge through the stack. In 1976, dose rates at the base of the stack were less than 1 mR/hr. Inside the base of the stack, smearable alpha was present at about 130 dpm/100 cm^2, and smearable beta was present up to 5,000 dpm/sq cm. In 1980 and 1981, the stack was shortened to 53 m (173 ft), and the rubble was placed in the remaining portion of the stack.
117-KE	Process Unit/Plant	100-KR-2	18.0 x 11.9 x 10.7	Inactive	1955	N/A	This facility was designed to filter ventilation air from the confinement zone of the reactor building before discharging to the 116 Stack. In 1976, radiological readings on the inlet surfaces of the facility were about 20,000 cpm. Fission products were detected on standard smears taken throughout the facility, and the ventilation and gas tunnels are considered contaminated.
117-KW	Process Unit/Plant	100-KR-2	18.0 x 11.9 x 10.7	Inactive	1955	N/A	This facility was designed to filter ventilation air from the confinement zone of the reactor building before discharging to the 116 Stack. In 1976, radiological readings on the inlet surfaces of the 117-KW Exhaust Air Filter Building were about 20,000 cpm. Fission products were detected on standard smears taken throughout the facility, and the ventilation and gas tunnels are considered contaminated.
119-KE	Process Unit/Plant	100-KR-2	4.3 x 6.1	Inactive	1960	N/A	This building housed the majority of the instrumentation associated with the Reactor Confinement Project and was located over the ventilation ducts to the filter building. Instrumentation was included to measure the buildup of radioactive material on the filters, differential pressure across the filters and across the entire system, exhaust flow, filter seals pressure, and iodine 131 in the exhaust air stream. It also contained monitoring equipment for the automatic filter samplers, and the halogen charcoal sampler system. Exhaust air samples were taken of the reactor facility discharges downstream of the 117 Filters. The 119-KE Exhaust Air Sample Building was deactivated in 1971.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
119-KW	Process Unit/Plant	100-KR-2	4.3 x 6.1	Inactive	1961	N/A	This building housed most of the instrumentation for the exhaust air systems. Instrumentation was included to measure the buildup of radioactive material on the filters, differential pressure across the filters and across the entire system, exhaust flow, filter seals pressure, and iodine 131 in the exhaust air stream. It also contained monitoring equipment for the automatic filter samplers, and the halogen charcoal sampler system.
142-K	Process Unit/Plant	100-KR-2	24.4 x 70.6 x 10.7	Active	2001	N/A	The CVDF removes free water from metallic uranium and prepares nuclear fuel for storage in a helium atmosphere. The SNF was packaged into multi-canister overpacks and removed from the KE and KW Basins. Removal of free water was necessary to halt water-induced corrosion of exposed uranium surfaces and to allow the overpacks to be transported safely to the Hanford Site 200-East Area and stored within the Canister Storage Building. The 142-K Building is listed as radiologically contaminated.
142-KA	Electrical Substation	100-KR-2	4.9 x 11.0	Active	2001	N/A	The purpose of the 142-KA, CVDF Generator Building, was to provide emergency power to the 142-K Building in the event of a power outage.
1506-K1	Process Unit/Plant	100-KR-2	41.39 m^2	Active	1995	N/A	The 1506-K1 Facility, the Fiber Optics Computer Hut, contained the Lockheed Martin Services, Inc., Hanford Local Area Network terminal to support the 100-K Area computing needs.
150-KE	Process Unit/Plant	100-KR-2	12.2 x 6.1 x 3.7	Demolished	1955	2005	The Heat Recovery Facility was an outdoor concrete slab with equipment mounted on reinforced-concrete pads. This space heating system serviced all occupied buildings in the area, as well as heated certain tanks. The primary source of heat for the space heating system was the process effluent system from the Reactor Building. The supplemental source of heat for this system was steam from the boilers in the 165 Building. The heat exchangers heated up the 34% ethylene glycol solution, which was then pumped to space heaters located throughout the area. The heat exchangers were removed and used in the 105-KE Fuel Storage Basin. The site has been remediated was reclassified as interim closed out in 2005.
150-KW	Process Unit/Plant	100-KR-2	12.2 x 6.1 x 3.7	Demolished	1955	2005	The Heat Recovery Facility was an outdoor concrete slab with equipment mounted on reinforced-concrete pads. This space heating system serviced all occupied buildings in the area, as well as heated certain tanks. The primary source of heat for the space heating system was the process effluent system from the Reactor Building. The supplemental source of heat for this system was steam from the boilers in the 165 Building. The heat exchangers heated up the 34% ethylene glycol solution, which was then pumped to space heaters located throughout the area. The heat exchangers were removed and used in the 105-KW Fuel Storage Basin. The site has been remediated and was reclassified as interim closed out in 2005.
151-K	Electrical Substation	100-KR-2	15.1 x 11.4	Active	1955	N/A	The 151-K Switching Station brings alternative power from the southern Midway loop into the 100-K Area. Primary power from Midway station is provided to the 151 substations through 230-KV lines tapped off the northern loop.
151-KE	Electrical Substation	100-KR-2	23.5 x 52.7	Active	1955	N/A	This substation was connected into the 230-KV loop that furnishes electrical power to the 100 and 200 Area. One line connected this substation with the 100-D Substation, and one line connects with 151-KW. Equipment is set on concrete pads. Steel units include towers, switching structures, and posts. Other substation features include three primary oil circuit breakers, 10 air disconnect switches, steel structures, overhead static wires, large ground mat, six lightning arrestors, and underground feeders to the switchgear in the 165 Building. Historical evaluations of past operations of similar substations at other reactor areas suggests there is a significant potential for unrecorded transformer and circuit breaker oil leaks and spills.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
151-KW	Electrical Substation	100-KR-2	23.5 x 52.7	Active	1955	N/A	This substation was connected into the 230-KV loop that furnishes electrical power to the 100 Area and 200 Area. One line connected this substation with the 100-D Substation and one line connects with 151-KW. Equipment is set on concrete pads. Steel units include towers, switching structures, and posts. Other substation features include three primary oil circuit breakers, 10 air disconnect switches, steel structures, overhead static wires, large ground mat, six lightning arrestors, and underground feeders to the switchgear in the 165 Building. Historical evaluations of past operations of similar substations at other reactor areas suggests there is a significant potential for unrecorded transformer and circuit breaker oil leaks and spills.
1604-K	Process Unit/Plant	100-KR-2	30.48 x 9.14	Active	1996	N/A	The 1604-K Facility was a pre-engineered, insulated sheet metal structure with a concrete footer and floor slab. The treatment center was used to remove CrVI from groundwater in the 100-KR-4 OU. Water was received from the 1606-K and 1607-K Facilities, and also directly from two additional extraction wells (199-K-116A and 199-K-125A) and stored in the influent storage tank. The water was then treated in three Ix skid, each of which contained four columns. The treated water was stored in the effluent tank before being pumped to one of several injection wells (199-K-124A, 199-K-123A, 199-K-122A, 199-K-121A, and 199-K-128).
1605-KE	Control Structure	100-KR-1	2.0 x 2.0 x 2.4	Active	1955	N/A	This facility was a guard tower set on a high steel platform at the 181-KE River Pump Station. As part of the security system, guards would occupy the facility, prevent any unauthorized entry and watch for fires. It was equipped with a sound-powered telephone, internal light, external 2 million candlepower searchlight, and floodlight for the stairway.
1605-KW	Control Structure	100-KR-2	2.0 x 2.0 x 2.4	Active	1955	N/A	This facility was a guard tower set on a high steel platform at the 181-KW River Pump Station. As part of the security system, guards would occupy the 1605-KW Guard Tower, prevent any unauthorized entry, and watch for fires. It was equipped with a sound-powered telephone, internal light, external 2 million candlepower searchlight, and floodlight for the stairway.
1606-K	Pump Station	100-KR-2	26.6 m^2	Active	1996	N/A	The 1606-K Facility was a pre-engineered metal building erected on a concrete floor slab. The facility housed pumping equipment, with a large water storage tank located just northwest of the building. The building was used to transfer well water extracted from wells 199-K-112A, 199-K-113A, and 199-K-115A to the 1604-K Building for dichromate removal. Water was stored in the tank before being pumped in an above ground pipe to 1604-K.
1607-K	Pump Station	100-KR-2	26.6 m^2	Active	1996	N/A	The 1607-K Facility was a pre-engineered metal building erected on a concrete floor slab. The facility housed pumping equipment, with a large water storage tank located just northwest of the building. The building was used to transfer well water extracted from wells 199-K-119A, 199-K-120A, and 199-K-127 to the 1604-K Building for dichromate removal. Water was stored in the tank before being pumped in an above ground pipe to 1604-K.
1614-K	Monitoring Stations	100-KR-2	2.4 x 2.4	Inactive	1955	N/A	One of these Environmental Monitoring Stations was centrally located between the KW and KE Reactor Buildings. The other two were just inside the fence line, in the southeast and southwest corners of the 100-K Area. They were constructed of concrete block on a concrete slab.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
165-KE	Process Unit/Plant	100-KR-2	73.2 x 33.5 x 4.6	Active	1955	N/A	This facility is the Power Control Building, part of a common structure that includes the 190-KE Building. It was the nerve center of the entire water and power plant, more so than the comparable 190 Control Rooms in any of the older reactor areas. The facility includes the powerhouse, control room, valve pit, electrical switchgear room, and glycol pump room. The central control room contained the I&C for the electrical distribution system, emergency power generating equipment, process pumping system, river pumping system, service pumping system, and the central valve system. The electrical room contained the I&C for the substation. The facility was partially deactivated in 1971. Two boilers and one fuel oil system were left in service to supply steam for area heating. The compressed air system, service water loop, water softeners, and chemical mix and injection equipment for boiler operation also remained in service. Some of this equipment remained in service to support the spent fuel removal activities.
165-KW	Process Unit/Plant	100-KR-2	73.2 x 33.5 x 4.6	Inactive	1955	N/A	This facility is the Power Control Building, part of a common structure that includes the 190-KW Building. It was the nerve center of the entire water and power plant, more so than the comparable 190 Control Rooms in any of the older reactor areas. The facility includes the powerhouse, control room, valve pit, electrical switchgear room, and glycol pump room. The central control room contained the I&C for the electrical distribution system, emergency power generating equipment, process pumping system, river pumping system, service pumping system, and the central valve system. The electrical room contained the I&C for the substation.
166-AKE	Storage	100-KR-2	4.0 x 7.0	Inactive	1955	N/A	The 166-AKE Oil Storage Facility Valvehouse served as the instrument shed for the 166-KE Oil Bunker and equipment. The valvehouse controlled steam heating, pumping, and monitored levels. It was a 27 m^2 (288 ft^2) butler building.
166-AKW	Storage	100-KR-2	4.0 x 7.0	Inactive	1955	N/A	166-AKW Oil Storage Facility Valvehouse served as the instrument shed for the 166-KE Oil Bunker and equipment. The valvehouse controlled steam heating, pumping, and monitored levels. It was a 27 m^2 (288 ft^2) butler building.
166-KE	Storage Tank	100-KR-2	42.5 x 28.5 x 7.2	Inactive	1955	N/A	The 166-KE Oil Storage and Oil Pump Equipment facility was designed to provide storage for the fuel oil used in KE. A concrete penthouse is located at ground level. One underground oil storage tank is located west of the control building. Bunker No. 6 fuel oil was stored in the tanks. The tanks contain two compartments, with a combined capacity of 24.2 million L (6.4 million gal), two 170,000 L (45,000 gal) day tanks, and a pump room. As required, it was pumped into the day tank where it was maintained at a higher temperature by the day tank oil heater. In 1976, the oil was removed from the storage bunkers. From 1981 to 1985, the facility was used for the storage of Bunker C oil for the 100-N Area. An estimated 7,571 L (2,000 gal) of oil remain in the storage tank, and the site was listed as hazardous/dangerous in 2005.
166-KW	Storage Tank	100-KR-2	42.5 x 28.5 x 7.2	Inactive	1955	N/A	The 166-KW Oil Storage and Oil Pump Equipment facility was designed to provide storage for the fuel oil used in KW. Bunker "C" (No. 6) fuel oil was received by tank car or truck. A concrete penthouse is located at ground level. As required, it was pumped into the day tank where it was maintained at a higher temperature by the day tank oil heater. The tank contain two compartments with a combined capacity of 22.4 million L (1.7 million gal), two 170,000 L (45,000 gal) day tanks, and a pump room. This would provide a 90-day supply of oil to the 165 Building at a load of 4,200 KW on the turbo-generator. In 1976, oil was removed from the storage bunkers. An estimated 7,571 L (2,000 gal) of oil remain in the storage tank, and the site was listed as hazardous/dangerous in 2005.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
167-K	Process Unit/Plant	100-KR-2	3.1 x 4.6 x 3.1	Inactive	1955	N/A	The 167-K Crosstie Tunnel Building is a concrete and steel structure used as the midway entry and ventilation shaft for the crosstie tunnel that connected the 190/165 Buildings in the KE and KW Areas. The tunnel was used as a conduit for the various backup utility services in the 100-K Area. The crosstie tunnel itself was 535.5 m (1,757 ft) long by 2.4 m (8 ft) square underground concrete structure open to the 165 Buildings at each end (HW-24800-103). It contained electrical lines, a 61 cm (24 in.) service water emergency crosstie and fire water line, 25 cm (10 in.) heating supply and return lines, and a 10 cm (4 in.) sanitary water line.
1701-K	Office	100-KR-2	14.9 x 9.5 x 4.1	Inactive	1955	N/A	This was a one-story facility attached to the 1720-K Building, and located at the main entrance to the 100-K Area.
1701-KA	Office	100-KR-2	3.1 x 3.1 x 3.1	Removed	1955	1992	A one-story concrete and steel frame structure, with concrete block walls and concrete foundation. Facility was refurbished in April 1983 for the Rockwell Patrol Badgehouse for the 100-K Exclusion Area entrance. The 1701-KA Facility was replaced in the early 1990s by the MO-214 Structure.
1702-KE	Office	100-KR-2	4.0 x 5.0	Demolished	1955	1993	The Guard House was a one-story wooden frame structure on a concrete floor and foundation. Asbestos shake siding, flat wooden roof covered with roll roofing. Approximately 19.5 m^2 (210 ft^2).
1702-KW	Office	100-KR-2	4.0 x 5.0	Demolished	1955	1993	The Guard House was a one-story wooden frame structure on a concrete floor and foundation. Asbestos shake siding, flat wooden roof covered with roll roofing. Approximately 19.5 m^2 (210 ft^2).
1704-K	Office	100-KR-2	61.0 x 19.5	Removed	1955	N/A	1704-K was a one-story building with a flat roof and 1,250 m^2 (13,500 ft^2) floor area. The 1704-K Building served as a first aid station and also provided office space. It included working space to accommodate 60 people, a conference room, lunchroom, lobby, vestibule, and first aid station. The 1704-K Building was removed from the 100-K Area in 1974 and relocated to the 300 Area, where it became the 3765 Building. Several mobile office trailer facilities now occupy the site of the building at the 100-K Area.
1705-KE	Process Unit/Plant	100-KR-2	7.5 x 7.5 (headhouse) 26 x 2.7 x 1.8 (basin)	Inactive	1955	N/A	The 1705-KE Effluent Water Treatment Pilot Plant was a 51 m^2 (552 ft^2) concrete block structure and settling basin attached to 165-KE. The plant was a scaled-down version of a K Reactor water treatment plant as far as flocculation, settling, and filter rates were concerned. The concrete block portion housed the basin inlet, chemical addition and storage facilities, and the operating station. The facility was completely deactivated in 1971.
1706-KE	Test Facility/Component	100-KR-2	30.5 x 17.1 x 4.6	Inactive	1955	N/A	In 1984, the 1706-KE Waste Treatment System was installed to treat radioactive mixed wastes generated in the building. The equipment included an evaporation and epoxy encapsulation system. Accumulated wastes were transferred to an ion exchange column then on to a heated evaporation tank where they were solidified. Following numerous failures, the system was abandoned. In 1986, 1706-KE was known as the Chemistry and Waste Treatment Technology Building, and was used for physical and chemical test of various N Reactor systems. The facility was considered a dangerous waste treatment facility, and had laboratories that generated nonradioactive nonhazardous wastes, hazardous wastes, and radioactive mixed wastes. The types of studies included the corrosion properties of new cladding materials, reactor effluent reactivity, coolant treatments, and corrosion inhibitors (Specialty Irradiation Services). This included four separate filter systems with associated clearwells, and four different chemical treatment tanks. A wet fish studies laboratory was located in the northwest corner of the building, run by PNNL, in conjunction with the three outdoor fish ponds. After the N Reactor was permanently shut down in 1987, the complex continued operations as the Engineering and Environmental Demonstration Laboratory, operating non-radioactive and limited radioactive chemical engineering unit operation laboratories and equipment, while continuing to support KE and KW Basin operations. The facility was later used for equipment cleaning until 1996, then as a health physics facility performing radiological counting for air and water samples.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
1706-KEL	Laboratory	100-KR-2	11.0 x 22.9 x 4.3	Inactive	1962	N/A	The 1706-KEL Coolant Systems Development Laboratory supported the 1706-KE and 1706-KER Testing Facilities. The primary purpose of the laboratory was to study and eliminate the deleterious effects of fouling. The facility was divided into two main work areas: a cold laboratory for work with uncontaminated, non-irradiated materials and equipment; and a hot laboratory for work with irradiated or low-level contaminated materials and equipment. The facility conducted corrosion and decontamination studies for nuclear reactor coolant systems by obtaining data on water quality requirements, insoluble foreign material in the process water stream and film deposition, corrosion of reactor materials (carbon steel, aluminum, Zr-2, and stainless steel), and decontamination methods. The facility was left fully operational in 1971 for Battelle Northwest's Corrosion Research Engineering Section.
1706-KER	Test Facility/Component	100-KR-2	8.2 x 24 .4	Inactive	1956	N/A	The facility provided experimental data on the effect of water qualities, water temperature and pressure, and physical and chemical properties of materials of construction upon reactor operation and control, on reactor tubes and slugs, and on associated equipment when operating closed in-pile recirculation systems at elevated temperatures and pressures. In 1959, Loop #3 was contaminated by the failure of a zirconium-jacketed slug. The reason for the failure was never satisfactorily explained, but 1706-KE received some of the contamination. In 1964, the 100 m^2 (1,085 ft^2) decontamination and hot maintenance shop was added below grade to the west end of the 1706-KER Building. The facility discontinued hot operations in 1964. The facility was partially deactivated in 1971 and had most of the original equipment removed subsequent to that. It was never fully deactivated, as it supplied electrical power to 1706-KEL, which continued as a non-reactor support laboratory. By 1975, engineering development work had begun in support of preparations for storing N Reactor spent fuels in the 105KE and 105KW Fuel Storage Basins, requiring expanded use of the 1706-KER Basement areas. The basement maintenance shop was converted to a hot laboratory with ventilated hoods primarily for corrosion studies. By the 1990s, the facility was performing general laboratory functions on low-level radioactive materials in support of characterization of contaminated water in the 100-K Reactor irradiated fuel storage basins.
1709-K	Office	100-KR-2	125 m^2	Active	Transferred	N/A	The 1709-K Facility consisted of two sheet metal and plywood trailers on I-beam trailer frames. The 1709-K Building provided office space for personnel in the 100-K Area. It was previously located in the 100-N Area, where it was known as the 1109-N Building. Assuming it retained the same configuration it had at 100-N, MO-102 contained eight offices and restroom facilities.
1711-K	Office	100-KR-2	143 m^2	Active	Transferred	N/A	1711-K consisted of two sheet metal and plywood trailers on I-beam trailer frames. The interior of the facility was divided into seven rooms. The primary purpose of 1711-K was to provide office space. It had previously been located in the 100-N Area, where it was known as 1111-N.
1713-KE	Maintenance Shop	100-KR-2	12.2 x 6.1	Active	1955	N/A	A 74 m^2 (800 ft^2) sheet metal building with concrete slab floor. In the 1980s, the facility was used for miscellaneous materials storage, and an oil house.
1713-KER	Storage	100-KR-2	12.2 x 6.1	Active	1955	N/A	A 74 m^2 (800 ft^2) Butler type building with a concrete floor, essentially the same as 1713-KE. It was originally used as a warehouse, and later used for the storage of miscellaneous equipment.
1713-KW	Maintenance Shop	100-KR-2	12.2 x 6.1	Active	1954	N/A	A 74 m^2 (800 ft^2) Butler type building, essentially identical to the 1713-KE Building.
1714-KE	Storage	100-KR-2	4.9 x 3.9	Active	1955	N/A	A 19 m^2 (200 ft^2) Butler type building on a 30 cm (12 in.) concrete foundation. There were heating cables placed under the rebar in the concrete floor. In the 1970s, the facility was used for storing snow removal equipment and oils for machining and equipment. In the 1980s, it was used by K and D Areas maintenance for storage and a work area.
1714-KW	Storage	100-KR-2	8.0 x 9.0	Active	1954	N/A	A 74 m^2(800 ft^2) light gage steel, pre-engineered building with metal siding and roofing. It has a reinforced-concrete floor slab and foundation. It was used primarily for electrical equipment storage.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
1717-K	Maintenance Shop	100-KR-2	53.6 x 18.6 x 4.0	Active	1955	N/A	A one-story concrete and steel frame structure. Maintenance facilities included a mechanical shop, electrical shop, instrument shop, stores and supplies, tool crib, riggers loft area, oil storage, paint storage, equipment and switchgear area, garage (including minor automotive repairs), offices, and personnel facilities. In the 1970s, it was used as a maintenance shop for decommissioning and surveillance activities.
1718-K	Office	100-KR-2	1017.8 m^2	Active	Transferred	N/A	The 1718-K Building was originally the 1118-N Facility in the 100-N Area. It was relocated to the 100-K Area in 1993. The 1718-K Building provided office space for personnel in the 100-K Area. It consisted of 12 sheet metal and plywood trailers on I-beam trailer frames.
1719-K	Office	100-KR-2	1017.8 m^2	Active	Transferred	N/A	The 1719-K Building was originally the 1117-N Facility in the 100-N Area. It was relocated to the 100-K Area in 1994. It consisted of 12 sheet metal and plywood trailers on I-beam trailer frames. The 1719-K Building provided office space in the 100-K Area. It also contained kitchen and restroom facilities.
1720-K	Office	100-KR-2	22.6 x 15.2 x 4.0	Inactive	1955	N/A	A one-story building designed to provide facilities for security patrol, duplicating, and mail operations. A portion of the building was used for the telephone exchange and patrol radio rooms. A 300-line dial telephone exchange was designed to serve the 100-B, 100-C, and 100-K Areas. This included 464 m (5,000 ft) of buried 27-quad cable, 697 m (7,500 ft) of 13-quad cable, and 1,133 m (12,200 ft) of 202-pair cable. The portion of the building housing the telephone exchange and patrol radio rooms was constructed of bomb-resistant reinforced-concrete and structural steel. The remainder of the building contained offices, an ordinance room, an assembly room, a locker room, and other personnel facilities. The building shared a common wall with the 1701-K Building. It also provided office and laboratory space for several UNC Nuclear Industries organizations.
1721-K	Office	100-KR-2	8.5 x 20	Inactive	Transferred	N/A	The 1721-K Building (MO-382) was a double-wide mobile office trailer facility in the 100-K Area. The 1721-K Facility provided office space for personnel in the 100-K Area. Utilities were disconnected from the MO-382 Facility in 2003.
1722-K	Office	100-KR-2	8.5 x 20	Active	Transferred	N/A	The 1722-K (MO-907) Building was a double-wide mobile office trailer facility in the 100-K Area. The 1722-K Facility was used to provide office space for personnel working in the 100-K Area.
1723-K	Office	100-KR-2	122.6 m^2	Active	Transferred	N/A	The 1723-K Building (MO-928) was originally the 1123-N Facility in the 100-N Area. It was relocated to the 100-K Area in 1994 and consisted of two sheet metal and plywood trailers on I-beam trailer frames. The 1723-K Building provided office space in the 100-K Area. The basic configuration of the Building was seven offices, a kitchen, and restrooms.
1724-K	Maintenance Shop	100-KR-2	15.2 x 30.5 x 5.3 (maintenance shop) 9.1 x 6.4 x 3(equipment shed) 7.3 x 7.3 x 4.9 (gas bottle storage shed)	Active	1997	N/A	The 1724-K Maintenance Shop was a one-story concrete and steel frame structure. The 1724 K Buildings were used to perform everyday maintenance and repair (nonproject) jobs. It contained areas for general shop equipment, a sign shop, a paint booth, and a breaker testing area. A small, covered storage area was attached to the building. The 1724-KA Equipment Shed was a one-story concrete and steel frame structure. It was used for storage of snow removal equipment. The 1724-KB Gas Bottle Storage Building was a one-story open-sided, concrete and steel frame structure. It was used primarily for the storage of gas canisters.
1725-K	Office	100-KR-2	20.1 x 42.7	Active	Transferred	N/A	The 1725-K Building was a 10-wide mobile office trailer facility. The 1725-K (MO-293) Facility provided office space for personnel in the 100-K Area. It was installed in 1994 and was connected to an underground septic holding tank system just east of the facility.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
1726-K	Office	100-KR-2	8.5 x 20.1	Active	Installed	N/A	The 1726-K Facility was a double-wide mobile office trailer facility. The 1726-K Building provided office space in the 100-K Area. It also contained document files and document control personnel. The facility was installed in 1994 and was connected to an underground septic holding tank system. It contained offices, restrooms, a lunchroom, and document files.
1728-KW	Change House	100-KR-2	20.1 x 8.5	Active	Installed	N/A	The1728-KW (MO-236) Building was a double-wide mobile office trailer facility. The facility served as a change house for workers in the 100-K Area. It contained locker rooms and restroom facilities, along with a small storage room near the center of the facility.
1729-KW	Change House	100-KR-2	8.5 x 20.1	Active	Installed	N/A	The 1729-KW (MO-237) was a double-wide mobile office trailer facility in the 100-K Area. The facility was used as a change house, lunchroom, and office facility. The facility contained locker rooms, restrooms, a large lunchroom area, and two offices/meeting rooms.
1730-KE	Change House	100-KR-2	17.1 x 18.3	Active	Installed	N/A	The 1730-KE Structure was a four-wide mobile office trailer facility in the 100-K Area. The facility was remodeled in 1996 to use as a change house, and contains five offices, locker rooms, and storage areas. Utilities included potable water, electricity, and a wastewater holding tank connection.
1731-KW	Office	100-KR-2	3.7 x 15.2	Active	Transferred	N/A	1731-KW (MO-323) was a single-wide mobile office trailer facility in the 100-K Area. It was equipped with radio remote base stations, including an antenna on the roof.
1732-KW	Office	100-KR-2	18.3 x 7.3	Active	Transferred	N/A	The 1732-KW (MO-955) Building was a double-wide mobile office trailer building that was originally constructed in 1982 and located in the 100-N Area. By the mid-1990s, the building had been excessed and relocated to the 200-E Area. By the late 1990s, the building had been moved again, this time to the 100-K Area. Assuming 1732-KW maintained the same configuration as in the 100-N Area, it may have served as a lunchroom for personnel in the 100-K Area.
1733-K	Office	100-KR-2	Not Documented	Removed	1994	N/A	The 1733-K (MO-301) Facility consisted of four sheet metal and plywood trailers on I-beam trailer frames. It had originally been located in the 100-N Area until it was relocated to the 100-K Area in 1994. As was the case with most of the mobile trailer buildings on the Hanford Site, the primary purpose of the 1733-K Facility was to provide office space. Assuming the configuration of the building remained the same after it was moved to 100-K, it contained 15 offices, a kitchen, and restrooms.
1733-KE	Office	100-KR-2	171.7 m^2	Active	Transferred	N/A	1733-KE (MO-048) was a double-wide mobile office trailer facility in the 100-K Area. It had previously been located in the 200 Area. The 1733-KE Facility may have been used as a lunchroom in the 100-K Area.
1734-K	Office	100-KR-2	331.7 m^2	Active	Transferred	N/A	1734-K (MO-054) was originally the 1113-N Mobile Office in the 100-N Area, which was moved to the 100-K Area in the late 1990s. It consisted of four sheet metal and plywood trailers on I-beam trailer frames.
1737-K	Office	100-KR-2	Not Documented	Active	Installed	N/A	The 1737-K (MO-500) Structure was a 16-wide mobile office trailer facility in the 100-K Area. It was installed in 2000 and contained offices, conference rooms, cubicles, a computer room, lunchroom, and restrooms. The MO-500 Facility was used to provide office space for personnel in the 100-K Area. In particular, it was used to support the K Basin project. On May 4, 2006, a crew of RCTs from the CS&I organization were performing routine annual radiological surveys in the MO-500 office areas. The survey of a mock fuel piece located in cubicle B105 identified fixed contamination readings on the piece of 100 to 150 counts per minute per probe area (reported as 9,000 dpm/100 sq cm). The RCTs then removed the item from the office area for further evaluation. Spectroscopy results indicated that thorium was the predominant isotope with only trace quantities of uranium.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
181-KE	Pump Station	100-KR-1	27.4 x 18.9	Active	1955	N/A	The purpose of the 181-KE River Pump House was to transfer water from the Columbia River to the 183-KE Water Treatment Facilities. In an emergency, raw water could be pumped directly to the reactor. The pump house is essentially a reinforced-concrete river-intake structure with all pumps and control equipment outdoors. The intake bay was dredged to about 6.1 m (20 ft) below the low water level, then riprap was applied to the sides and bottom of the channel for stability. The operating floor was 1.2 m (4 ft) above maximum flood level. The river pump house was operated from the 165-KE Building Control Room and supplied the 183-KE Headhouse through two underground lines. These pumps extended nearly 20 m (65 ft) below the operating floor. Additionally, a 3 m (10 ft) square guard house, constructed of steel and with windows on all sides, was placed along an elevated stairway 4.9 m (16 ft) above the centerline of the facility on the river side. The river water was pumped through two 1.5 m (60 in.) lines to the 183-KE Headhouse for treatment before use as process water and sanitary water. During a 1961 upgrade to increase production, six additional pumps were emplaced in the facility, and the existing pumps received new, higher capacity impellers. Following the reactor shutdown in 1971, the facility continued to provide water for the storage basin, as well as to some of the 183-KE Sedimentation Basins where salmon smolt were being reared.
181-KW	Pump Station	100-KR-1	27.4 x 18.9	Inactive	1955	N/A	The purpose of the 181-KW River Pump House was to transfer water from the Columbia River to the 183-KW Water Treatment Facilities. In an emergency, raw water could be pumped directly to the reactor. The pump house is essentially a reinforced-concrete river-intake structure with all pumps and control equipment outdoors. The intake bay was dredged to about 6.1 m (20 ft) below the low water level, then riprap was applied to the sides and bottom of the channel for stability. The operating floor was 1.2 m (4 ft) above maximum flood level. The river pump house was operated from the 165-KW Building Control Room and supplied the 183-KW Headhouse through two underground lines. Additionally, a 3 m (10 ft) square guard house, constructed of steel and with windows on all sides, was placed along an elevated stairway 4.9 m (16 ft) above the centerline of the facility on the river side. River water entered the intake bay through two trash racks and two traveling screens that removed debris and fish and flushed them downstream of the intake. The river water was pumped through two 1.5 m (60 in.) lines to the 183-KW Headhouse for treatment before use as process water and sanitary water. During a 1961 upgrade to increase production, six additional pumps were emplaced in the facility, and the existing pumps received new, higher capacity impellers.
182-K	Storage Tank	100-KR-2	17.7 x 13.7	Inactive	1962	N/A	This facility, completed in July 1962, housed three diesel engine-driven pumps and related equipment for emergency reactor cooling. The 182-K, Emergency Water Pumphouse, was considered the last ditch system for providing cooling water to both reactors but not both reactors simultaneously. The primary coolant system was powered by the low-lift and high-lift electrical pumps in the 190 buildings. The secondary system was a combination of low-lift steam turbine pumps, and steam-driven electrical generators supplying the low-lift electrical pumps, also located in the 190 buildings. It could pump treated cooling water from either the KE or KW clearwells to either the 105KE or 105KW reactor buildings. Two 66,623 L (17,600 gal) underground steel diesel oil storage tanks were located on the north side of the facility, prior to their removal in 1993. Following the 1993 removal of the underground tanks, the surrounding soil was sampled, and the site backfilled.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
183-KE	Process Unit/Plant	100-KR-2	Chlorine Car Protection Building: 10.7 x 29.3 x 6.4 Headhouse (183.1KE): 41.5 x 9.4 x 6 (top portion)21.3 x 18.3 x 6 (stem portion) Flocculation and sedimentation basins (183.2KE): 39.6 x 88. 4 x 5.2 (Each Basin) Filter Plant (183.3KE):246 x 24.7 x 8.5 (including the central tunnel) Clearwells (183.4KE):246 x 46.6 x 7.3 (including the central tunnel) Lime Feeder Buildings (183.5KE and 183.6KE): 11 x 8.2 x 5.2 Pipe Tunnel (183.7KE): 376	Active	1955	N/A	The water treatment plant consists of a headhouse, six double sedimentation basins complete with flocculators, monorakes, filter beds, two clear wells, storage for liquid/dry chemicals, chlorine house, alum manufacturing plant (Bauxite system), laboratory, compressed air system, steam and glycol heating lines, sulfuric acid, liquid alum, dichromate, separan storage, and pumping systems. Process wastes from the building and supporting chemical storage tanks were routed through a 41 cm (16 in.) north-south pipe-in-trench located in the basement of the building. This line received overflow line and drain line wastes from the outside storage tanks (sulfuric acid, dichromate, alum, and caustic) through direct buried lines; overflow line and drain line wastes from the six inside mixing and storage tanks; and floor and lab sink drains on both the first floor and basement. The laboratory stored, handled, and disposed of a number of chemicals including sodium dichromate, sulfuric acid, and solvents. When K Reactors were shut down, the excess sulfuric acid was tested for use at the N Reactor, and mercury was detected in very high concentrations in precipitate found in the acid storage tanks. This contaminant was traced back to the commercial-grade sulfuric acid that was obtained from the Bunker Hill Company during 1968 through 1971. A 1985 sample from a 183-KW drywell analyzed above dangerous waste limits for mercury, and contained barium, chromium, lead, and selenium. The basins were largely deactivated in 1971. Sedimentation basin #5 was left in service to support treatment of water to supply cooling water to the spent fuel storage basins, and remained in service to support spent fuel removal activities. In 1993, the easternmost sediment basin in the west half began to be used for raising salmon smolt. In 1994, basin #7 contained fish pens.
183-KW	Process Unit/Plant	100-KR-2	Chlorine Car Protection Building: 10.7 x 29.3 x 6.4 Headhouse (183.1KE): 41.5 x 9.4 x 6 (top portion)21.3 x 18.3 x 6 (stem portion) Flocculation and sedimentation basins (183.2KE): 39.6 x 88. 4 x 5.2 (Each Basin) Filter Plant (183.3KE): 246 x 24.7 x 8.5 (including the central tunnel) Clearwells (183.4KE): 246 x 46.6 x 7.3 (including the central tunnel) Lime Feeder Buildings (183.5KE and 183.6KE): 11 x 8.2 x 5.2 Pipe Tunnel (183.7KE): 376	Inactive	1955	N/A	The sanitary water system for the 100-K Area was located at 183-KW during the operating years. The water treatment plant consists of a headhouse, six double sedimentation basins, complete with flocculators, monorakes, filter beds, two clear wells, storage for liquid and dry chemicals, chlorine house, alum manufacturing plant (Bauxite system), compressed air system, steam and glycol heating lines, sulfuric acid, liquid alum, dichromate, separan storage, and pumping systems. Process wastes from the building and supporting chemical storage tanks were routed through a 41 cm (16 in.) north-south pipe-in-trench located in the basement of the building. The trench was 1.1 m (3 ft 6 in.) wide and ran the entire length of the building. This line received overflow line and drain line wastes from the outside storage tanks (sulfuric acid, dichromate, alum, and caustic) through direct buried lines; overflow line and drain line wastes from the six inside mixing and storage tanks; and floor and lab sink drains on both the first floor and basement. The laboratory stored, handled, and disposed of a number of chemicals including sodium dichromate, sulfuric acid, and solvents. In 1985, a French drain and dry well near the acid tanks at the headhouse were identified as having acid sludge containing hazardous inorganic materials. In addition, the drywell contained concentrations of mercury, which classify it as a dangerous waste site. The sludge was residue that was removed from sulfuric acid storage tanks in the late 1960s and early 1970s.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
1904-K	Outfall	100-KR-1	10 x 10.7 x 2 (outfall structure) 68.6 x 3 (spillway) 10.1 x 10.67 x 2.13 (diversion box)	Active	1955	N/A	The spillway, WIDS Site 100-K-83 (also referred to as a "flume") was a combination of a three-sided, reinforced-concrete trough beginning at the diversion box, followed by an open earthen trench extending from the end of the concrete trough to the Columbia River shore. The spillway was an alternate discharge point for the diversion box. It was planned to be used only if the pipelines were blocked, damaged, or undergoing maintenance. There is no corroborated physical or historical evidence that the spillway was ever used. During decommissioning work performed during the 1980s, all but the uppermost 15 m (50 ft) of the concrete portion of the spillway were demolished and covered with soil. In 1994, both pipelines were found to be exposed along most of the river run, protruding 1.2 to 2.5 m (4 to 8 ft) above the riverbed. As of February 2005, the KE pipeline was still in use as a NPDES discharge point by the SNF Program. During a visit to the site on February 7, 2005, it was noted that the initial 15 m (50 ft) of the concrete spillway, nearest to the diversion box, is intact, and the remainder appears to have been demolished to grade level and backfilled with soil. The earthen trench remains open nearly to the shoreline.
1908-KE	Monitoring Station	100-KR-1	3.6 x 3.6 x 3.0	Inactive	1955	N/A	The 1908-KE Effluent Water Monitoring Station was a beta radiation monitoring station provided at the point where the retention basin effluent lines meet to run parallel to the outfall structure (diversion box). This building housed a rotating sample chamber and a recorder. Process effluent samples were pumped from the KW process effluent line (through manhole #3) and from the KE process effluent line (through manhole #4) into this station for measurement of beta activity levels. A composite sample pump obtained samples from the concrete flume sewer system, which received drainage from the potentially contaminated K area buildings. These composite samples were analyzed weekly in the laboratory for pH and radioactivity. The flow rate and temperature of the process effluent being discharged to the river were continuously recorded and logged daily.
1909-KE	Valve Pit	100-KR-2	10.7 x 10.4	Inactive	1955	N/A	The 1909-KE Effluent valve pit (junction box) purpose was to transfer the reactor effluent water from the downcomer arrangement into the 1.8 m (72 in.) line and to the retention basins. There was a 91 cm (36 in.) and a 1.8 m (72 in.) diameter pipe housed in this junction box. A manhole was located on the 1.8 m (72 in.) pipe, and there was a 10 cm (4 in.) drain in the junction box floor. The 91 cm (36 in.) line was a bypass to the river to permit the discharge of effluent water directly to the river during normal discharge operations. The junction box was located immediately adjacent to the wall of the reactor building. For cleanup purposes, this building is considered part of the reactor building itself. The junction box likely contained radiological contaminants because it was used in transporting process effluent.
1909-KW	Valve Pit	100-KR-2	10.7 x 10.4	Inactive	1955	N/A	The 1909-KW Effluent Valve Pit (junction box) purpose was to transfer the reactor effluent water from the downcomer arrangement into the 1.8 m (72 in.) line and to the retention basins. There was a 91 cm (36 in.) and a 1.8 m (72 in.) diameter pipe housed in this junction box. A manhole was located on the 1.8 m (72 in.) pipe, and there was a 10 cm (4 in.) drain in the junction box floor. The 91 cm (36 in.) line was a bypass to the river to permit the discharge of effluent water directly to the river during normal discharge operations. The junction box was located immediately adjacent to the wall of the reactor building. For cleanup purposes, this building is considered part of the reactor building itself. The junction box likely contained radiological contaminants because it was used in transporting process effluent.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
190-KE	Pump Station	100-KR-2	55.8 x 43.6 x 9.1	Inactive	1955	N/A	The pumphouse is a one-story building designed to pump the treated cooling water from the clearwells to and through the 105-KE Reactor. Pumping and valving was controlled through the 165-KE Building. The facility contained six dual-pumping sets of process pumps the discharged into 61 cm (24 in.) reactor coolant headers. In addition to the electrically operated pumping system, a separate steam-turbine-driven pump was provided in the facility, to supply emergency flow to the reactor in the event both the primary (BPA) and turbo-generator electrical power failed. The facility also contained two backwash pumps for backwashing the 183-KE Plant Filters, as well as four service water pumps. These latter pumps provided water to all facilities for general use and fire protection, and were connected to a 61 cm (24 in.) service water loop that extended around the periphery of the 190-KE Building and into the 165-KE Building Valve Pit. The partial basement housed the oiling systems for the high lift pumps, the high lift motor cooling system, interconnecting lines between the low and high lift pumps, and the discharge lines from the pumps in the building. The facility was mostly deactivated in 1971. Selected equipment remained active to supply cooling water to the spent fuel storage basins, power house requirements, fire protection, and sanitary water needs. Two service water pumps and two backwash pumps were left in service as well as heating and ventilation units. These pumps were left in place to support the spent fuel removal activities. A new roof was installed in 1982.
190-KW	Pump Station	100-KR-2	55.8 x 43.6 x 9.1	Inactive	1955	N/A	The pumphouse is a one-story building designed to pump the treated cooling water from the clearwells to and through the 105-KW Reactor. Pumping and valving was controlled through the 165-KW Building. The facility contained six dual-pumping sets of process pumps that discharged into 61 cm (24 in.) reactor coolant headers. The primary pumps, consisting of deep-well turbine-type pumps, took water from the clearwells to develop the high positive suction head requirements of the secondary pumps. The primary pumps were also piped to bypass the secondary pumps and cool the reactor in an emergency. In addition to the electrically operated pumping system, a separate steam-turbine-driven pump was provided in the facility, to supply emergency flow to the reactor in the event both the primary (BPA) and turbo-generator electrical power failed. The facility also contained two backwash pumps for backwashing the 183-KW Plant Filters, as well as four service water pumps. These latter pumps provided water to all facilities for general use and fire protection, and were connected to a 61 cm (24 in.) service water loop that extended around the periphery of the 190-KW Building and into the 165-KW Building Valve Pit. The partial basement houses the oiling systems for the high lift pumps, the high lift motor cooling system, interconnecting lines between the low and high lift pumps and the discharge lines from the pumps in the building.
6004-KW	Process Unit/Plant	100-KR-2	12.19 x 24.38	Active	2007	N/A	The 6004-KW Facility was a prefabricated metal building on a concrete pad. It contained equipment needed for removing dichromate from groundwater, including pumps, ion exchange equipment, an effluent storage tank, and filters. Water was pumped out of four extraction wells in the 100-K Area (199-K-132, 199-K-138, 199-K-139, and 199-K-140) and piped to the 6004-KW Facility. It was then treated using a Dowex 21 resin bed system, which captures CrVI and other similar ions. After treatment, the water was injected back into the ground using an injection well (199-K-35, 199-K-137, and 199-K- 108 were used as backup injection wells).
MO-060	Office	100-KR-2	8.5 x 20.1	Active	Installed	N/A	MO-060 was a double-wide mobile office trailer facility in the 100-K Area that was installed in 2001. The facility served as a training center for personnel in the 100-K Area.
MO-205-K	Office	100-KR-2	27.9 m^2	Removed	Installed	N/A	The MO-205 Conference Trailer was present in the 100-K Area during the mid-1990s. This small, single-wide trailer facility served as a conference facility.
MO-214	Office	100-KR-2	3.7 x 17.1	Active	Transferred	N/A	The MO-214 Facility was moved from the 100B/C Area to the 100-K Area in the early 1990s, where it replaced the old 1701-KA Facility. The facility was used to screen personnel as they entered the 100-K Exclusion Area. The building contained two portal monitors, a restroom, and an office.

Table D-1. Summary of 100-K Facilities

Facility Code	Facility Type	Operable Unit	Site Dimensions (m)	Facility Status	Construction Date	Demolition Date	Facility Description
MO-420	Storage	100-KR-2	3.7 x 17.1	Removed	Installed	N/A	The MO-420 facility was a single-wide mobile office trailer facility in the 100-K Area. The building was used as a temporary storage facility for water samples. It may also have provided office space. The building was removed from the 100-K Area and relocated to the 200 Area by the mid-2000s.
MO-422-K	Office	100-KR-2	3.7 x 9.8	Active	Transferred	N/A	The MO-422 Facility was a single-wide modular office trailer and relocated to the 100-K Area in 2007. It was a "dry" trailer, with no water or sewer connections. The facility was used in the 100-K Area to support the WCH Rad-Con training program.
MO-474-K	Office	100-KR-2	234.1 m^2	Removed	Transferred	N/A	The MO-474 Facility was a double-wide trailer. The facility was originally located in the 100-K Area before being relocated to the 100-B/C Area by 1996 as an office building. The function of the facility in the 100-K Area could not be confirmed.
MO-495	Office	100-KR-2	3.7 x 17.1	Removed	Installed	N/A	The MO-495 Facility was a single-wide mobile office trailer facility in the 100-K Area. It appears to have been involved with the construction of the 142-K Facility. The facility was relocated to the 200 West Area in 2005.
MO-506	Office	100-KR-2	3.7 x 17.1	Active	Installed	N/A	The MO-506 Facility was a single-wide mobile trailer facility in the 100-K Area. The building supported operations at the 142-K Cold Vacuum Drying Facility.
MO-507	Office	100-KR-2	3.7 x 17.1	Active	Installed	N/A	The MO-507 Facility was a single-wide mobile trailer facility in the 100-K Area. The MO-507 Building served as an office in support of the 142-K Cold Vacuum Drying Facility.
MO-750	Office	100-KR-2	7.3 x 18.3	Active	Installed	N/A	MO-750 was a double-wide mobile office trailer facility near the 100-K Area. The trailer served as an office trailer at the 118-K-1 Remediation Site but was scheduled to be removed from the site in 2008.
MO-751	Change House	100-KR-2	3.7 x 17.1	Active	Installed	N/A	MO-751 was a single-wide mobile office trailer facility near the 100-K Area. The trailer served as a restroom trailer at the 118-K-1 Remediation Site but was scheduled to be removed from the site in 2008.
MO-753	Office	100-KR-2	3.7 x 17.1	Active	Installed	N/A	MO-753 was a single-wide mobile office trailer facility near the 100-K Area. The trailer served as an RCT trailer at the 118-K-1 Remediation Site but was scheduled to be removed from the site in 2008.
MO-917-K	Office	100-KR-2	7.3 x 18.3	Active	Installed	N/A	MO-917 was a double-wide mobile office trailer facility and provides office space in the 100-K Area. Room 17 of the facility was also used for temporary records storage.

BPA = Bonneville Power Administration
CS&I = Closure Services and Infrastructure
CrVI = hexavalent chromium
CVDF = Cold Vacuum Drying Facility
ERDF = Environmental Restoration Disposal Facility
I&C = radiological instrument and control
Ix = ion exchange
N/A = not applicable
NPDES = National Pollutant Discharge Elimination System
OU = radiological Operable Unit
PNNL = Pacific Northwest National Laboratory
RCT = radiological control technician
SNF = Spent Nuclear Fuel
UNC = UNC Nuclear Industries
WIDS = Waste Information Data System

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Revision 0

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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

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Concurrence

U.S. Department of Energy, Richland Operations Office

Signature 10-23-09 Date

U.S. Environmental Protection Agency

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Terms

ALARA	as low as reasonably achievable
CFR	*Code of Federal Regulations*
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DOH	Washington State Department of Health
DQA	data quality assessment
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FS	feasibility study
gal./day	gallons per day
HASQARD	Hanford Analytical Services Quality Assurance Requirements Documents
HEIS	Hanford Environmental Information System
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
SAP	sampling and analysis plan
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
VOC	volatile organic compound
WAC	*Washington Administrative Code*

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1 Introduction

This sampling and analysis plan (SAP) supports the remedial investigation (RI)/feasibility study (FS) process for the 100-K Decision Unit. The 100-K Decision Unit is located on the Hanford Site in southeastern Washington State and is associated with two source operable units: 100-KR-1 and 100-KR-2. The 100-KR-4 Groundwater Operable Unit underlies the two source operable units. This SAP describes the sampling and analysis to be performed associated with environmental investigation borings (boreholes), groundwater monitoring wells, and aquifer tubes. Figure 1-1 shows the location of the planned and existing boreholes, groundwater monitoring well network, and aquifer tubes within the scope of this SAP. Table 1-1 presents the intersection of data needs presented in Addendum 2 and the sampling and analysis activities. Chapter 2 of DOE/RL-2008-46, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 2,* describes the site background and environmental setting of the 100-K Decision Unit.

Table 1-1. Plan Activities and Data Needs

Planned Activity	100-K Area		Data Needs No.
	Quantity	Location	
New boreholes (vadose zone)*	2	116-K-2 Trench West 116-K-2 Trench East	2, 3, 12
New wells to characterize deep vadose zone and unconfined aquifer*	9	Well #1 Well #2 Well #3 Well #4 Well #5 Well #6 Well #7 Well #8 Well #9	5, 10
New wells to characterize deep vadose zone, unconfined aquifer and Ringold upper mud unit*	4	Well R1 Well R2 Well R3 Well R4	7, 9, 10, 12
New aquifer tubes	3 tubes at 1 location	Location #1	5
Sample spatial/temporal uncertainty groundwater monitoring wells	18 existing locations		13

NOTE: This sampling and analysis plan may be in addition to other scheduled field activities.

* Boreholes and groundwater monitoring wells will be logged with a neutron moisture tool and the high-resolution spectral gamma ray logging system. Geologic samples will also be logged.

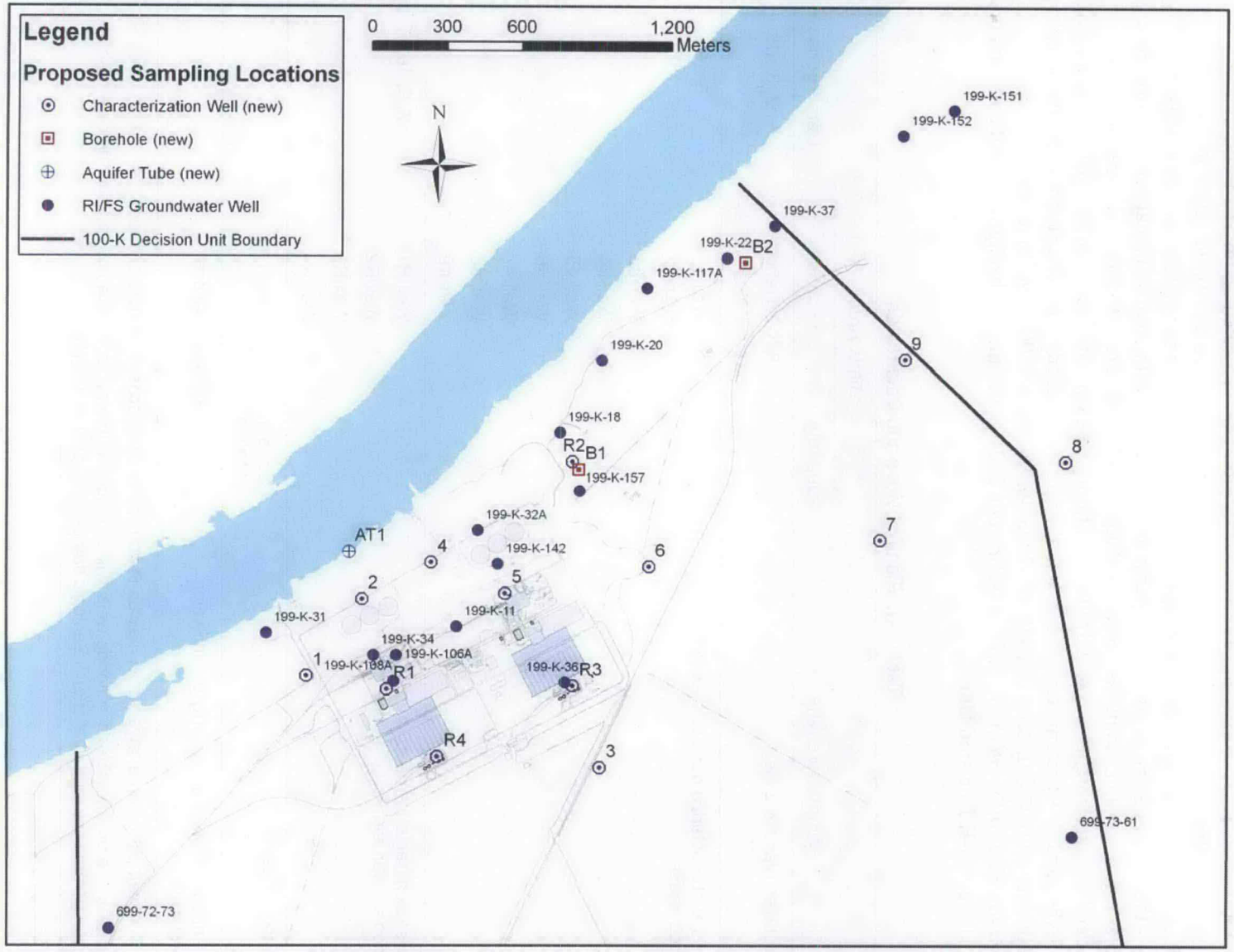

Figure 1-1. 100-K Decision Unit Planned and Existing Sampling Locations

1.1 Vadose Zone Characterization

This SAP describes the activities planned to characterize the vadose zone beneath the 116-K-2 Trench. Groundwater wells drilled as part of the 100-K Decision Unit RI also will have deep vadose zone soil samples collected during drilling at 13 groundwater monitoring well locations. Samples will be collected and analyzed to evaluate the nature and extent of contamination. The aquifer tubes will not have soil samples collected during drilling.

1.2 Groundwater Characterization

Groundwater samples will be collected and analyzed from new and existing groundwater monitoring wells to define the extent of contamination and to support evaluation of contaminant transport. Where possible, new well locations and construction have been selected to satisfy multiple project data needs, such as delineating vadose zone and groundwater contamination.

1.3 Target Analytes and Contaminants of Potential Concern

Method-based analysis addresses the suites of analytical methods that will yield results for the target analytes or contaminants of potential concern (COPCs) needed. This method of laboratory analysis provides an umbrella effect in that analyses are provided for the target analytes or COPCs, as well as for any related constituents. Method based analysis will be performed for all chemical soil/aquifer sediment and water samples analyzed for the 100-K Decision Unit.

As presented in Appendix A, the standard laboratory method reporting lists that are used when running Hanford Site samples under current contractual agreements will be reported in the Hanford Environmental Information System (HEIS) database. The tables in Appendix A have been provided to define the analytes which will be reported when using a method based analysis approach. In addition, tentatively identified compounds will be reported for SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods,* Method 8260.

1.3.1 Soil/Aquifer Sediment Target Analytes

Table 1-2 presents the soil/aquifer sediment master list of target analytes. WCH-326, *100-K Decision Unit Target Analyte List Development for Soil* presents the approach used for development of the master list and waste site-specific target analytes. Waste site-specific constituents for analysis are based on the master list.

Table 1-2. Master Soil/Aquifer Sediment Target Analytes

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

PCB = polychlorinated biphenyl

1.3.2 Groundwater COPCs

Table 1-3 presents the groundwater COPCs. Chapter 4 of the work plan presents the approach used for development of the COPCs.

Table 1-3. Groundwater Contaminants of Potential Concern

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

1.4 Data Needs

A systematic planning process was used to identify 100-K Decision Unit problem statements and data gaps. The identified data needs resulting from the systematic planning process are discussed in Chapter 4 of 100-K Decision Unit RI/FS Work Plan (Addendum 2).

1.5 Sampling Design

The type of sampling design is judgmental (e.g., based on prior knowledge and professional judgment/expertise). The locations of waste sites, groundwater monitoring wells, and aquifer tubes were defined to address the uncertainties and data needs identified during systematic planning. Figure 1-1 shows the locations of boreholes, groundwater monitoring wells, and aquifer tubes described in this SAP. Tables 2-2 through 2-4 present the selected analytical methods to meet the required detection limits and the analytical performance requirements.

1.6 Project Schedule

The 100-K Area RI field efforts will occur between October 2009 and June 2010. The drilling lead will prepare the relative borehole and groundwater well schedule for new installations. A spatial and temporal uncertainty sample round, or event, will be collected from each the seasonal "high" water level, a seasonal "low" water level, and a "mid-point" water level, for a total of three samples per well. Each round of monitoring in the network of wells and aquifer tubes for this decision unit will be completed within 30 consecutive calendar days to minimize statistical variability in water levels. The RI Report will document the results provided by sampling and analysis in this plan.

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2 Quality Assurance Project Plan

The quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection, including planning, implementation, and assessment of sampling, field measurements, and laboratory analysis. The work performed under this plan is conducted in accordance with:

- DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD)
- DOE O 414.1C, *Quality Assurance*
- 10 CFR 830, Subpart A, "Nuclear Safety Management, Quality Assurance Requirements"
- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5.

Sections 6.5 and 7.8 of the *Hanford Federal Facility Agreement and Consent Order Action Plan (*Ecology et al., 1989b), require that quality assurance (QA)/quality control (QC) and sampling and analysis activities specify the QA requirements for treatment, storage, and disposal units, as well as past-practice processes. Therefore, this QAPjP follows the QA elements of EPA/240/B-01/003. The QAPjP demonstrates conformance to Part B requirements of ANSI/ASQC E4-1994, *Quality Systems for Environmental Data Collection and Environmental Technology Programs: Requirements with Guidance for Use.*

In addition to the requirements cited above, the following reference was also used as a resource for identifying QAPjP elements:

- EPA-505-B-04-900A, *Intergovernmental Data Quality Task Force, Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental Data Collection and Use Programs, Part 1: UFP-QAPP Manual.*

EPA-505-B-04-900A is not imposed through the Tri-Party Agreement (Ecology et al., 1989a *Hanford Federal Facility Agreement and Consent Order*). However, EPA-505-B-04-900A is a valuable resource and provides a comprehensive treatment of quality elements that should be addressed in any SAP. EPA-505-B-04-900A was designed to be compatible with EPA/240/B-01/003, which forms the basis for this QAPjP.

The QAPjP is divided into the following four sections, which describe the quality requirements and controls applicable to this investigation.

Section 2.1 Project Management – This section addresses project management, including the project history and objectives, roles, and responsibilities of the participants. These elements ensure the project has a defined goal, participants understand the goal and the approach to be used, and planning outputs are documented.

Section 2.2 Data Generation and Acquisition – This section addresses aspects of project design and implementation. Implementing these elements ensures appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and are properly documented.

Section 2.3 Assessment and Oversight – This section addresses the activities for assessing the effectiveness of implementing the project and associated QA and QC activities. The purpose of assessment is to ensure the QAPjP is implemented as prescribed.

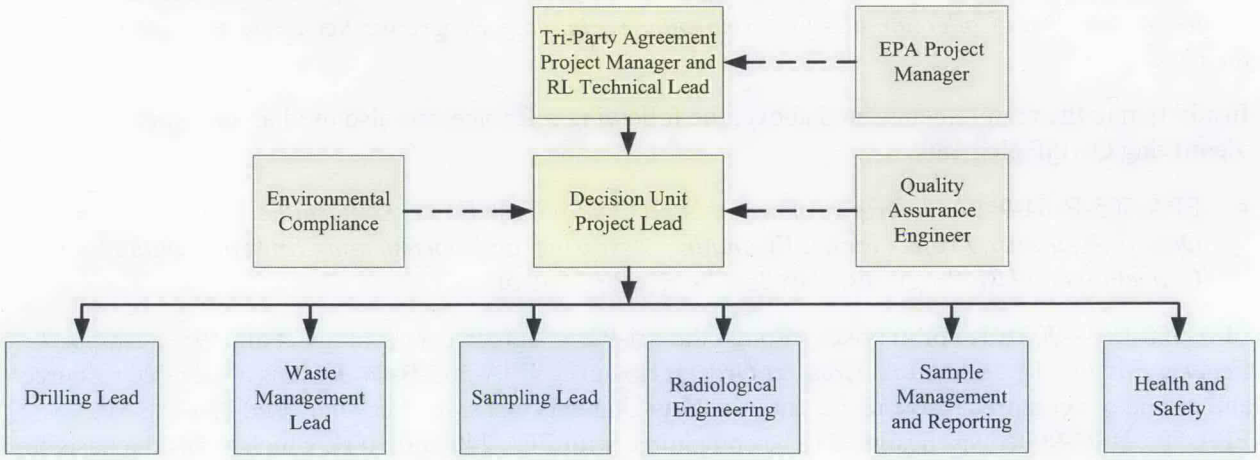
Section 2.4 Data Validation and Usability – This section addresses the QA activities occurring after the data collection or generation phase of the project is completed. Implementing these elements ensures data conform to the specified criteria, thus achieving the project objectives.

2.1 Project Management

The following sections address the basic aspects of project management, ensuring that the project has defined goals, the project team understands the goals and the approaches used, and the planned outputs are appropriately documented. Project management roles and responsibilities discussed in this section apply to the major activities covered under the SAP.

2.1.1 Project and Task Organization

The Plateau Remediation Contractor and River Corridor Closure Contractor, or its approved subcontractor, is responsible for planning, coordinating, sampling, preparing, packaging, and shipping samples to the laboratory. The following sections describe the project organization concerning sampling and characterization, also shown in Figure 2-1. The project lead maintains a list of individuals or organizations as points of contact for each functional element in the figure. For each functional primary contractor role, there is a corresponding oversight role within the U.S. Department of Energy (DOE).



EPA	=	U.S. Environmental Protection Agency
RL	=	U.S. Department of Energy, Richland Operations Office
Tri-Party Agreement	=	Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order*

Figure 2-1. Project Organization

EPA Project Manager. The U.S. Environmental Protection Agency (EPA) has assigned project managers responsible for oversight of cleanup projects and activities. EPA has approval authority as lead regulatory agency for the work being performed under this SAP. EPA will work with the DOE, Richland Operations Office (RL) to resolve concerns over the work as described in this SAP in accordance with the Tri-Party Agreement (Ecology et al., 1989a).

Tri-Party Agreement Project Manager and RL Technical Lead. The Tri-Party Agreement Project Manager is responsible for authorizing the RI/FS activities for the 100 Area decision units. The Tri-Party Agreement Project Manager also is responsible for obtaining lead regulatory approval of the work plan and SAP that authorize the RI/FS activities under the Tri-Party Agreement. The RL technical lead is

responsible for overseeing the contractor in performing the work scope, working with the contractor and the regulatory agencies to identify and work through issues, and providing technical input to the Tri-Party Agreement Project Manager.

Environmental Compliance. The environmental compliance officer provides technical oversight, direction, and acceptance of project and subcontracted environmental work, and develops appropriate mitigation measures with a goal of minimizing adverse environmental impacts. The environmental compliance officer also reviews plans, procedures, and technical documents to ensure that environmental requirements have been addressed; identifies environmental issues affecting operations and develops cost-effective solutions; and responds to environmental/regulatory issues or concerns raised by RL and/or the regulatory agencies. The environmental compliance office also oversees project implementation for compliance with applicable internal and external environmental requirements.

Decision Unit Project Lead. The project lead is responsible for direct managing of sampling documents and requirements, field activities, and subcontracted tasks, and for ensuring that the project file is properly maintained. The project lead ensures that the sampling design requirements are converted into field instructions (e.g., work packages) providing specific direction for field activities. The project lead works closely with QA, Health and Safety, the drilling lead, and the sampling lead to integrate these and the other lead disciplines in planning and implementing the workscope. The project lead maintains a list of individuals or organizations filling each of the functional elements of the project organization (Figure 2-1). In addition, the project lead is responsible for version control of the SAP to ensure personnel are working to the most current job requirements. The project lead also coordinates with RL and the primary contractor management on sampling activities. The project lead supports RL in coordinating sampling activities with the regulators.

Quality Assurance Engineer. The QA point of contact is matrixed to the project lead and is responsible for QA issues on the project. Responsibilities include overseeing implementation of the project QA requirements; reviewing project documents, including data needs summary reports, SAPs, and the QAPjP; and participating in QA assessments on sample collection and analysis activities, as appropriate. The QA point of contact must be independent of the unit that is generating the data.

Drilling Lead. The drilling lead has overall responsibility for planning, coordinating, and executing drilling activities. Specific responsibilities include coordinating with the geological and drilling contractors. The drilling lead will also communicate with the decision unit project lead designee to identify field constraints or emergent conditions affecting sampling design/execution, and direct the procurement and installation of materials and equipment needed to support fieldwork.

Waste Management Lead (Waste Coordinator). The waste management lead communicates policies and procedures, and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner. In addition, Waste Management is responsible for identifying waste management sampling/characterization requirements to ensure regulatory compliance, interpreting the characterization data to generate waste designations and profiles, and preparing and maintaining other documents confirming compliance with waste acceptance criteria.

Sampling Lead. The sampling lead has overall responsibility for planning, coordinating, and executing sampling activities. Specific responsibilities include converting the sampling design requirements into field task instructions to provide specific direction for field activities, as well as directing training, mock-ups, and practice sessions with field personnel to ensure the sampling design is understood and can be performed as specified. The sampling lead also communicates with the decision unit project lead designee to identify field constraints or emergent conditions affecting sampling design and execution, directs the procurement and installation of materials and equipment needed to support fieldwork, and

prepares data packages based on instructions from the project lead designee and information contained in this SAP. The shipping lead reports to the sampling lead for shipment authorization. No sample material will be transported on or off the Hanford Site without permission from an authorized shipper or designee.

Radiological Engineering. The Radiological Engineering lead is responsible for the radiological/health physics support within the project. Specific responsibilities include conducting as low as reasonably achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization for work planning. In addition, the Radiological Engineering lead identifies radiological hazards and implements appropriate controls to maintain worker exposures ALARA (e.g., requiring personal protective equipment). The Radiological Engineering lead also interfaces with the project Health and Safety contact, and plans and directs radiological control technician support for activities.

Sample Management and Reporting. Sample Management and Reporting coordinates laboratory analytical work, ensuring the laboratories conform to Hanford Site internal laboratory QA requirements, or their equivalent, as approved by DOE, EPA, and the Washington State Department of Ecology (Ecology). Sample Management and Reporting receives the analytical data from the laboratories, performs the data entry into the HEIS database, and arranges for data validation. Sample Management and Reporting is responsible for informing the project lead of any issues reported by the analytical laboratory. Sample Management and Reporting develops and oversees implementation of the letter of instruction to the analytical laboratories, oversees data validation, and works with the project lead to prepare a characterization report on the sampling and analysis results.

Sample Management and Reporting is also responsible for the performance of data needs process, or equivalent. Additional related responsibilities include development of the SAP, including documentation of the data needs and the sampling design, preparation of associated presentations, resolution of technical issues, and preparation of any revisions to the SAP.

Samples taken in the field and released to the River Corridor Closure Contractor for shipping and analysis, as well as the resulting data, will be managed in accordance with applicable procedures and work plans.

Laboratories. The laboratories analyze samples in accordance with established procedures, provide necessary sample reports, and explain results in support of data validation. The laboratories must meet site-specific QA requirements and must have an approved QA plan in place.

Health and Safety. Health and Safety is responsible for coordinating industrial safety and health support within the project, as carried out through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulation or by internal primary contractor work requirements. In addition, Health and Safety provides assistance to project personnel in complying with applicable health and safety standards and requirements. Health and Safety coordinates with Radiological Engineering to determine personnel protective equipment requirements.

2.1.2 Problem Definition and Background

This SAP describes the sampling and analysis to be performed associated with environmental investigation borings (boreholes), groundwater monitoring wells, and aquifer tubes. The specific problems to be solved, background information, and general information are provided in the work plan. Media to be sampled include water, aquifer sediment, and soil. Figure 1-1 shows the location of the planned and existing boreholes, groundwater monitoring wells, and aquifer tubes within the scope of this SAP. The regulatory drivers and references to agreement documents for the activity are provided in the work plan.

2.1.3 Project and Task Description

Chapter 3 presents the field sampling plan. Tables 1-2 and 1-3 present the target analytes and COPCs. Section 1.6 provides guidance on the implementation schedule.

2.1.4 Quality Objectives and Criteria

The QA objective of this plan is to develop implementation guidance providing data of known and appropriate quality. Data quality indicators describe data quality, by evaluation against identified data needs, and by evaluation against the work activities identified in this SAP. The applicable QC guidelines, quantitative target limits, and levels of effort for assessing data quality are dictated by the intended use of the data and the nature of the analytical method. The principal data quality indicators are precision, bias or accuracy, representativeness, comparability, completeness, and sensitivity. These data quality indicators are defined for the purposes of this document in Table 2-1. The data quality indicators will be evaluated during the data quality assessment (DQA) process (Section 2.4.3).

Table 2-2 presents soil/aquifer sediment analytical performance requirements by location, based on the master target analyte list in Table 1-2. Table 2-3 presents analytical performance requirements for deep vadose zone soil/aquifer sediment samples from groundwater wells. Table 2-4 presents analytical performance requirements for water samples. Laboratory operations and analytical services will be in compliance with Volume 4 of HASQARD (DOE/RL-96-98) and any specific criteria identified in Tables 2-2 through 2-4. Criteria in Tables 2-2 through 2-4 take precedence over similar criteria in HASQARD. In consultation with the laboratory, the project lead, and/or others as appropriate, Sample Management and Reporting can approve changes to analytical methods.

Table 2-1. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Action Examples
Precision	The measure of agreement among repeated measurements of the same property under identical or substantially similar conditions; calculated either as the range or as the standard deviation. May also be expressed as a percentage of the mean of the measurements, such as relative range, relative percent difference, or relative standard deviation (coefficient of variation).	Use the same analytical instrument to make repeated analyses on the same sample. Use the same method to make repeated measurements of the same sample within a single laboratory or have two or more laboratories analyze identical samples with the same method. Split a sample in the field and submit both for sample handling, preservation and storage, and analytical measurements. Collect, process, and analyze co-located samples for information on sample acquisition, handling, shipping, storage, preparation, and analytical processes and measurements.	Field precision: At randomly selected locations, duplicate samples will be taken 1 per 20 samples per media. Laboratory precision: Analysis of laboratory duplicate or matrix spike duplicate.	If duplicate data do not meet objective: • Evaluate apparent cause (e.g., sample heterogeneity). • Request reanalysis or re-measurement • Qualify the data before use.
Accuracy	A measure of the overall agreement of a measurement to a known value; includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations.	Analyze a reference material or reanalyze a sample to which a material of known concentration or amount of pollutant has been added (a spiked sample); usually expressed either as percent recovery or as a percent bias.	Laboratory accuracy determination based on matrix spikes and matrix spike duplicates.	If recovery does not meet objective: • Qualify the data before use • Request re-analysis or re-measurement.

Table 2-1. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Action Examples
Representativeness	A qualitative term to express "the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition" (ANSI/ASQC S2-1995).	Evaluate whether measurements are made and physical samples collected in such a manner that the resulting data appropriately reflect the environment or condition being measured or studied.	Samples will be collected as described in the sampling design. Judgment sampling ensures areas most likely to be contaminated, based on current information, will be evaluated.	If results are not representative of the system sampled: • Identify the reason for result not being representative • Reject the data, or, if data are otherwise usable, qualify the data for limited use and define the portion of the system the data represent • Redefine sampling and measurement requirements and protocols • Resample and reanalyze.
Comparability	A qualitative term expressing the measure of confidence that one data set can be compared to another and can be combined for the decision(s) to be made.	Compare sample collection and handling methods, sample preparation and analytical procedures, holding times, stability issues, and QA protocols.	Sampling personnel will use the same sampling protocols. Samples will be submitted to the same laboratories when possible for analysis by the same methods, thus data results will be comparable.	If data are not comparable to other data sets: • Identify appropriate changes to data collection and/or analysis methods • Identify quantifiable bias, if applicable • Qualify the data as appropriate • Resample and/or reanalyze if needed • Revise sampling/analysis protocols to ensure future comparability.

Table 2-1. Data Quality Indicators

Data Quality Indicator	Definition	Example Determination Methodologies	Project Specific Information*	Corrective Action Examples
Completeness	A measure of the amount of valid data needed to be obtained from a measurement system.	Compare the number of valid measurements completed (samples collected or samples analyzed) with those established by the project's data needs.	The percent complete will be determined during data validation.	If data set does not meet completeness objective: • Identify appropriate changes to data collection and/or analysis methods • Identify quantifiable bias, if applicable • Qualify the data as appropriate • Resample and/or reanalyze if needed • Revise sampling/analysis protocols to ensure future comparability.
Sensitivity	The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.	Determine the minimum concentration or attribute to be measured by a method (method detection limit), by an instrument (instrument detection limit), or by a laboratory (quantitation limit). The practical quantitation limit is the lowest level that can be routinely quantified and reported by a laboratory.	Ensure that sensitivity, as measured by detection limits, is appropriate for the action levels.	If sensitivity does not meet objective: • Request reanalysis or re-measurement • Qualify/reject the data before use.

* Field sampling requirements are noted. Laboratories will follow requirements for use and interpretation of laboratory control samples.

ANSI/ASQC S2-1995, *Introduction to Attribute Sampling.*

Table 2-2. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from the 116-K-2 Trench

CAS	Analyte	EQL	Preliminary Cleanup Goals			Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
			Direct Exposure	Groundwater Protection	River Protection			
Performance Requirements for Field Measurements								
—	Gross gamma	10 pCi/g	N/A	N/A	N/A	Portable sodium iodide detector	±50	—[b]
—	Gross alpha	100 dpm/ 100 cm^2	N/A	N/A	N/A	Portable contamination detector	±50	—[b]
—	Gross beta	5,000 dpm/ 100 cm^2	N/A	N/A	N/A	Portable contamination detector	±50	—[b]
Performance Requirements for Laboratory Measurements (Radiological)								
10045-97-3	Cesium-137	0.1 pCi/g	6.2 pCi/g	NV[c]	NV[c]	GEA	±30[d]	70-130[d]
10198-40-0	Cobalt-60	0.05 pCi/g	1.4 pCi/g	NV[c]	NV[c]			
14683-23-9	Europium-152	0.1 pCi/g	3.3 pCi/g	NV[c]	NV[c]			
15585-10-1	Europium-154	0.1 pCi/g	3.0 pCi/g	NV[c]	NV[c]			
—	Plutonium-239/240	1 pCi/g	33.9 pCi/g	NV[c]	NV[c]	Isotopic-Pu	±30[d]	70-130[d]
10098-97-2	Strontium-90[e]	1 pCi/g	4.5 pCi/g	NV[c]	NV[c]	Gas flow proportional counting	±30[d]	70-130[d]
14762-75-5	Carbon-14	2 pCi/g	5.16 pCi/g	NV[c]	NV[c]	LSC – C-14	±30[d]	70-130[d]
13981-37-8	Nickel-63	30 pCi/g	4,026 pCi/g	NV[c]	NV[c]	LSC – Ni-63	±30[d]	70-130[d]
14133-76-7	Technetium-99	0.25 pCi/g	5.7 pCi/g	0.46 pCi/g	0.46 pCi/g	LSC – Tc-99	±30[d]	70-130[d]
10028-17-8	Tritium	10 pCi/g	510 pCi/g	15.8 pCi/g	15.8 pCi/g	LSC – Tritium	±30[d]	70-130[d]

Table 2-2. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from the 116-K-2 Trench

CAS	Analyte	EQL	Preliminary Cleanup Goals: Direct Exposure	Preliminary Cleanup Goals: Groundwater Protection	Preliminary Cleanup Goals: River Protection	Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
Performance Requirements for Laboratory Measurements (Nonradiological)								
16984-48-8	Fluoride	5 mg/kg	4,800 mg/kg	2,880 mg/kg	5,770 mg/kg	EPA 300.0 (anions by IC)	±30[f]	70-130[f]
14797-55-8	Nitrate (as N)[g]	2.5 mg/kg	128,000 mg/kg	40 mg/kg	80 mg/kg			
14797-65-0	Nitrite (as N)[g]	2.5 mg/kg	8,000 mg/kg	4 mg/kg	8 mg/kg			
7440-36-0	Antimony	6 mg/kg[h,i]	32 mg/kg	5.4 mg/kg	25.3 mg/kg	EPA 6010 (ICP metals)	±30[f]	70-130[f]
7440-38-2	Arsenic	10 mg/kg	20 mg/kg	20 mg/kg	20 mg/kg			
7440-39-3	Barium	2 mg/kg	16,000 mg/kg	1,650 mg/kg	3,300 mg/kg			
7440-41-7	Beryllium	0.5 mg/kg	160 mg/kg	63.2 mg/kg	126 mg/kg			
7440-43-9	Cadmium	0.5 mg/kg[i]	80 mg/kg	0.69 mg/kg	0.25 mg/kg			
7440-47-3	Chromium (total)	1 mg/kg	120,000 mg/kg	2,000 mg/kg	2,600 mg/kg			
7440-48-4	Cobalt	2 mg/kg	24 mg/kg	15.7 mg/kg	NV[c]			
7440-50-8	Copper	1 mg/kg	3,200 mg/kg	284 mg/kg	1,150 mg/kg			
7439-92-1	Lead	5 mg/kg	250 mg/kg	3,000 mg/kg	840 mg/kg			
7439-96-5	Manganese[j]	5 mg/kg	3,760 mg/kg	512 mg/kg	512 mg/kg			
7440-02-0	Nickel	4 mg/kg	1,600 mg/kg	130 mg/kg	357 mg/kg	EPA 6010 (ICP metals)	±30[f]	70-130[f]
7782-49-2	Selenium	10 mg/kg[h,i]	400 mg/kg	5.2 mg/kg	1.04 mg/kg			
7440-22-4	Silver	1 mg/kg[h,i]	400 mg/kg	13.6 mg/kg	0.884 mg/kg			
7440-28-0	Thallium	5 mg/kg[i]	5.6 mg/kg	1.59 mg/kg	4.46 mg/kg			
7440-62-2	Vanadium	2.5 mg/kg	560 mg/kg	2,240 mg/kg	NV[c]			
7440-66-6	Zinc	1 mg/kg	24,000 mg/kg	5,970 mg/kg	226 mg/kg			

Table 2-2. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from the 116-K-2 Trench

CAS	Analyte	EQL	Preliminary Cleanup Goals			Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
			Direct Exposure	Groundwater Protection	River Protection			
18540-29-9	Hexavalent Chromium	0.5 mg/kg	240 mg/kg	18.4 mg/kg	7.7 mg/kg	EPA 7196 (Cr VI)	±30[f]	70-130[f]
7439-97-6	Mercury	0.2 mg/kg	24 mg/kg	2.09 mg/kg	0.33 mg/kg	EPA 7471 (Hg cold vapor)	±30[f]	70-130[f]
71-43-2	Benzene	0.005 mg/kg[i]	18.2 mg/kg	0.00448 mg/kg	0.014 mg/kg	EPA 8260 (VOCs)	±30[k]	70-130[k]
67-66-3	Chloroform	0.005 mg/kg	164 mg/kg	0.038 mg/kg	0.0607 mg/kg			
7440-38-2	Arsenic	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
7440-39-3	Barium	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
7440-43-9	Cadmium	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
7440-47-3	Chromium	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
18540-29-9	Hexavalent Chromium	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 7196	±30[f]	70-130[f]
7439-92-1	Lead	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
7440-22-4	Silver	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
7782-49-2	Selenium	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[f]	70-130[f]
Performance Requirements for Physical Properties								
—	Grain-size (sieve) analysis	N/A	N/A	N/A	N/A	Field procedure or ASTM D422-63	N/A	N/A

Table 2-2. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from the 116-K-2 Trench

CAS	Analyte	EQL	Preliminary Cleanup Goals			Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
			Direct Exposure	Groundwater Protection	River Protection			
—	Porosity	N/A	N/A	N/A	N/A	Calculation	N/A	N/A
—	Sediment moisture content	N/A	N/A	N/A	N/A	ASTM D2216	N/A	N/A
—	Saturated hydraulic conductivity	N/A	N/A	N/A	N/A	ASTM D5084 for soil with low hydraulic conductivity (silt or a mud) ASTM D2434 for soil with high hydraulic conductivity (sand or sandy gravel)	N/A	N/A
—	Bulk density	N/A	N/A	N/A	N/A	ASTM D2937	N/A	N/A

a. Equivalent methods may be substituted. For EPA Method 300.0, see EPA/600/4-79/020, *Methods for Chemical Analysis of Water and Wastes*. For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*.

b. Field measurements have no specific accuracy quality control requirement except to perform checks to verify manufacturer's expected performance.

c. Generic residual radioactivity modeling reported in DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, predicts the contaminant will not reach groundwater within 1,000 years.

d. Accuracy criteria shown are for associated batch laboratory control sample percent recoveries. Except for GEA, additional accuracy criteria include analysis-specific evaluations performed for matrix spike, tracer, and/or carrier recoveries as appropriate to the method. The precision criteria shown are for batch laboratory replicate sample relative percent differences.

e. Strontium-90 will be assessed as total radioactive strontium.

f. Accuracy criteria specified are for calculated percent recoveries for associated analytical batch matrix spike samples. Additional accuracy evaluation based on statistical control limits for analytical batch laboratory control samples also is performed. The precision criteria shown are for batch laboratory replicate matrix spike or replicate sample relative percent differences.

g. Nitrate/Nitrite may also be reported as nitrogen in nitrate/nitrite by Method 353.1/353.2/353.3 with the reporting limits specified in Appendix A.

h. To meet or approach calculated cleanup goals, laboratories must use axial-based ("trace") ICP analytical methods. The laboratory also may substitute graphite furnace or ICP/mass spectrometry methods if required detection limits are met.

i. Calculated cleanup goals are below established analytical methodology capabilities. The analytical detection limits will be used for working levels, and will be periodically reviewed to establish if lower detection limit capabilities have become available.

j. The manganese preliminary remediation goal groundwater and river protection values are not risk based. They are predicated on a secondary maximum

Table 2-2. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from the 116-K-2 Trench

CAS	Analyte	EQL	Preliminary Cleanup Goals: Direct Exposure	Preliminary Cleanup Goals: Groundwater Protection	Preliminary Cleanup Goals: River Protection	Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)

contaminant level (taste and/or odor) and are based on Hanford site background.

k. Accuracy criteria shown are the minimum for associated batch laboratory control sample percent recoveries. Laboratories must meet statistically based control if more stringent. Additional accuracy criteria include analyte-specific evaluations performed for matrix spike, and surrogate recoveries as appropriate to the method. The precision criteria shown are for batch laboratory replicate matrix spike analysis relative percent differences. Tentatively identified compounds will be reported for Method SW-846 8260.

ASTM D422-63, *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D2216-05, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.*

ASTM D2434-68, *Standard Test Method for Permeability of Granular Soils (Constant Head).*

ASTM D2937-04, *Standard Test Method for Density of Soil in Place by the Drive Cylinder Method,*

ASTM D5084-03, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.*

CAS	=	Chemical Abstracts Service	ICP	=	inductively coupled plasma
dpm	=	disintegrations per minute	LSC	=	liquid scintillation counter
EQL	=	estimated quantitation limit	N/A	=	not applicable
GEA	=	gamma energy analysis	NV	=	no value
IC	=	ion chromatography	VOC	=	volatile organic compound

Table 2-3. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from Groundwater Wells

CAS	Analyte	EQL	Preliminary Cleanup Goals			Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
			Direct Exposure	Groundwater Protection	River Protection			
Performance Requirements for Field Measurements								
—	Gross gamma	10 pCi/g	N/A	N/A	N/A	Portable sodium iodide detector	±50	—[b]
—	Gross alpha	100 dpm/ 100 cm^2	N/A	N/A	N/A	Portable contamination detector	±50	—[b]
—	Gross beta	5,000 dpm/ 100 cm^2	N/A	N/A	N/A	Portable contamination detector	±50	—[b]
Performance Requirements for Laboratory Measurements (Radiological)								
10045-97-3	Cesium-137	0.1 pCi/g	6.2 pCi/g	NV[c]	NV[c]	GEA	±30[d]	70-130[d]
10198-40-0	Cobalt-60	0.05 pCi/g	1.4 pCi/g	NV[c]	NV[c]			
14683-23-9	Europium-152	0.1 pCi/g	3.3 pCi/g	NV[c]	NV[c]			
15585-10-1	Europium-154	0.1 pCi/g	3.0 pCi/g	NV[c]	NV[c]			
10098-97-2	Strontium-90[e]	1 pCi/g	4.5 pCi/g	NV[c]	NV[c]	Gas flow proportional counting	±30[d]	70-130[d]
Performance Requirements for Laboratory Measurements (Nonradiological)								
7440-36-0	Antimony	6 mg/kg[f,g]	32 mg/kg	5.4 mg/kg	25.3 mg/kg	EPA 6010 (ICP metals)	±30[h]	70-130[h]
7440-38-2	Arsenic	10 mg/kg	20 mg/kg	20 mg/kg	20 mg/kg			
7440-41-7	Beryllium	0.5 mg/kg	160 mg/kg	63.2 mg/kg	126 mg/kg			
7440-43-9	Cadmium	0.5 mg/kg[g]	80 mg/kg	0.69 mg/kg	0.25 mg/kg			
7440-47-3	Chromium (total)	1 mg/kg	120,000 mg/kg	2,000 mg/kg	2,600 mg/kg			
7440-50-8	Copper	1 mg/kg	3,200 mg/kg	284 mg/kg	1,150 mg/kg			
7439-92-1	Lead	5 mg/kg	250 mg/kg	3,000 mg/kg	840 mg/kg			

Table 2-3. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from Groundwater Wells

CAS	Analyte	EQL	Preliminary Cleanup Goals			Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
			Direct Exposure	Groundwater Protection	River Protection			
7439-96-5	Manganese[i]	5 mg/kg	3,760 mg/kg	512 mg/kg	512 mg/kg			
7440-02-0	Nickel	4 mg/kg	1,600 mg/kg	130 mg/kg	357 mg/kg			
7782-49-2	Selenium	10 mg/kg[f,g]	400 mg/kg	5.2 mg/kg	1.04 mg/kg			
7440-22-4	Silver	1 mg/kg[f,g]	400 mg/kg	13.6 mg/kg	0.884 mg/kg			
7440-28-0	Thallium	5 mg/kg[g]	5.6 mg/kg	1.59 mg/kg	4.46 mg/kg			
7440-62-2	Vanadium	2.5 mg/kg	560 mg/kg	2,240 mg/kg	NV[c]			
7440-66-6	Zinc	1 mg/kg	24,000 mg/kg	5,970 mg/kg	226 mg/kg			
7439-97-6	Mercury[j]	0.2 mg/kg	24 mg/kg	2.09 mg/kg	0.33 mg/kg	EPA 7471 (Hg cold vapor)	±30[g]	70-130[g]
18540-29-9	Hexavalent chromium	0.5 mg/kg	240 mg/kg	18.4 mg/kg	7.7 mg/kg	EPA 7196 (Cr VI)	±30[h]	70-130[h]
7440-38-2	Arsenic	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
7440-39-3	Barium	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
7440-43-9	Cadmium	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
7440-47-3	Chromium	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
18540-29-9	Hexavalent chromium	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 7196	±30[h]	70-130[h]

Table 2-3. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from Groundwater Wells

CAS	Analyte	EQL	Preliminary Cleanup Goals			Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)
			Direct Exposure	Groundwater Protection	River Protection			
7439-92-1	Lead	50 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
7440-22-4	Silver	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
7782-49-2	Selenium	100 µg/L	N/A	N/A	N/A	Batch leach followed by EPA 6010 (ICP metals)	±30[h]	70-130[h]
Performance Requirements for Physical Properties								
—	Grain-size (sieve) analysis	N/A	N/A	N/A	N/A	Field procedure or ASTM D422-63	N/A	N/A
—	Porosity	N/A	N/A	N/A	N/A	Calculation	N/A	N/A
—	Sediment moisture content	N/A	N/A	N/A	N/A	ASTM D2216	N/A	N/A
—	Saturated hydraulic conductivity	N/A	N/A	N/A	N/A	ASTM D5084 for soil with low hydraulic conductivity (silt or a mud) ASTM D2434 for soil with high hydraulic conductivity (sand or sandy gravel)	N/A	N/A
—	Bulk density	N/A	N/A	N/A	N/A	ASTM D2937	N/A	N/A

a. Equivalent methods may be substituted. For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*.

b. Field measurements have no specific accuracy quality control requirement except to perform checks to verify manufacturer's expected performance.

c. Generic residual radioactivity modeling reported in DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, predicts the contaminant will not reach groundwater within 1,000 years.

d. Accuracy criteria shown are for associated batch laboratory control sample percent recoveries. Except for GEA, additional accuracy criteria include analysis-specific evaluations performed for matrix spike, tracer, and/or carrier recoveries as appropriate to the method. The precision criteria shown are for

Table 2-3. Analytical Performance Requirements for Soil/Aquifer Sediment Samples from Groundwater Wells

CAS	Analyte	EQL	Preliminary Cleanup Goals: Direct Exposure	Preliminary Cleanup Goals: Groundwater Protection	Preliminary Cleanup Goals: River Protection	Analytical Method[a]	Precision Requirement (%)	Accuracy Requirement (%)

batch laboratory replicate sample relative percent differences.

e. Strontium-90 will be assessed as total radioactive strontium.

f. To meet or approach calculated cleanup goals, laboratories must use axial-based ("trace") ICP analytical methods. The laboratory also may substitute graphite furnace or ICP mass spectrometry methods if required detection limits are met.

g. Calculated cleanup goals are below established analytical methodology capabilities. The analytical detection limits will be used for working levels, and will be periodically reviewed to establish if lower detection limit capabilities have become available.

h. Accuracy criteria specified is for calculated percent recoveries for associated analytical batch matrix spike samples. Additional accuracy evaluation based on statistical control limits for analytical batch laboratory control samples is also performed. The precision criteria shown is for batch laboratory replicate matrix spike or replicate sample relative percent differences.

i. The manganese preliminary remediation goal groundwater and river protection values are not risk based. They are predicated on a secondary maximum contaminant level (taste and/or odor) and are based on Hanford site background.

j. Mercury is to be analyzed for only at Wells R3 and R4.

ASTM D422-63, *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM D2216-05, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.*

ASTM D2434-68, *Standard Test Method for Permeability of Granular Soils (Constant Head).*

ASTM D2937-04, *Standard Test Method for Density of Soil in Place by the Drive Cylinder Method,*

ASTM D5084-03, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.*

CAS = Chemical Abstracts Service
dpm = disintegrations per minute
EQL = estimated quantitation limit
GEA = gamma energy analysis
IC = ion chromatography
ICP = inductively coupled plasma
LSC = liquid scintillation counter
N/A = not applicable
NV = no value

Table 2-4. Analytical Performance Requirements for Water Samples

CAS	Analyte	Analytical Method[a]	EQL	Precision Requirement (%)[b]	Accuracy Requirement (%)[b]	Action Level	Action Level Basis
Performance Requirements for Field Measurements							
—	Oxidation reduction potential	REDOX PROBE	N/A	—[c]	—[c]	N/A	N/A
—	pH measurement	PROBE	0.5 pH unit	—[c]	—[c]	N/A	N/A
—	Specific conductance	PROBE	1 µS/cm	—[c]	—[c]	N/A	N/A
—	Temperature	PROBE	--	—[c]	—[c]	N/A	N/A
—	Dissolved oxygen	PROBE	--	—[c]	—[c]	N/A	N/A
—	Turbidity	PROBE	0.1 NTU	—[c]	—[c]	N/A	N/A
Performance Requirements for Laboratory Measurements (Radiological)							
14762-75-5	Carbon-14	LSC - Carbon-14	200 pCi/L	±30	70-130	2,000 pCi/L	40 CFR 141.66
10098-97-2	Strontium-90	Strontium 89/90 – Sr-90	2 pCi/L	±30	70-130	8 pCi/L	40 CFR 141.66
10028-17-8	Tritium	LSC - Tritium (H-3)	400 pCi/L	±30	70-130	20,000 pCi/L	40 CFR 141.66
Performance Requirements for Laboratory Measurements (Nonradiological)							
7440-36-0	Antimony	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	5 µg/L	±20	80-120	5.6 µg/L	Human Health for the Consumption of Water + Organism
7440-38-2	Arsenic	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	4 µg/L[d]	±20	80-120	0.018 µg/L	Human Health for the Consumption of Water + Organism
7440-39-3	Barium	EPA 6010 (ICP metal)	20 µg/L	±20	80-120	1,000 µg/L	Human Health for the Consumption of Water + Organism
7440-41-7	Beryllium	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	2 µg/L	±20	80-120	4.0 µg/L	40 CFR 141.62

Table 2-4. Analytical Performance Requirements for Water Samples

CAS	Analyte	Analytical Method[a]	EQL	Precision Requirement (%)[b]	Accuracy Requirement (%)[b]	Action Level	Action Level Basis
7440-43-9	Cadmium	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	2 µg/L[d]	±20	80-120	0.25 µg/L	Freshwater CCC
7440-47-3	Chromium	EPA 6010 (ICP metal)	10 µg/L	±20	80-120	74 µg/L	Freshwater CCC
7440-48-4	Cobalt	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	4 µg/L	±20	80-120	4.8 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-50-8	Copper	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	8 µg/L	±20	80-120	9 µg/L	Freshwater CCC
18540-29-9	Hexavalent chromium	EPA 7196	10 µg/L	±20	80-120	10 µg/L	WAC 173-201A
7439-92-1	Lead	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	2 µg/L	±20	80-120	2.5 µg/L	Freshwater CCC
7439-96-5	Manganese	EPA 6010 (ICP metal)	5 µg/L	±20	80-120	50 µg/L	40 CFR 143.3
7439-97-6	Mercury	EPA 7470 or 200.8	0.5 µg/L[d]	±20	80-120	0.012 µg/L	WAC 173-201A
7440-02-0	Nickel	EPA 6010 (ICP metal)	40 µg/L	±20	80-120	52 µg/L	Freshwater CCC
7782-49-2	Selenium	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	4 µg/L	±20	80-120	5 µg/L	Freshwater CCC
7440-28-0	Thallium	Trace – ICP (6010) or ICP/MS (6020 or 200.8)	2 µg/L[d]	±20	80-120	0.24 µg/L	Human Health for the Consumption of Water + Organism
7440-61-1	Uranium	Total Uranium (chemical)	1 µg/L	±20	80-120	30 µg/L	40 CFR 141.62
7440-62-2	Vanadium	EPA 6010 (ICP metal)	25 µg/L	±20	80-120	112 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)
7440-66-6	Zinc	EPA 6010 (ICP metal)	10 µg/L	±20	80-120	120 µg/L	Freshwater CCC
75-35-4	1,1-Dichloroethene	EPA 8260 (VOCs)	2 µg/L[d]	±20	80-120	0.073 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)

Table 2-4. Analytical Performance Requirements for Water Samples

CAS	Analyte	Analytical Method[a]	EQL	Precision Requirement (%)[b]	Accuracy Requirement (%)[b]	Action Level	Action Level Basis
79-00-5	1,1,2-Trichloroethane	EPA 8260 (VOCs)	2 µg/L[d]	±20	80-120	0.59 µg/L	Human Health for the Consumption of Water + Organism
71-43-2	Benzene	EPA 8260 (VOCs)	1.5 µg/L[d]	±20	80-120	0.795 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)
56-23-5	Carbon tetrachloride	EPA 8260 (VOCs)	1 µg/L[d]	±20	80-120	0.23 µg/L	Human Health for the Consumption of Water + Organism
67-66-3	Chloroform	EPA 8260 (VOCs)	5 µg/L	±20	80-120	5.7 µg/L	Human Health for the Consumption of Water + Organism
79-01-6	Trichloroethene	EPA 8260 (VOCs)	1 µg/L[d]	±20	80-120	0.49 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)
127-18-4	Tetrachloroethene	EPA 8260 (VOCs)	5 µg/L[d]	±20	80-120	0.081 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)
75-01-4	Vinyl chloride	EPA 8260 (VOCs)	5 µg/L[d]	±20	80-120	0.025 µg/L	Human Health for the Consumption of Water + Organism
16887-00-6	Chloride	EPA 300.0 (anions by IC)	200 µg/L	±20	80-120	230,000 µg/L	Freshwater CCC
16984-48-8	Fluoride	EPA 300.0 (anions by IC)	500 µg/L	±20	80-120	960 µg/L	WAC 173-340-720(4)(b)(iii)(A) and (B)
14797-55-8	Nitrate	EPA 300.0 (anions by IC)	250 µg/L	±20	80-120	10,000 µg/L	40 CFR 141.62
14797-65-0	Nitrite	EPA 300.0 (anions by IC)	250 µg/L	±20	80-120	1,000 µg/L	40 CFR 141.62
14808-79-8	Sulfate	EPA 300.0 (anions by IC)	500 µg/L	±20	80-120	250,000 µg/L	40 CFR 143.3

a. Equivalent methods may be substituted. For the three-digit EPA method, see EPA/600/4-79/020, *Methods for Chemical Analysis of Water and Wastes*. For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods*. Tentatively identified compounds will be reported for Method SW-846 8260.

b. Accuracy criteria for associated batch matrix spike percent recoveries. Evaluation based on statistical control of laboratory control samples also is

Table 2-4. Analytical Performance Requirements for Water Samples

CAS	Analyte	Analytical Method[a]	EQL	Precision Requirement (%)[b]	Accuracy Requirement (%)[b]	Action Level	Action Level Basis

performed. Precision criteria for batch laboratory replicate matrix spike analyses or replicate sample analyses.

c. Field measurements have no specific accuracy quality control requirement except to perform checks to verify manufacturer's expected performance.

d. Calculated cleanup goals are below established analytical methodology capabilities. The analytical detection limits will be used for working levels, and will be periodically reviewed to establish if lower detection limit capabilities have become available.

"National Recommended Water Quality Criteria" (EPA, 2009)

CAS	=	Chemical Abstract Services	ICP	=	inductively coupled plasma
CCC	=	criterion continuous concentration	MS	=	mass spectrometry
EQL	=	estimated quantitation limit	N/A	=	not applicable
GEA	=	gamma energy analysis	NTU	=	nephelometric turbidity units
IC	=	ion chromatography	VOC	=	volatile organic compound

2.1.5 Special Training and Certification

A graded approach is used to ensure that workers receive a level of training commensurate with responsibilities that complies with applicable DOE orders and government regulations. The sampling lead and drilling lead, in coordination with line management, will ensure that field personnel meet special training requirements.

Typical training requirements or qualifications have been instituted by the primary contractor management team to meet training requirements imposed by the contract, regulations, DOE orders, DOE contractor requirements documents, American National Standards Institute/American Society of Mechanical Engineers, and *Washington Administrative Code*. For example, the environmental, safety, and health training program provides workers with the knowledge and skills necessary to execute assigned duties safely. Field personnel typically will have completed the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training and supervised 24-hour hazardous waste site experience
- 8-hour hazardous waste worker refresher training (as required)
- Hanford general employee radiation training
- Hanford general employee training
- Radiological worker training.

Project-specific safety training, geared specifically to the project and the day's activity, will be provided. Project-specific training includes the following:

- Training requirements or qualifications needed by sampling personnel will be in accordance with QA requirements.
- Samplers are required to have training and/or experience in the type of sampling being performed in the field, including soil/aquifer sediment sampling and water sampling.
- The Radiation Protection Program establishes qualification requirements for radiological control technicians. The radiological control technicians assigned to these activities will be qualified through the prescribed training program and will undergo ongoing training and qualification activities.

In addition, pre-job briefings will be performed to evaluate an activity and its hazards by considering many factors, including the following:

- Objective of the activities
- Individual tasks to be performed
- Hazards associated with the planned tasks
- Controls applied to mitigate the hazards
- Environment in which the job will be performed
- Facility where the job will be performed
- Equipment and material required
- Safety procedures applicable to the job
- Training requirements for individuals assigned to perform the work
- Level of management control

- Proximity of emergency contacts.

Training records are maintained for each individual in an electronic training record database. The contractor training organization maintains the training records system. Line management will be used to confirm an individual employee's training is appropriate and up-to-date before performing any fieldwork.

2.1.6 Documents and Records

The project lead is responsible for ensuring that the current version of the SAP is being used and for providing any updates to field personnel. The administrative document control process maintains version control. Before implementation, DOE and the lead regulatory agency will review and approve changes to the sampling plan that affect the data needs. Information pertinent to sampling and analysis will be recorded in field checklists and bound logbooks in accordance with existing sample collection protocols in accordance with DOE/RL-96-98.

The sampling lead or drilling lead is responsible for ensuring that the field instructions are maintained up-to-date and aligned with any revisions or other approved changes to the SAP. The sampling lead or drilling lead will ensure that deviations from the SAP or problems encountered in the field are documented appropriately (e.g., in the field logbook or on nonconformance report forms) in accordance with internal corrective action procedures.

The project lead, drilling lead, sampling lead, or designee will be responsible for communicating field corrective action requirements and for ensuring immediate corrective actions are applied to field activities. Table 2-5 presents the change control for this project.

Table 2-5. Change Control for 100-K Decision Unit Project

Type of Change	Action	Documentation
By drilling lead or sampling lead: • Increasing sampling frequency based on field screening results or visual observations.	No SAP revision necessary	Field logbooks or operational records
By project management: • Change in target analytes or COPCs • Adding or removing wells • Significant increases or decreases in sampling frequency.	Revise SAP (can be accomplished with Tri-Party Agreement Change Notice); obtain regulatory approval; distribute plan	Revised plan or approved Tri-Party Agreement Change Notice.

Logbooks are required for field activities. The logbook must be identified with a unique project name and number. Individuals responsible for logbooks will be listed. Only authorized persons may make entries in logbooks. Logbooks will be signed by the sampling lead, drilling lead, cognizant scientist/engineer, or other responsible individual. Logbooks will be permanently bound, waterproof, and ruled with sequentially numbered pages. Pages will not be removed from logbooks for any reason.

Logbook entries will be made in indelible ink. Corrections will made by marking the erroneous data through with a single line, entering the correct data, and initialing and dating the changes.

The project lead is responsible for ensuring that a project file is properly maintained. The project file will contain the records or references to their storage locations. The project file will include the following, as appropriate:

- Field logbooks or operational records
- Data forms
- Global positioning system data
- Chain-of-custody forms
- Sample receipt records
- Inspection or assessment reports and corrective action reports
- Interim progress reports
- Final reports
- Forms required by WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," and the master drilling contract
- Laboratory data packages
- RI report
- Verification and validation report.

The laboratory is responsible for maintaining, and having available upon request, the following:

- Analytical logbooks
- Raw data and QC sample records
- Standard reference material and/or proficiency test sample data
- Instrument calibration information.

Records may be stored in either electronic or hard copy format. Documentation and records, regardless of medium or format, are controlled in accordance with internal work requirements and processes to ensure the accuracy and availability of stored records. Records required by the Tri-Party Agreement will be managed in accordance with the requirements of the Agreement.

2.2 Data Generation and Acquisition

The following sections address data generation and acquisition to ensure that the project's methods for sampling, measurement, and analysis; data collection or generation; data handling; and QC activities are appropriate and documented.

2.2.1 Sampling Process Design (Experimental Design)

The sampling design is judgmental sampling. In judgmental sampling, sampling unit selection (e.g., the number and location, and/or timing of collecting samples) is based on knowledge of the feature or condition under investigation and on professional judgment. Judgmental sampling is distinguished from probability-based sampling in that inferences are based on professional judgment, not statistical scientific theory. Therefore, conclusions about the target population are limited and depend entirely on the validity

and accuracy of professional judgment; probabilistic statements about parameters are not possible. Section 3.5 provides the types, number, and location of samples.

2.2.2 Sampling Methods

Section 3.6 describes the sampling methods, The specific information includes the following:

- Field sampling methods
- Corrective actions for sampling activities (ultimately, the task lead will be responsible for corrective action)
- Decontamination of sampling equipment
- Radiological field data.

2.2.3 Sample Handling and Custody

A sampling and data tracking database is used to track the samples from the point of collection through the laboratory analysis process. Samplers should note any anomalies (e.g., sample appears unusual or sample is sludge) with the samples to prevent batching across similar matrices. If anomalies are found, the samplers should write "DO NOT BATCH" on the chain-of-custody form and inform Sample Management and Reporting.

Laboratory analytical results are entered and maintained in HEIS. HEIS sample numbers are issued to the sampling organization for the project. Each chemical, radiological, and physical properties sample is identified and labeled with a unique HEIS sample number. Section 3.7 provides specific sample handling information:

- Container packaging
- Container labeling
- Sample custody requirements
- Sample transportation.

Sample custody during laboratory analysis is addressed in the applicable laboratory standard operating procedures. Laboratory custody procedures will ensure that sample integrity and identification are maintained throughout the analytical process. Storage of samples at the laboratory will be consistent with laboratory instructions prepared by Sample Management and Reporting.

2.2.4 Analytical Methods

Tables 2-2 through 2-4 provide information on analytical methods. These analytical methods are controlled in accordance with the laboratory's QA plan and the requirements of this QAPjP. The primary contractor or vadose zone contractor, as applicable, participates in oversight of offsite analytical laboratories to qualify them for performing Hanford Site analytical work.

If the laboratory uses a nonstandard or unapproved method, then the laboratory must provide method validation data to confirm that the method is adequate for the intended use of the data. This includes information such as determination of detection limits, quantitation limits, typical recoveries, and analytical precision and bias. Deviations from the analytical methods noted in Tables 2-2 through 2-4 must be approved by Sample Management and Reporting in consultation with project lead.

Laboratories providing analytical services in support of this SAP will have in place a corrective action program that addresses analytical system failures and documents on the effectiveness of corrective

actions. Issues affecting analytical results are to be resolved by Sample Management and Reporting in coordination with the project lead.

Batch leach contacting tests will be performed on select soil and aquifer sediment samples. Standardized batch leach tests are done using a leach procedure based on ASTM D-3987-06, *Standard Test Method for Shake Extraction of Solid Waste with Water*. The procedure recommends using soil screened through 3/8-inch mesh. Demineralized water, pH adjusted according to EPA's West Coast recommendation, will be used as the leaching liquid. Selected soil samples will be leached at soil to water weight ratios of 1 to 1, 1 to 2.5, and 1 to 5 with one test in each series duplicated. Soil/water mixtures are placed in clean water-tight sample containers (extraction vessels) and rotated end-over-end through the vessel centerline at a rate of about 30 rotations per minute for 18 hours. Following 18 hours of mixing, the soil/water slurry is filtered using a 0.45-μm filter. The leachate will be analyzed for pH, conductivity, and metals or other contaminants of interest. Details of the test will be discussed with the laboratory personnel before analysis.

Grain-size (sieve) analysis may be performed as a field procedure or in the laboratory based on ASTM D422-63, *Standard Test Method for Particle-Size Analysis of Soils*. Field grain size analysis may be used to select well screens for groundwater wells.

2.2.5 Quality Control

The QC procedures must be followed in the field and laboratory to ensure that reliable data are obtained. Field personnel will collect QC samples to evaluate the potential for cross-contamination and to provide information pertinent to field variability. Field QC for sampling will require the collection of field duplicates, trip or field transfer blanks, equipment blanks, and field splits. Laboratory QC samples estimate the precision and bias of the analytical data. Table 2-6 summarizes field and laboratory QC samples. Additional QC samples may be collected if conditions arise.

Table 2-6. Project Quality Control Checks

QC Sample Type	Purpose	Frequency
Field Quality Control		
Full trip blank	Assess contamination from containers or transportation	One per 20 samples *per media sampled.*
Field transfer blank	Assess contamination from sampling site	One per day when volatile organic compounds are sampled *per media sampled.*
Equipment rinsate	Verify adequacy of sampling equipment decontamination	As needed.[a] If only disposable equipment is used or equipment is dedicated to a particular well, then an equipment rinsate blank is not required. Otherwise, 1 per 20 samples *per media sampled.*
Field duplicates	Estimate precision, including sampling and analytical variability	One per batch,[b] 20 samples maximum *per media sampled.*
Field split	Estimate precision, including sampling, analytical, and inter-laboratory variability	At a minimum, one per analytical method, per media for analyses performed where detection limit and precision and accuracy criteria have been defined in the Performance Requirements Tables.
Laboratory Quality Control[b]		

Table 2-6. Project Quality Control Checks

QC Sample Type	Purpose	Frequency
Method blank	Assess response of an entire laboratory analytical system	One per batch,[b] 20 samples maximum, or as identified by the method guidance *per media sampled.*
Matrix spike	Identify analytical (preparation and analysis) bias; possible matrix affect on the analytical method used	When required by the method guidance, one per batch,[b] 20 samples maximum, or as identified by the method guidance, *per media sampled.*
Matrix duplicate or matrix spike duplicate	Estimate analytical bias and precision	When required by the method guidance, one per batch,[b] 20 samples maximum, or as identified by the method guidance, *per media sampled.*
Laboratory control samples	Assess method accuracy	One per batch,[b] 20 samples maximum, or as identified by the method guidance *per media sampled.*
Surrogates	Estimate recovery/yield	When required by the method guidance, as identified by the method guidance.

a. Whenever a new type of non-dedicated equipment is used, an equipment blank will be collected every time sampling occurs until it can be shown less frequent collection of equipment blanks is adequate to monitor the decontamination procedure for the non-dedicated equipment.

b. Batching across projects is allowed for similar matrices (e.g., Hanford Site groundwater).

2.2.5.1 Field QC Samples

The field QC sample types are discussed within this section.

Full trip blanks are samples prepared by the sampling team before traveling to the sampling site. The preserved bottle set is identical to the set collected in the field, but it is filled with reagent water or silica sand, as appropriate to the primary sample media. The bottles are sealed and transported, unopened, to the field in the same storage container used for samples collected the same day. Full trip blanks are typically analyzed for the same constituents as the samples from the associated sampling event. However, the analytical list for full trip blanks on soil may be limited to volatile organic analysis, semivolatile organic analysis, and total petroleum hydrocarbons, depending on resolution/determination of the target analyte list. Full trip blanks are not required on aquifer sediments being analyzed for metals, mercury, and hexavalent chromium.

Field transfer blanks are preserved volatile organic analysis sample containers filled at the sample collection site with reagent water or silica sand, as appropriate to the primary sample media, transported to the field. The samples are prepared during the sampling to evaluate potential contamination caused by field conditions. After collection, field transfer blank bottles are sealed and placed in the same storage container with the samples from the associated sampling event. The field transfer blank samples are analyzed for volatile organic compounds (VOCs) only.

A minimum of one field transfer blank will be collected at each borehole where the samples will undergo volatile organic analysis. The field transfer blank will consist of reagent water or silica sand, as appropriate to the primary sample media, added to clean sample containers at the location where the VOC sample was collected. The field transfer blank will be batched with samples for which volatile organic analysis is being requested.

Equipment rinsate blanks are collected for sampling devices reused to assess the adequacy of the decontamination process. Equipment blanks will consist of silica sand or reagent water poured over the decontaminated sampling equipment and placed in containers, as identified on the project sampling authorization form. If disposable (i.e., single-use) equipment is used, equipment blanks will not be required.

For the field transfer blanks (i.e., full trip blanks, field transfer blanks, and equipment rinsate), results above two times the method detection limit are identified as suspected contamination. However, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is five times the method detection limit. For radiological data, blank results are flagged if they are greater than two times the total minimum detectable activity.

Field duplicate samples are used to evaluate sample consistency and the precision of field sampling methods. Field duplicates are independent samples that are collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently.

A minimum of one soil and one aquifer sediment field duplicate will be collected for each day of sampling. The duplicate should be collected generally from an area expected to have some contamination so valid comparisons between the samples can be made (e.g., at least some of the constituents will be above the detection limit). When sampling is performed from a split spoon, VOC samples and VOC duplicate samples are collected directly from the sampler. The remaining soil/aquifer sediment is then composited in a stainless steel mixing bowl. The soil/aquifer sediment sample and duplicate sample are collected from this composited material.

Evaluation of the results can provide an indication of intra-laboratory variability. Large relative percent differences can be an indication of laboratory performance problems and should be investigated. Only those field duplicates with at least one result greater than five times the method detection limit or minimum detectable activities are evaluated.

A **field split** is a representative sample(s) from a sampling event(s) sent to a third-party laboratory (i.e., reference laboratory). Evaluation of the results can provide an indication of inter-laboratory variability. Large relative percent differences can be an indication of laboratory performance problems and should be investigated. Only those results greater than five times the method detection limit or minimum detectable activity at both laboratories are evaluated.

2.2.5.2 Laboratory QC Samples

The laboratory QC samples (e.g., method blanks, laboratory control sample/blank spike, and matrix spike) are defined for three-digit EPA methods (see EPA/600/4-79/020, *Methods for Chemical Analysis of Water and Wastes,* and EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*) and for the four-digit EPA methods (see SW-846) and will be run at the frequency specified in respective reference. QC checks outside of control limits will be reflected in the data validation process and during the DQA described in Section 2.4.

2.2.5.3 QC Requirements

If only disposable equipment is used or equipment is dedicated to a particular well, then an equipment rinsate blank is not required. If no VOC samples are collected, then a field transfer blank is not required. Field transfer blanks are not required when simply transferring samples to the field gas chromatograph for analysis.

Field duplicates must agree within 20 percent, as measured by the relative percent difference, to be acceptable. Only those field duplicates with at least one result greater than five times the appropriate detection limit are evaluated. Unacceptable field duplicate results are also flagged with a "Q" qualifier in the HEIS database.

For chemical analyses, the acceptance criteria for laboratory duplicates, matrix spikes, matrix spike duplicates, surrogates, and laboratory control samples are stated in Tables 2-2 through 2-4.

Holding time is the elapsed time period between sample collection and analysis. Exceeding required holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Required holding times depend on the analytical method, as specified for three-and four-digit EPA methods (EPA/600/4-79/020; EPA/600/R-94/111; SW-846). Data associated with exceeded holding times are flagged.

Additional QC measures include laboratory audits and participation in nationally based performance evaluation studies. The laboratories participate in national studies such as the EPA-sanctioned water pollution and water supply performance evaluation studies. The Soil and Groundwater Remediation Project periodically audits the analytical laboratories to identify and solve quality problems or to prevent such problems. Audit results are used to improve performance. Summaries of audit results and performance evaluation studies are presented in the annual groundwater monitoring report (e.g., DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). Failure of QC will be determined and evaluated during data validation and DQA process. Data will be qualified, as appropriate.

2.2.6 Instrument and Equipment Testing, Inspection, and Maintenance

Equipment used for collection, measurement, and testing should meet the applicable standards (e.g., American Society for Testing and Materials) or have been evaluated as acceptable and valid in accordance with the procedures, requirements, and specifications. The sampling lead or equivalent will ensure that the data generated from instructions using a software system are backed up and/or downloaded regularly. Software configuration will be acceptance tested before use in the field.

Measurement and testing equipment used in the field or in the laboratory directly affects the quality of analytical data will be subject to preventive maintenance measures to ensure minimization of measurement system downtime. Laboratories and onsite measurement organizations must maintain and calibrate their equipment. Maintenance requirements (such as documentation of routine maintenance) will be included in the individual laboratory and the onsite organization QA plan or operating procedures, as appropriate. Maintenance of laboratory instruments will be performed in a manner consistent with the three- and four-digit EPA methods (EPA/600/4-79/020; EPA/600/R-94/111; SW-846), or with auditable Hanford Site and contractual requirements. Consumables, supplies, and reagents will be reviewed in accordance with SW-846 requirements and will be appropriate for their use.

2.2.7 Instrument and Equipment Calibration and Frequency

Section 3.4 provides specific field equipment calibration information. Analytical laboratory instruments and measuring equipment are calibrated in accordance with the laboratory's QA plan.

2.2.8 Inspection and Acceptance of Supplies and Consumables

Supplies and consumables used in support of sampling and analysis activities will be procured in accordance with internal work requirements and processes described in the contractor acquisition system. Responsibilities and interfaces necessary to ensure items are procured/acquired for the contractor to meet the specific technical and quality requirements must be in place. The procurement system ensures

purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users before use. Supplies and consumables procured by the analytical laboratories are procured, checked, and used in accordance with the laboratories' QA plans.

2.2.9 Non-Direct Measurements

Non-direct measurements include data obtained from sources such as computer databases, programs, literature files, and historical databases. Non-direct measurements will not be evaluated as part of this activity.

2.2.10 Data Management

Sample Management and Reporting, in coordination with the project lead, is responsible for ensuring analytical data is appropriately reviewed, managed, and stored in accordance with the applicable programmatic requirements governing data management procedures. Electronic data access, when appropriate, will be through a database (e.g., HEIS or a project-specific database). Where electronic data are not available, hard copies will be provided in accordance with Section 9.6 of the *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b).

Laboratory errors are reported to Sample Management and Reporting routinely. For reported laboratory errors, a sample issue resolution form will be initiated in accordance with contractor procedures. This process is used to document analytical errors and to establish resolution with the project lead. The sample issue resolution forms become a permanent part of the analytical data package for future reference and for records management.

Planning for sample collection and analysis will be in accordance with the programmatic requirements governing fixed laboratory sample collection activities, as discussed in sampling procedures. If specific procedures do not exist for a particular work evolution, or if it is determined that additional guidance is needed to complete certain tasks, a work package will be developed to adequately control the activities, as appropriate. Examples of sampling procedure requirements include activities associated with the following:

- Chain-of-custody/sample analysis requests
- Project and sample identification for sampling services
- Control of certificates of analysis
- Logbooks
- Checklists
- Sample packaging and shipping.

When this SAP is implemented, approved work control packages and procedures will be used to document field activities, including radiological and nonradiological measurements,. Field activities will be recorded in the field logbook. Examples of the types of documentation for field radiological data include the following:

- Instructions regarding the minimum requirements for documenting radiological controls information in accordance with 10 CFR 835, "Occupational Radiation Protection"
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of primary contractor radiological records
- Minimum standards and practices necessary for preparing, performing, and retaining radiological-related records

- Indoctrination of personnel on the development and implementation of sample plans
- Requirements associated with preparing and transporting regulated material
- Daily reports of radiological surveys and measurements collected during field investigation activities. Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results.

2.3 Assessment and Oversight

The elements included in assessment and oversight address the activities for assessing the effectiveness of project implementation and associated QA and QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

2.3.1 Assessments and Response Actions

Contractor management, regulatory compliance, quality, and/or Health and Safety organizations may conduct random surveillance and assessments to verify compliance with the requirements outlined in this SAP, project work packages, the QAPjP, procedures, and regulatory requirements. Section 2.4 discusses the only planned assessment, a DQA, for the activities identified in this SAP. The results of the DQA will be provided to the project lead.

If circumstances arise in the field dictating the need for additional assessment activities, then additional assessments would be performed. Deficiencies identified by these assessments will be reported in accordance with existing programmatic requirements. The project's line management chain coordinates corrective actions/deficiencies in accordance with the contractor QA program, the corrective action management program, and associated procedures implementing these programs.

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with the laboratories' QA plans. The contractor conducts oversight of offsite analytical laboratories and qualifies the laboratories for performing Hanford Site analytical work.

2.3.2 Reports to Management

Reports to management on data quality issues will be made if these issues are identified. Issues reported by the laboratories are communicated to Sample Management and Reporting, which initiates a sample issue resolution form in accordance with contractor procedures. This process is used to document analytical or sample issues and to establish resolution with the project lead. At the end of the project, a DQA report will be prepared to determine if the type, quality, and quantity of collected data met the quality objectives described in this SAP.

2.4 Data Validation and Usability

The elements under data validation and usability address the QA activities occurring after the data collection phase of the project is completed. Implementation of these elements determines whether the data conform to the specified criteria, thus satisfying the project objectives.

2.4.1 Data Review, Verification, and Validation

The criteria for verification include, but are not limited to, review for completeness (samples were analyzed as requested), use of the correct analytical method/ procedure, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors. Laboratory personnel may perform data verification.

Data validation will be performed to ensure that the data quality goals established during the planning phase have been achieved. Data validation will be in accordance with internal procedures. The criteria for data validation are based on a graded approach. The primary contractor has defined five levels of validation, Level A through Level E. Level A is the lowest level and is the same as verification. Level E is a 100 percent review of data (e.g., calibration data; calculations of representative samples from the dataset).Validation will be performed to contractor Level C, which is a review for the QC data. Level C validation specifically requires verification of deliverables; requested versus reported analyses; and qualification of the results based on analytical holding times, method blank results, matrix spike/matrix spike duplicates, surrogate recoveries, duplicates, and analytical method blanks. Level C validation will be performed on at least 5 percent of the data by matrix and analyte group. Analyte group refers to categories, such as radionuclides, VOCs, semivolatile organic compounds, polychlorinated biphenyls, metals, and anions. The goal is to cover the various analyte groups and matrices during the validation.

Relative to analytical data in sample media, physical data and/or field screening results are of lesser importance in making inferences of risk. Field QA/QC will be reviewed to ensure that physical property data and/or field screening results are useable.

2.4.2 Verification and Validation Methods

Validation activities will be based on EPA functional guidelines. Data validation may be performed by Sample Management and Reporting and/or by a party independent of both the data collector and the data user. Data validation qualifiers must be compatible with the HEIS database.

When outliers or questionable results are identified, additional data validation will be performed. The additional validation will be performed for up to 5 percent of the statistical outliers and/or questionable data. The additional validation will begin with Level C and may increase to Levels D and E as needed to ensure that data are usable. Level C validation is review of the QC data, while Levels D and E include review of calibration data and calculations of representative samples from the dataset. Data validation will be documented in data validation reports. An example of questionable data is if the positive detections are greater than the practical quantitation limit or reporting limit in soil/aquifer sediment from a site that should not have exhibited contamination. Similarly, results below background would not be expected and could trigger a validation inquiry. The determination of data usability will be conducted and documented in a DQA report. Data validation will be documented in data validation reports, which will be included in the project file.

2.4.3 Reconciliation with User Requirements

The DQA process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the data evaluation is to determine if quantitative data are of the correct type and are of adequate quality and quantity to meet the project data needs. The results of the DQA will be used in interpreting the data and determining if the objectives of this activity have been met. The DQA will be in accordance with EPA/240/B-06/002, *Data Quality Assessment: A Reviewer's Guide,* and EPA/240/B-06/003, *Data Quality Assessment: Statistical Methods for Practitioners.*

2.4.4 Corrective Actions

The responses to data quality defects identified through the DQA process will vary and may be data- or measurement-specific. Some pre-identified corrective actions are identified in Table 2-1.

3 Field Sampling Plan

Additional details regarding field-specific collection requirements are provided in the following sections.

3.1 Site Background and Objectives

Site background information is contained in Addendum 2. The target analytes and COPCs are presented in Tables 1-2 and 1-3. Section 1.6 of this SAP provides a schedule for implementation. The objective of the field sampling plan is to clearly identify project sampling and analysis activities. The field sampling plan uses the sampling design identified during the systematic planning process and presents the design to identify sampling locations, the total number of samples to be collected, and the analyses to be performed.

3.2 Documentation of Field Activities

Logbooks or data forms are required for field activities. Section 2.1.6 provides logbook requirements. Data forms may be used to collect field information. However, the data forms must follow the same requirements as those for logbooks presented below and the data forms must be referenced in the logbooks. The following is a summary of information to be recorded in logbooks:

- Purpose of activity
- Day, date, time, weather conditions
- Names, titles, organizations of personnel present
- Deviations from the QAPjP or procedures
- All site activities, including field tests
- Materials quality documentation (e.g., certifications)
- Details of samples collected (preparation, splits, duplicates, matrix spikes, blanks)
- Location and types of samples
- Chain-of-custody details and variances relating to chain-of-custody
- Field measurements
- Field calibrations and surveys and equipment identification numbers, as applicable
- Equipment decontaminated, number of decontaminations, and variations to any decontamination procedures
- Equipment failures or breakdowns, and descriptions of any corrective actions
- Telephone calls relating to field activities.

3.3 Sampling Design

As Section 2.2.1 presents, the sampling design is judgmental sampling.

3.4 Calibration of Field Equipment

The sampling lead is responsible for ensuring that field equipment is calibrated appropriately. Onsite environmental instruments are calibrated in accordance with manufacturer operating instructions, internal work requirements and processes, and/or work packages that provide direction for equipment calibration or verification of accuracy by analytical methods. The results from instrument calibration activities are recorded in logbooks and/or work packages. Hard copy or electronic versions are acceptable.

Calibrations must be performed as follows:

- Before initial use of a field analytical measurement system
- At the frequency recommended by the manufacturer or procedure, or as required by regulations
- Upon failure to meet specified QC criteria.

Field instrumentation, calibration, and QA checks will be performed in accordance with the following.

- As specified in its program documentation, Pacific Northwest National Laboratory calibrates radiological field instruments on the Hanford Site.
- Daily calibration checks will be performed and documented for each instrument used to characterize areas under investigation. These checks will be made on standard materials sufficiently like the matrix under consideration for direct comparison of data. Analysis times will be sufficient to establish detection efficiency and resolution.

3.5 Sample Location and Frequency

The purpose of this section is to identify the sampling locations and frequencies and define the sampling and analysis requirements for samples and measurements to be collected. Figure 1-1 shows the approximate location of boreholes, groundwater monitoring wells, and aquifer tubes described in this SAP. The actual locations will be determined based on a field walkdown of current site conditions to avoid Hanford Site National Historic restrictions, roads, and other obstructions.

3.5.1 Vadose Zone Characterization

Samples will be collected from two planned boreholes and 13 planned groundwater monitoring wells to support characterization of the vadose zone and groundwater as outlined in Table 1-1. Two boreholes will be drilled into the groundwater in the 116-K-2 Trench. Each groundwater well will also have deep vadose zone samples collected for vadose zone characterization. The vadose zone will be characterized by performing intrusive investigations at the 116-K-2 Trench. Intrusive investigations consist mainly of collecting and analyzing samples from planned boreholes in areas of known or suspected contamination. These activities are planned to characterize the nature and vertical extent of contamination in the vadose zone beneath waste sites, characterize the physical properties of soil/aquifer sediments, locate potential sources, and verify contaminant distribution coefficients to support modeling and an assessment of risk. The data from the activities will be used to verify the adequacy of interim remedial actions and refine the preliminary conceptual site model of the 100-K Decision Unit.

The scope of vadose zone characterization efforts includes field screening, collecting and analyzing soil samples from the vadose zone, collecting and analyzing aquifer sediment samples, performing groundwater sampling and analysis, and performing geophysical logging. The general intent of the borehole sampling design is to begin sample collection at the maximum depth of remedial action or bottom of the waste site and sample periodically to the water table. Vadose zone samples will be collected according to the sampling scheme shown in Table 3-1. The sampling scheme for each borehole also

includes collection of one sample of aquifer sediments and one filtered groundwater sample 1.5 m (5 ft) into the water table. The sampling scheme for deep vadose zone samples at groundwater wells includes collecting soil samples periodically above the water table and collecting samples of aquifer sediments in the water table. Additional samples may be collected based on observations made in the field.

Physical property samples will be collected to provide site-specific values to support modeling efforts. The physical property samples will be collected from lithologies representing major facies and surrounding the Hanford Ringold contact. The physical property samples will be collected in conjunction with split-spoon sample intervals, where possible.

3.5.1.1 Field Screening

Radiological field screening data, visual observation of lithologies, visual observation of contamination, or site geologist professional judgment may be used to adjust the sampling points presented in Table 3-1, assist in determining sample shipping requirements, and support worker health and safety monitoring. Section 3.6.3 describes radiological field screening methods.

3.5.1.2 Geophysical Logging

The planned boreholes and groundwater monitoring wells will be geophysically logged with the high-resolution, spectral gamma-ray logging system to determine the vertical distribution and concentration of gamma-emitting radionuclides. Soil moisture will be determined using a neutron logging tool. The boreholes and groundwater monitoring wells will be logged before the casing is telescoped and before the borehole is decommissioned. The starting point for logging will be recorded; this is usually at the ground surface or the top of the casing. Boreholes will be decommissioned with DOE/RL and EPA approval, in accordance with WAC 173-160, after geophysical logging and all sampling is completed.

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
116-K-2 Trench West One borehole to groundwater. Justification: Interim remedial action was successfully completed at this site in 2005 to mitigate impacts from this potential source. Results from this activity indicate the maximum concentration of hexavalent chromium within the trench exceeds the soil concentration for protection of the Columbia River.	25-27.5, 27.5-30, 30-32.5 (37.5-40[b] aquifer sediment sample) by **split spoon** (4 samples)	Target analytes, field screening parameters, and batch leach contacting test in accordance with Table 2-2	During drilling 37.5-40 aquifer water sample[b] (1 filtered groundwater sample)	Metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes by **split spoon** (2 samples)	Physical properties in accordance with Table 2-2		
116-K-2 Trench East One borehole to groundwater. Justification: Interim remedial action was successfully completed at this site in 2005 to mitigate impacts from this potential source. Results from this activity indicate the maximum concentration of hexavalent chromium exceeds the soil concentrations for protection of the Columbia River.	25-27.5, 27.5-30, 30-32.5, 32.5-35, 35-37.5, 37.5-40, (45-47.5[b] aquifer sediment sample) by **split spoon** (7 samples)	Target analytes, field screening parameters and batch leach contacting test in accordance with Table 2-2	During drilling 45-47.5 aquifer water sample[b] (1 filtered groundwater sample)	Metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes by **split spoon** (2 samples)	Physical properties in accordance with Table 2-2		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #1 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the hexavalent chromium upgradient extent of the western extent of the 105-KW Reactor groundwater plume.	During drilling, samples to be **grab** collected every 5 ft or where lithology changes occur, in one pint jar and chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #2 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the extent of hexavalent chromium, carbon-14, TCE, and strontium-90 in groundwater near the 116-KW-3 waste site, 107-KW condensate tanks, and downgradient of 105-KW Reactor area.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #3 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the hexavalent chromium upgradient extent of the 105-KE Reactor plume	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #4 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the extent of a identified "hot" spot of hexavalent chromium and strontium-90 in groundwater . Existing wells are available to define the extent of the hot spot to the east and north. No wells are currently available to define this anomalous hexavalent chromium concentration to the northwest and west.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #5 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: A replacement for well 199-K-109A to further monitor and define the extent of strontium-90 hot spot	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #6 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the hexavalent chromium upgradient extent of the 116-K-2 Trench plume.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #7 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the hexavalent chromium upgradient extent of the 116-K-2 Trench plume.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table, at the water table, 5 ft below the water table, and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #8 To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the hexavalent chromium upgradient extent of the 116-K-2 Trench plume	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table, and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well #9[d] To be drilled and installed in the unconfined aquifer in the 100-K Area Justification: To define the extent of hexavalent chromium in groundwater.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer (12 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table, and at the bottom of the unconfined aquifer by **split spoon** (7 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well R1 Install borehole reaching a total depth approximately 50 ft within the RUM. Complete the borehole as a well in a water-producing zone within the RUM, if found, in the 100-K Area. Justification: To determine the extent of contamination that may reside in the RUM, physical and hydrologic properties of the RUM, and potential transport of contamination within the RUM.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer and from water-bearing intervals of the RUM Unit if sufficient water is available (14 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table, 5 ft below the water table; at the bottom of the unconfined aquifer; and from the top, middle, and bottom of the non-water-bearing units of the RUM Unit by **split spoon** (10 samples)	In accordance with Table 2-3: • Batch leach contacting test • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well R2 Install borehole reaching a total depth approximately 50 ft within the RUM. Complete the borehole as a well in a water-producing zone within the RUM, if found, in the 100-K Area. Justification: To determine the extent of contamination that may reside in the RUM, physical and hydrologic properties of the RUM, and potential transport of contamination within the RUM.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer and from water-bearing intervals of the RUM unit if sufficient water is available (14 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; at the bottom of the unconfined aquifer; and from the top, middle, and bottom of the non-water-bearing units of the RUM unit by **split spoon** (10 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well R3 Install borehole reaching a total depth approximately 50 ft within the RUM. Complete the borehole as a well in a water-producing zone within the RUM, if found, in the 100-K Area. Justification: To determine the extent of contamination that may reside in the RUM, physical and hydrologic properties of the RUM, and potential transport of contamination within the RUM.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer and from water-bearing intervals of the RUM Unit if sufficient water is available (14 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; at the bottom of the unconfined aquifer; and from the top, middle, and bottom of the non-water-bearing units of the RUM unit by **split spoon** (10 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010 • Mercury by EPA 7471	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Well R4 Install borehole reaching a total depth approximately 50 ft within the RUM. Complete the borehole as a well in a water-producing zone within the RUM, if found, in the 100-K Area. Justification: To determine the extent of contamination that may reside in the RUM, physical and hydrologic properties of the RUM, and potential transport of contamination within the RUM.	During drilling, samples will be **grab** collected every 5 ft or where lithology changes occur in one pint jar and a chip tray from the drill cuttings.[c]	Geologic archive samples	During drilling, samples to be collected at 5-ft intervals throughout unconfined aquifer and from water-bearing intervals of the RUM unit if sufficient water is available (14 samples)	Constituents and field screening parameters in accordance with Table 2-4
	During drilling, samples to be collected 15, 10, 5, and 2 ft above water table; at the water table; 5 ft below the water table; at the bottom of the unconfined aquifer; and from the top, middle, and bottom of the non-water-bearing units of the RUM unit by **split spoon** (10 samples)	In accordance with Table 2-3: • Radiological methods • EPA Methods 7196 and 6010 • Mercury by EPA 7471	During drilling, 5 ft below water table[b] (1 filtered groundwater sample)	Filtered groundwater sample for metals and hexavalent chromium in accordance with Table 2-4
	Major formation and lithology changes, and 10 ft and 5 ft above the Hanford Ringold contact, at the Hanford Ringold contact, and 5 ft below the Hanford Ringold contact by **split spoon** (6 samples)	Physical properties in accordance with Table 2-3		

Table 3-1. Sample/Measurement Locations and Depth

Sampling Location	Soil/Aquifer Sediment Sample/Measurement		Water Sample/Measurement	
	Sample Interval Depth (ft bgs)[a]	Properties of Interest	Sample Interval Depth (ft bgs)/frequency	Analyte List
Sample 18 spatial/temporal uncertainty monitoring wells (Table 3-2) Multiple rounds	None	None	Collect one sample per well multiple sampling rounds to support remedial investigation. (18 wells x approximately 3 rounds = 54 samples)	Constituents and field screening parameters in accordance with Table 2-4
Summary				
Number of samples:	Soil/Aquifer sediment chemical: 103 Physical property: 78 Geologic archive samples: variable		Water samples collected during drilling: 166 Spatial/temporal uncertainty samples: 54 (3 rounds total)	
Minimum number of field quality control samples:	Soil/Aquifer sediment chemical: 19 (6 equipment blank, 6 field blank, 6 duplicate, 1 split) Physical property: 0 Geologic archive samples: 0		Water samples collected during drilling: 28 (9 equipment blank, 9 field blank, 9 duplicate, 1 split) Spatial/temporal uncertainty samples: 10 (3 equipment blank, 3 field blank, 3 duplicate, 1 split)	
Total number of samples:	Soil/aquifer sediment chemical: 122 Physical property: 78 Geologic archive samples: variable		Water samples collected during drilling: 194 Spatial/temporal uncertainty samples: 64	

a. Upon visual observation of contamination, a depth discrete sample will be collected for applicable analysis. For example, if hexavalent chromium contamination is observed at any interval other than those stated for sampling, a depth discrete sample would be collected for hexavalent chromium analysis.

b. This sample in intended to be collected from 5 ft into the unconfined aquifer.

c. Archive samples may be omitted at the discretion of the field geologist due to radiological field data.

d. Well #9 is pending approval per Section 106 of the National Historic Preservation Act.

For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

bgs = below ground surface

RUM = Ringold upper mud

TCE = trichloroethene

3.5.2 Groundwater Characterization

Groundwater characterization, including well activities, identification of wells to be sampled, well depth and screen placement, and well drilling and completion procedures is discussed in this section.

3.5.2.1 New Groundwater Wells

Table 3-1 summarizes groundwater monitoring well activities. From the new wells screened in the Ringold upper mud unit, slug testing and pump testing will be performed to characterize hydraulic conductivity.

Well Depth and Screen Placement

For the nine new groundwater wells in the unconfined aquifer in the 100-K Area, a 6.1 m (20 ft) or longer screen will be installed.

For the four new groundwater wells reaching a total depth approximately 15 m (50 ft) within the Ringold upper mud unit, complete the boreholes as wells in a water-producing zone within the Ringold upper mud unit, if found. Up to a 6.1 m (20-ft) screen will be installed based on ability to produce water in the water-bearing Ringold upper mud unit.

Well Drilling and Completion Procedures

Well drilling will be performed in accordance with WAC 173-160. The wells will be drilled using 25.4 cm (10 in.) diameter (or larger) casing to total depth. The drilling method will be determined based on discussions between the drilling lead and drilling contractor.

The wells will be constructed as 15.2 cm (6-in.) wells with Schedule 10, Type 304 or 316, stainless steel, V-slot continuous wire wrap screen, atop a 1.5 m (5 ft) long, stainless steel sump with end cap. A Schedule 10 stainless steel riser will be used to extend the permanent well into the vadose zone, with Schedule 10 stainless steel casing through the vadose zone to ground surface. Colorado silica sand will be used for the sand pack; sodium bentonite pellets and/or natural sodium bentonite chunks, crumbles, or powdered bentonite will be used for bentonite sealing material; and Type I/ II Portland cement will be used for cement grout.

Surface construction consisting of protective casing, protective guard posts, and cement pad must be in place before job completion. The protective casing will be a minimum of 5 cm (2 in.) larger in diameter than the permanent casing. Protective casing will rise approximately 0.9 m (3 ft) above the ground surface. Permanent casing will rise to approximately 0.3 m (1 ft) below the top of the protective casing. Protective casing will have a lockable well cap extending approximately 38 cm (15 in.) above the top of the protective casing.

Final well design, including screen placement and length, will be determined by concurrence of the field geologist, drilling lead, and operable unit lead based upon field conditions. If the completion differs from the WAC 173-160 requirements, then variances will be obtained from Ecology.

3.5.2.2 Groundwater Network to Evaluate Spatial and Temporal Uncertainty

Table 3-1 summarizes groundwater monitoring activities to address spatial and temporal uncertainties. Table 3-2 presents the wells to be sampled. Multiple rounds of groundwater samples will be collected for analysis to support the RI in the existing groundwater wells for each contaminant identified in Table 1-3.

Table 3-2. Spatial and Temporal Uncertainty Risk Assessment Groundwater Monitoring Well Network

199-K-11	199-K-31	199-K-37	199-K-142	199-K-157
199-K-18	199-K32A	199-K-106A	199-K-151	699-72-73
199-K-20	199-K-34	199-K-108A	199-K-152	699-73-61
199-K-22	199-K-36	199-K-117A		

To determine spatial and temporal risk uncertainty for potential human and ecological receptors, the RI process requires that the groundwater be sampled, providing representative data of aquifer conditions. It is required the groundwater be sampled throughout a decision unit without regard to the location of surface facilities or known groundwater plumes. If there are temporal changes in groundwater conditions, samples must be collected to capture these varying stages to properly delineate temporal risk uncertainties to potential receptors. The following discussion explains the method used to develop both the number and location of sampling points along with the sampling frequency for the decision units associated with the River Corridor RI/FS investigations. The resulting well network data will be used to evaluate the groundwater risk information presented in DOE/RL-2007-21, *Risk Assessment Report for the 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment.* Observations and conclusions regarding the data collected and the DOE/RL-2007-21 evaluation will be documented in the RI report (e.g., risk uncertainties associated with temporal and spatial representativeness, verifying groundwater risk conclusions, ensuring no contaminants were inadvertently overlooked, and establishing a "present condition" dataset that can be used to measure the progress of future cleanup actions).

Sample Number and Location

Sampling well locations within a groundwater decision unit must be identified to spatially represent all of the areas within a decision unit, regardless of facility or known contaminant plume locations. These sampling networks should represent locations where human or ecological receptors could potentially encounter groundwater. The primary pathway for human exposure is through direct contact with groundwater obtained from a residential or community water well. Identification of sampling locations to assess the direct exposure pathways is to assume development of the land for future human habitation. With this scenario as a guide to assessing a viable sampling grid of plausible groundwater pathways, land use regulations were used to develop a reasonable network of supply wells for each decision unit, based on state regulations and site-specific hydrologic properties. This approach resulted in a sampling grid and corresponding network of monitoring wells tailored for each decision unit. As part of this semi-quantitative approach, the locations of community water delivery systems were developed to meet not only the negotiated Tri-Party land use needs but also State of Washington requirements.

Rules and regulations of the Washington State Department of Health (DOH) regarding public water supplies, WAC 246-290, "Group A Public Water Supplies," are explained in the associated guidance document, DOH 331-123, *Water System Design Manual.* This manual is maintained by the DOH and provides the necessary information on specifications to develop groundwater resources for human use. By applying these specifications to the possible locations of water supply wells that might act as complete exposure pathways, the number and spacing of sampling locations is determined with credibility for each decision unit, providing justified and defensible monitoring networks.

Based on remedial action goals for DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, the assumption for future habitation is families will live on the land, grow a garden, and raise livestock to provide approximately 25 percent of the family's food requirements. This land usage places specific state and daily water requirements for each residence. Because the remedial action goals are based on groundwater restored to highest beneficial use (i.e. drinking water), the *Washington Growth*

Management Act requires each residence occupy at least one acre of land. It is also assumed that at least a 5-acre plot per unit is necessary to raise livestock. Thus, each residence in the following scheme assumes a family plot size of 5 acres.

Therefore, residential water usage must be sufficient to supply not only in-house needs but also to irrigate a large garden and to water livestock. For a water well that supplies one residence, Ecology requires a minimum of 1,514.2 liters per day (L/day) (400 gallons per day [gal./day]). Thus, an extreme lower limit is established for in-house use. However, for a communal system, which the DOH regulates, guidance on the daily water use is found in DOH 331-123. One of the key parameters for estimating potential water use is the lot size of the individual residence.

Another important consideration is location of the well within the state because of climate differences east and west of the Cascade Mountains. Based on utility records in eastern Washington, which has a dominantly arid climate, a residence's maximum day demand is 5,675 L/day (1,500 gal./day) for lot sizes in excess of 2.5 acres. Although values as high as 30,283.3 L/day (8,000 gal./day) have been recorded, the historical sizing guideline of 5,675 L/day (1,500 gal./day) has generally been adequate. With the information on requirements for residential water supplies, the number of possible supply wells and thus the number of sampling points is calculated based on how much water the local aquifer is expected to produce.

To provide the number of sampling points for the well network, the average groundwater yields, calculated from pump tests conducted at each decision unit, are used to determine the number of residences supported on one supply well. Thus the grid size specific to each decision unit is determined. Use of a random grid generator provides approximate locations for sampling points based on the final number of sampling points and the total area of each decision unit. To the degree possible, one well within each grid was chosen to represent the potential exposure pathway; thereby providing a network of sampling points to provide a spatially representative sampling network of groundwater wells.

In addition to determining the maximum number and location of potential exposure pathways, additional wells were added to networks to define potential exposures associated with known contaminant plumes. Current monitoring wells were chosen to provide data on maximum contaminant levels and to define plume extents. For decision units with active remedial activities, extraction/injection and chemical treatment wells were not included in any of the well networks. The pump and treat wells are not configured for routine sampling and the chemical treatment wells are not representative of ambient groundwater conditions.

Sampling Frequency

To capture baseline aquifer conditions fully, it is required that samples represent not only spatial variations but also changes that occur over time. Near the river, these varying conditions are observed as changes in groundwater flow, both direction and rate, causing temporary movement of contaminants through different portions of the unconfined aquifer. For decision units bordering on the Columbia River, the changing aquifer conditions are caused by fluctuating river elevations associated with flood control and hydroelectric production. For representing baseline groundwater conditions, samples are required to represent these varying aquifer conditions associated with high, low, and mid-point or transitional river elevations. The date and frequency of sample collection is based on measurements of the river elevation to optimize collection of samples representing these temporal changes in groundwater conditions.

Effect of River Elevation on Groundwater Conditions

Along the Columbia River, rapid, periodic, or cyclic elevation fluctuations of the river occur in controlled response to flood conditions, hydroelectric production, and salmon spawning programs at a series of dams and reservoirs upriver of the Hanford site. These rapid elevation changes in the river cause periodic

influences on flow conditions within the aquifer. For example, there are two times during a calendar year when the river elevation peaks and two times the river elevation is low. The highest river elevation occurs in early June when water is released from reservoirs that have reached capacity from the melting snow pack in the Cascade Mountains. The lowest river elevation is engineered in late September to early October to encourage salmon spawning in low pockets of the river bottom along the Hanford Reach.

When water is released upriver, the river elevation rises above the elevation of the local aquifer causing movement of water from the river into the aquifer. At this time, the flow direction in the aquifer is modified from the ambient condition and varies with local conditions along the river. This flow from the river brings cleaner river water into the groundwater causing a temporary reduction in contaminant levels in monitoring wells near the river.

When the river elevation is artificially lowered to a level below the aquifer by holding water back in the upriver reservoirs, groundwater moves from the aquifer into the river. The river then recharges from the aquifer, causing a change in the flow direction to roughly perpendicular to the river's edge, once again varying with specific locations along the river. These changes in direction may bring contaminated groundwater through observation wells at certain places and into the river. Thus, near the river/groundwater interface, the flow direction and rate change with time. The effect on aquifer conditions is greatest when the river peaks in June and, again, at its lowest level in late September to early October. To capture these temporal effects on contaminant plumes within the aquifer from the low river elevation, groundwater sampling should be conducted prior to late October.

Inland from the river, the rapid river elevation changes form a pressure pulse that appears to be transmitted along the free surface of the unconfined aquifer. This effect causes groundwater elevation changes in wells not affected by actual movement of aquifer water. For some places, the elevation increase may allow the groundwater to interact with contaminated soils located just above the water table. The timing of these periodic or cyclic river elevation changes determines the sampling frequency required to represent the temporal variations in groundwater conditions.

Groundwater Sampling Dates

Because the goal of the temporal uncertainty groundwater sampling is to determine groundwater conditions when the river has the maximum effect on flow rate and direction, sampling is scheduled for late May to mid-June during the highest peak and from late September to late October during the time of the lowest elevation. From the second week in June to mid-September, the river elevation is in transition, decreasing from the maximum elevation to the lowest elevation. Also from March through April, elevations change from low to the high that occur in the first week of June. Consequently, the best opportunity to capture transitional conditions occurs during the months of March and April or July and August.

Based on the previous discussion, three sampling events are recommended to represent the temporal fluctuations in groundwater conditions at each of decision units located along the river corridor. One sampling event captures the effect on the aquifer when the river stage is highest and the greatest increase in aquifer elevation occurs (May to mid-June). The second sampling interval ranges from mid-September to mid-October when the river is at the lowest elevation for the year. This period is when contamination from the aquifer might be affecting the river. The third sampling point represents the mid-point or transitional aquifer conditions occurring from either March through April or July through August. Thus, the groundwater sampling schedules, which support the temporal uncertainty evaluation for the RI/FS at each decision unit along the river, capture the maximum effects of changing river elevations on aquifer conditions as well as the transitional time between the maximum and minimum changing conditions.

3.5.2.3 *Aquifer Tubes*

Table 3-3 summarizes aquifer tube activities. If possible, aquifer tubes should be advanced using direct-push methods. A set of three new aquifer tubes will be installed to multiple depths at one location in the 100-K Area. The depth of each aquifer tube screen should be based on previously collected aquifer tube and well data. Direct-push methods can be used to drive a casing with a screened lower end to provide for in situ probes and data loggers. Ideal positioning is near the seasonally low-river-stage shoreline, for example, the river-stage shoreline when the lowest anticipated mean river discharge occurs. Historically, the lowest anticipated river discharge is September through November.

Aquifer tube water samples will be collected for analysis in three sampling rounds to support the RI when the river stage is low enough to obtain samples. Samples will be analyzed for carbon-14, hexavalent chromium, tritium, and trichloroethene (TCE).

Table 3-3. Aquifer Tube Sample/Measurement Locations and Depth

Sampling Location	Action	Water Chemistry	
		Frequency	Analyte List
Three new aquifer tubes at one location (Location #1) in the 100-K Area	Drive three new aquifer tubes to support RI	Collect one sample per aquifer tube for three rounds	C-14, hexavalent chromium, tritium, and TCE (in accordance with Table 2-4) Field screening parameters (in accordance with Table 2-4)
Total number of real samples:		9	
Minimum number of field quality control samples:		4 (1 equipment blank, 1 field blank, 1 duplicate, 1 split)	
Total number of samples:		13	

3.6 Sampling Methods

Soil/aquifer sediment sampling will be performed in accordance with approved procedures for soil and aquifer sediment sampling using a 10.2 cm (4 in.) split-spoon sampler. The split-spoon samplers will be equipped with four separate stainless steel or polycarbonate liners. Site personnel will not overdrive the sampling device. Samples for VOCs will be packaged first. Next, the remaining soil/aquifer sediment will be transferred to a pre-cleaned, stainless steel mixing bowl or other suitable pre-cleaned container, homogenized, and then containerized in accordance with the sampling procedure. If sample volume requirements cannot be met, samples will be collected according to the following priority, as applicable: hexavalent chromium, metals (including mercury), batch leach contacting test, tritium, nitrate, strontium-90, technetium-99, other radionuclides, VOCs, physical properties and other anions.

Groundwater samples collected during drilling, before development, will be pumped from selected intervals. The pump will be operated for a period of time sufficient to provide stabilized field readings, but not necessarily three casing volumes.

For the RA groundwater monitoring well network, before sample capture, the pump will be operated for a sufficient time to provide stabilized field readings, and at least three casing volumes. Aquifer tube samples will be grab sampled with a pump, with no purge before sample collection.

3.6.1 Corrective Actions and Deviations for Sampling Activities

The project lead, sampling lead, drilling lead, or designee must document deviations from procedures or other problems pertaining to sample collection, chain-of-custody, target analytes, COPCs, sample

transport, or noncompliant monitoring. Examples of deviations include samples not collected because of field conditions, changes in sample locations because of physical obstructions, or additions of sample depth(s).

As appropriate, such deviations or problems will be documented in the field logbook or on nonconformance report forms in accordance with internal corrective action procedures. The project lead, sampling lead, drilling lead, or designee will be responsible for communicating field corrective action requirements and for ensuring immediate corrective actions are applied to field activities.

More significant changes in sample locations not affecting the data needs will require notification and approval of the project lead. Changes to sample locations resulting in impacts to meeting data needs will require concurrence from DOE and regulatory project leads. Changes to the SAP will be documented as noted in Section 2.1.6.

3.6.2 Decontamination of Sampling and Drilling Equipment

Sampling equipment shall be decontaminated in accordance with the sampling equipment decontamination procedure. To prevent contamination of the samples, care should be taken to use clean equipment for each sampling activity. Special care should be taken to avoid the following common ways in which cross-contamination or background contamination may compromise the samples:

- Improperly storing or transporting sampling equipment and sample containers
- Contaminating the equipment or sample bottles by setting the equipment/sample bottle on or near potential contamination sources (e.g., uncovered ground)
- Handling bottles or equipment with dirty hands or gloves
- Improperly decontaminating equipment before sampling or between sampling events. Field decontamination (e.g., field washing and reuse) is not appropriate for sampling equipment.

The drill rig derrick, all down-hole equipment, and temporary casing will be field decontaminated (e.g., high pressure and temperature), at a minimum, before mobilization and demobilization.

3.6.3 Radiological Field Data

Alpha and beta/gamma data collection in the field will be used as needed to support sampling and analysis efforts. Generally, cuttings from boreholes (excluding slough) will be field screened for evidence of radiological contamination. Screening will be conducted visually and with field instruments. Radiological screening will be performed by the radiological control technician or other qualified personnel. The radiological control technician will record field measurements, noting the depth of the sample and the instrument reading. Measurements will be relayed to the field geologist for inclusion in the field logbook or operational records daily, as applicable.

The following information will be distributed to personnel performing work in support of this SAP:

- Instructions to radiological control technicians on the methods required to measure sample activity and media for gamma, alpha, and/or beta emissions, as appropriate.
- Information regarding the Geiger-Müller, portable alpha meter, dual-phosphors beta/gamma, and sodium iodide portable instruments, to include a physical description of the instruments, radiation and energy response characteristics, calibration/maintenance and performance testing descriptions, and the application/operation of the instrument. These instruments are commonly used on the Hanford

Site for obtaining measurements of removable surface contamination measurements and direct measurements of the total surface contamination.

- Information on the characteristics associated with the hand-held probes to be used in the performance of direct radiological measurements will include a physical description of the probe, the radiation and energy response characteristics, calibration/maintenance and performance testing descriptions, and application/operation of the instrument. The hand-held probe is an alpha detection instrument commonly used on the Hanford Site to obtain removable surface contamination measurements and direct measurements of the total surface contamination.

3.7 Sample Handling

Sample handling, including container packaging, container labeling, sample custody, and sample transportation, is discussed in this section.

3.7.1 Container Packaging

Level I EPA pre-cleaned sample containers will be used for soil/aquifer sediment and water samples collected for chemical analysis. Container sizes may vary depending on laboratory specific volumes and requirements for meeting analytical detection limits. Radiological Engineering will measure the contamination levels and dose rates associated with the sample containers. This information, along with other data, will be used to select proper packaging, marking, labeling, and shipping paperwork and to verify that the sample can be received by the analytical laboratory in accordance with the laboratory's acceptance criteria. If the dose rate on the outside of a sample container or the curie content exceeds levels acceptable by an offsite laboratory, the sampling lead, in consultation with Sample Management and Reporting, can send smaller volumes to the laboratory. Preliminary container types and volumes are identified in Tables 3-4 and 3-5.

Table 3-4. Sample Preservation, Container, and Holding Time for Soil/Aquifer Sediment Samples

Method	Preservation Requirement	Holding Time	Bottle Type	Minimum Sample Size[a]
Gamma energy analysis	None	6 months	G/P	750 g
Liquid scintillation counter	None	6 months	G	33 g
Isotopic - plutonium	None	6 months	G/P	5 g
Strontium-90	None	6 months	G/P	5 g
Gas flow proportional counting	None	6 months	G/P	5 g
EPA 6010	Cool ~4 °C	6 months	G/P	15 g
EPA 7196	Cool ~4 °C	30 days	G/P	50 g
EPA 7471	None	28 days	G/P	15 g
EPA 8260[b]	Cool ~4 °C	14 days	G	50 g
EPA 300.0	Cool ~4 °C	28 days/ 48 hours	G/P	50 g
ASTM D2216	None	None	Moisture-proof container	200 g
ASTM D2434-68	None	None	P	1,000 g
ASTM D2937	None	None	G/P	1,000 g

Table 3-4. Sample Preservation, Container, and Holding Time for Soil/Aquifer Sediment Samples

Method	Preservation Requirement	Holding Time	Bottle Type	Minimum Sample Size[a]
ASTM D5084	None	None	P	1,000 g
Batch Leaching Contacting Test	Cool ~4 °C	28 days from field to extraction	G	100 g/120 mL

a. Based on minimum QC requirements.

b. Field preservation EPA 5035A may also be used.

For EPA Method 300.0, see EPA/600/4-79/020, *Methods for Chemical Analysis of Water and Wastes.*

For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

ASTM D2216-05, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.*

ASTM D2434-68, *Standard Test Method for Permeability of Granular Soils (Constant Head).*

ASTM D2937-04, *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method.*

ASTM D5084-03, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.*

28 days/48 hours = 48 hours for nitrate, nitrite, phosphate, others 28 days. P = plastic

G = glass

Table 3-5. Sample Preservation, Container, and Holding Time for Water Samples

Method	Preservation Requirement	Holding Time	Bottle Type	Minimum Sample Size*
Carbon-14	None	6 months	G/P	60 mL
Strontium 89/90 - Sr-90	HNO_3 to pH <2	6 months	G/P	2000 mL
Tritium (H-3)	None	6 months	G	60 mL
EPA 6010	HNO_3 to pH <2	6 months	G/P	300 mL
EPA 6020 or 200.8	HNO_3 to pH <2	6 months	G/P	300 mL
EPA 7196	Cool ~4 °C	24 hours	aG	500 mL
EPA 7470 or 200.8	HNO_3 to pH <2	28 days	G	500 mL
EPA 8260	Cool ~4 °C, HCl or H_2SO_4 to pH <2	14 days	aGs	40 mL
EPA 300.0	Cool ~4 °C	28 days/48 hours	P	125 mL
Total uranium (chemical)	HNO_3 to pH <2	6 months	G/P	500 mL

* Based on minimum QC requirements

For EPA Method 200.8, see EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1.*

For EPA Method 300.0, see EPA/600/4-79/020, *Methods for Chemical Analysis of Water and Wastes.*

For the four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

28 days/48 hours = 48 hours for nitrate, nitrite, phosphate, others 28 days

aG = amber glass

aGs = amber glass septum (no head space)

G = glass

P = plastic

3.7.2 Container Labeling

The sample location, depth, and corresponding HEIS number are documented in the sampler's field logbook. A custody seal (e.g., evidence tape) is affixed to each sample container and/or the sample collection package in such a way as to indicate potential tampering. Each sample container will be labeled with the following information on firmly affixed, water-resistant labels:

- HEIS number
- Sample collection date and time
- Analysis required
- Preservation method (if applicable)
- Sampling authorization form number.

In addition to the above information, sample records must include the following information:

- Analysis required
- Source of sample
- Matrix
- Field data (pH and radiological readings).

Except for volatile organic analysis samples, a custody seal (i.e., evidence tape) will be affixed to the lid of each sample container. The custody seal will be inscribed with the sampler's initials and the date. Custody seals are not applied directly to volatile organic analysis bottles collected because of a potential for affecting analytical results and/or fouling of laboratory equipment. Custody seals and any other required labels or documentation can be fixed to exterior of a plastic bag holding vials in such a manner to detect potential tampering.

3.7.3 Sample Custody Requirements

Sample custody will be maintained in accordance with existing Hanford Site protocols to ensure the maintenance of sample integrity throughout the analytical process. Chain-of-custody procedures will be followed throughout sample collection, transfer, analysis, and disposal to ensure sample integrity is maintained. A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each set of samples shipped to any laboratory. Shipping requirements will determine how sample shipping containers are prepared for shipment. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form. Each time the responsibility changes for the custody of the sample, the new and previous custodians will sign the record and note the date and time. The sampler will make a copy of the signed record before sample shipment and will transmit the copy to Sample Management and Reporting within 48 hours of shipping.

The following information is required on a completed chain-of-custody form:

- Project name
- Signature of sampler
- Unique sample number
- Date and time of collection
- Matrix
- Preservatives

- Signatures of individual involved in sample transfer
- Requested analyses (or reference thereto).

3.7.4 Sample Transportation

Sample transportation will be in compliance with the applicable regulations for packaging, marking, labeling, and shipping hazardous materials, hazardous substances, and hazardous waste mandated by the U.S. Department of Transportation (49 CFR 171, "General Information, Regulations, and Definitions," through Part 177, "Carriage By Public Highway") in association with the International Air Transportation Authority, DOE requirements, and applicable program specific implementing procedures.

3.8 Management of Waste

All waste (including unexpected waste) generated by sampling activities will be managed in accordance with DOE/RL-97-01, *Interim Action Waste Management Plan for the 100-HR-3 and 100-KR-4 Operable Units*. Pursuant to 40 CFR 300.440, "Procedures for Planning and Implementing Off-Site Response Actions," approval from the CERCLA lead agency Remedial Project Manager is required before returning unused samples or waste from offsite laboratories.

4 Health and Safety

Field operations will be performed in accordance with health and safety requirements and appropriate Soil and Groundwater Remediation Project requirements. Additionally, work control documents will be prepared to further control site operations. Safety documentation will include an activity hazard analysis and, as applicable, radiological work permits. The sampling procedures and associated activities will implement ALARA practices to minimize the radiation exposure to the sampling team, consistent with the requirements defined in 10 CFR 835.

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Appendix A

Laboratory Standard Compound List

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Laboratory Standard Compound List

Tables A-1 through A-5 provide the laboratory standard compound list.

References

EPA/600/4-79/020, 1983, *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www5.hanford.gov/pdw/fsd/AR/FSD0001/FSD0047/D196019611/D196019611_58615572_76609_556.pdf

EPA/600/R-94/111, 1994, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*, U.S. Environmental Protection Agency, Washington, D.C.

SW-846, 2007, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*, as amended, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: www.epa.gov/SW-846/main.htm

Table A-1. U.S. Environmental Protection Agency Method 300.0

CAS #	Constituent	Water EQL (µg/L)	Soil EQL (µg/kg)	Precision Requirement Water/Soil	Accuracy Requirement Water/Soil
24959-67-9	Bromide	250	2,500	±20%/±30%	80-120%/70-130%
16887-00-6	Chloride	200	2,000	±20%/±30%	80-120%/70-130%
16984-48-8	Fluoride	500	5,000	±20%/±30%	80-120%/70-130%
14797-55-8	Nitrate*	250	2,500	±20%/±30%	80-120%/70-130%
14797-65-0	Nitrite*	250	2,500	±20%/±30%	80-120%/70-130%
NO_3-N	Nitrogen in nitrate*	75	750	±20%/±30%	80-120%/70-130%
NO_2-N	Nitrogen in nitrite*	75	750	±20%/±30%	80-120%/70-130%
14265-44-2	Phosphate*	500	5,000	±20%/±30%	80-120%/70-130%
14808-79-8	Sulfate	500	5,000	±20%/±30%	80-120%/70-130%

* Nitrate, nitrite, and phosphate suite or nitrogen in nitrate, nitrogen in nitrite, and phosphorus in phosphate suite may either be reported.

For EPA Method 300.0, see EPA/600/4-79/020, Methods for Chemical Analysis of Water and Wastes.

CAS = Chemical Abstracts Service

EQL = estimated quantitation limit

Table A-2. U.S. Environmental Protection Agency SW-846 Method 6010

CAS #	Constituent	Water EQL (µg/L)	Soil EQL (µg/kg)	Precision Requirement Water/Soil	Accuracy Requirement Water/Soil
7439-92-1	Lead	50	5,000	±20%/±30%	80-120%/70-130%
7439-93-2	Lithium	25	2,500	±20%/±30%	80-120%/70-130%
7439-98-7	Molybdenum	20	2,000	±20%/±30%	80-120%/70-130%
7440-28-0	Thallium	50	5,000	±20%/±30%	80-120%/70-130%
7440-38-2	Arsenic	100	10,000	±20%/±30%	80-120%/70-130%
7440-41-7	Beryllium	2	500	±20%/±30%	80-120%/70-130%
7440-42-8	Boron	20	2,000	±20%/±30%	80-120%/70-130%
7782-49-2	Selenium	100	10,000	±20%/±30%	80-120%/70-130%
7440-09-7	Potassium	4,000	400,000	±20%/±30%	80-120%/70-130%
7429-90-5	Aluminum	50	5,000	±20%/±30%	80-120%/70-130%
7439-89-6	Iron	50	5,000	±20%/±30%	80-120%/70-130%
7439-95-4	Magnesium	750	75,000	±20%/±30%	80-120%/70-130%
7439-96-5	Manganese	5	5,000	±20%/±30%	80-120%/70-130%
7440-02-0	Nickel	40	4,000	±20%/±30%	80-120%/70-130%
7440-22-4	Silver	10	1,000	±20%/±30%	80-120%/70-130%
7440-23-5	Sodium	500	50,000	±20%/±30%	80-120%/70-130%
7440-36-0	Antimony	60	6,000	±20%/±30%	80-120%/70-130%
7440-39-3	Barium	20	2,000	±20%/±30%	80-120%/70-130%
7440-43-9	Cadmium	2	500	±20%/±30%	80-120%/70-130%
7440-47-3	Chromium	10	1,000	±20%/±30%	80-120%/70-130%
7440-48-4	Cobalt	4	2,000	±20%/±30%	80-120%/70-130%
7440-50-8	Copper	8	1,000	±20%/±30%	80-120%/70-130%
7440-62-2	Vanadium	25	2,500	±20%/±30%	80-120%/70-130%
7440-66-6	Zinc	10	1,000	±20%/±30%	80-120%/70-130%
7440-70-2	Calcium	1,000	100,000	±20%/±30%	80-120%/70-130%
7440-31-5	Tin	100	10,000	±20%/±30%	80-120%/70-130%
7440-69-9	Bismuth	100	10,000	±20%/±30%	80-120%/70-130%
7723-14-0	Phosphorus	100	50,000	±20%/±30%	80-120%/70-130%
7440-21-3	Silicon	20	2,000	±20%/±30%	80-120%/70-130%
7440-24-6	Strontium (elemental)	10	1,000	±20%/±30%	80-120%/70-130%

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*

CAS = Chemical Abstracts Service EQL = estimated quantitation limit

Table A-3. U.S. Environmental Protection Agency Method 200.8 or SW-846 Method 6020

CAS #	Constituent	Water EQL (µg/L)	Soil EQL (µg/kg)	Precision Requirement Water/Soil	Accuracy Requirement Water/Soil
7439-92-1	Lead	2	500	±20%/±30%	80-120%/70-130%
7440-22-4	Silver	2	200	±20%/±30%	80-120%/70-130%
7440-28-0	Thallium	2	500	±20%/±30%	80-120%/70-130%
7440-36-0	Antimony	5	600	±20%/±30%	80-120%/70-130%
7440-38-2	Arsenic	4	1,000	±20%/±30%	80-120%/70-130%
7440-39-3	Barium	5	500	±20%/±30%	80-120%/70-130%
7440-41-7	Beryllium	2	200	±20%/±30%	80-120%/70-130%
7440-43-9	Cadmium	2	200	±20%/±30%	80-120%/70-130%
7440-47-3	Chromium	2	200	±20%/±30%	80-120%/70-130%
7782-49-2	Selenium	4	1,000	±20%/±30%	80-120%/70-130%

For EPA Method 200.8, see EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*.

For EPA Method 6020, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*

CAS = Chemical Abstracts Service

EQL = estimated quantitation limit

Table A-4. U.S. Environmental Protection Agency SW-846 Method 8260

CAS #	Constituent	Water EQL (µg/L)	Soil EQL (µg/kg)	Precision Requirement Water/Soil	Accuracy Requirement Water/Soil
100-41-4	Ethylbenzene	5	5	±20%/±30%	80-120%/70-130%
100-42-5	Styrene	5	5	±20%/±30%	80-120%/70-130%
10061-01-5	cis-1,3-dichloropropene	5	5	±20%/±30%	80-120%/70-130%
10061-02-6	trans-1,3-dichloropropene	5	5	±20%/±30%	80-120%/70-130%
107-06-2	1,2-dichloroethane	5	5	±20%/±30%	80-120%/70-130%
108-10-1	4-methyl-2-pentanone	10	10	±20%/±30%	80-120%/70-130%
108-88-3	Toluene	5	5	±20%/±30%	80-120%/70-130%
108-90-7	Chlorobenzene	5	5	±20%/±30%	80-120%/70-130%
124-48-1	Dibromochloromethane	5	5	±20%/±30%	80-120%/70-130%
127-18-4	Tetrachloroethene	5	5	±20%/±30%	80-120%/70-130%
1330-20-7	Xylenes (total)	10	10	±20%/±30%	80-120%/70-130%

Table A-4. U.S. Environmental Protection Agency SW-846 Method 8260

CAS #	Constituent	Water EQL (µg/L)	Soil EQL (µg/kg)	Precision Requirement Water/Soil	Accuracy Requirement Water/Soil
540-59-0	1,2-dichloroethene(total)	10	5	±20%/±30%	80-120%/70-130%
591-78-6	2-hexanone	20	20	±20%/±30%	80-120%/70-130%
67-64-1	Acetone	20	20	±20%/±30%	80-120%/70-130%
71-43-2	Benzene	1.5	5	±20%/±30%	80-120%/70-130%
71-55-6	1,1,1-trichloroethane	5	5	±20%/±30%	80-120%/70-130%
74-83-9	Bromomethane	10	10	±20%/±30%	80-120%/70-130%
74-87-3	Chloromethane	10	10	±20%/±30%	80-120%/70-130%
75-00-3	Chloroethane	10	10	±20%/±30%	80-120%/70-130%
75-01-4	Vinyl chloride	5	5	±20%/±30%	80-120%/70-130%
75-09-2	Methylene chloride	5	5	±20%/±30%	80-120%/70-130%
75-15-0	Carbon disulfide	5	5	±20%/±30%	80-120%/70-130%
75-25-2	Bromoform	5	5	±20%/±30%	80-120%/70-130%
75-27-4	Bromodichloromethane	5	5	±20%/±30%	80-120%/70-130%
75-34-3	1,1-dichloroethane	2	10	±20%/±30%	80-120%/70-130%
75-35-4	1,1-dichloroethene	10	10	±20%/±30%	80-120%/70-130%
78-87-5	1,2-dichloropropane	5	5	±20%/±30%	80-120%/70-130%
78-93-3	2-butanone	10	10	±20%/±30%	80-120%/70-130%
79-00-5	1,1,2-trichloroethane	2	5	±20%/±30%	80-120%/70-130%
79-34-5	1,1,2,2-tetrachloroethane	5	5	±20%/±30%	80-120%/70-130%
56-23-5	Carbon tetrachloride	1	5	±20%/±30%	80-120%/70-130%
79-01-6	Trichloroethene	1	5	±20%/±30%	80-120%/70-130%
67-66-3	Chloroform	5	5	±20%/±30%	80-120%/70-130%
106-46-7	1,4-Dichlorobenzene	5	5	±20%/±30%	80-120%/70-130%
156-59-2	cis-1,2-Dichloroethylene	5	5	±20%/±30%	80-120%/70-130%

SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B*

CAS = Chemical Abstracts Service

EQL = estimated quantitation limit

Table A-5. Gamma Spectroscopy, Germanium High-Energy Detectors (Gamma Energy Analysis)

CAS #	Constituent	Water EQL (pCi/L)	Soil EQL (pCi/g)	Precision Requirement Water/Soil	Accuracy Requirement Water/Soil
14331-83-0	Actinium-228	—	—	±30%	70-130%
14596-10-2	Americium-241	50	1	±30%	70-130%
13981-41-4	Barium-133	—	0.2	±30%	70-130%
13966-02-4	Beryllium-7	50	0.3	±30%	70-130%
14913-49-6	Bismuth-212	—	—	±30%	70-130%
14733-03-0	Bismuth-214	—	—	±30%	70-130%
CE/PR-144	Cerium/Praseodymium-144	—	—	±30%	70-130%
10045-97-3	Cesium-137	15	0.1	±30%	70-130%
10198-40-0	Cobalt-60	25	0.05	±30%	70-130%
14683-23-9	Europium-152	50	0.1	±30%	70-130%
15585-10-1	Europium-154	50	0.1	±30%	70-130%
14391-16-3	Europium-155	50	0.1	±30%	70-130%
15092-94-1	Lead-212	—	—	±30%	70-130%
15067-28-4	Lead-214	—	—	±30%	70-130%
14681-63-1	Niobium-94	—	—	±30%	70-130%
13966-00-2	Potassium-40	—	—	±30%	70-130%
13982-63-3	Radium-226	—	0.1	±30%	70-130%
15262-20-1	Radium-228	—	0.2	±30%	70-130%
14274-82-9	Thorium-228	—	—	±30%	70-130%
TH-232	Thorium-232	—	—	±30%	70-130%
15065-10-8	Thorium-234	—	—	±30%	70-130%
15832-50-5	Tin-126	—	—	±30%	70-130%
15117-96-1	Uranium-235	50	0.5	±30%	70-130%
U-238	Uranium-238	500	10	±30%	70-130%
14391-65-2	Silver-108m	—	0.2	±30%	70-130%

Where EQL is not specified, current EQLs of laboratories contracted to the Hanford Site are applicable.

CAS = Chemical Abstracts Service EQL = estimated quantitation limit

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